GEOLOGY OF CANADA.

GEOLOGICAL SURVEY OF CANADA.

REPORT OF PROGRESS

FROM

ITS COMMENCEMENT

TO

1863;

ILLUSTRATED BY 498 WOOD CUTS IN THE TEXT,

AND ACCOMPANIED BY

AN ATLAS OF MAPS AND SECTIONS.

OFFICERS OF THE SURVEY:

SIR WILLIAM E. LOGAN, LL.D., F.R.S., F.G.S., DIRECTOR.
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GEOLOGY OF CANADA.—1863.

The Maps for the Atlas designed to accompany this volume will be as follows:

I. A colored geological map of British North America, and of the adjacent parts of the United States; on a scale of 125 miles to an inch. This is reduced from a map on a scale of twenty-five miles to an inch; which is already engraved, and will be published separately.

II. A detailed map of the Laurentian rocks in the counties of Ottawa, Terrebonne, Argenteuil, and Two Mountains; on a scale of seven miles to an inch. This map shows the distribution of the limestones, anorthosites, and intrusive rocks of the Laurentian system, and also the outcrops of the adjacent Lower Silurian formations.

III. A detailed map of the Huronian series along the north shore of Lake Huron, showing also the relations of the Laurentian and Silurian systems; on a scale of eight miles to an inch.

IV. A detailed map of a portion of the Quebec group, from Stanbridge, C.E., to St. Alban's, Vermont, showing also its relations to the Potsdam and Trenton groups; on a scale of two miles to an inch.

V. A map of the limestones of the Quebec group at Point Lévis; on a scale of a mile to three inches.

VI. A map of the Superficial Geology, which will be upon the same scale as I.

All of these are engraved on steel or copper, and with the exception of IV, will be printed in oil colors by chromo-lithography.

The sections, which will be about ten in number, it is proposed to give on a scale of five miles to an inch.

This Atlas will not be ready before the end of the present year.

Montreal, July 15, 1863.

PREFACE.

The Geological Survey of Canada was instituted by the Provincial Government in 1843; since which time the results arrived at in its investigations have been submitted to the successive Governors-General in Annual Reports, which have been from time to time transmitted to the Legislature, and published by authority. Of these Annual Reports, particularly of the earlier ones, there was in general but a moderate number of copies issued; and, with the exception of one or two of the later Reports, they are now all out of print. The present volume contains, in a condensed form, the substance of all the previous Reports, with much original matter; and the work may be considered a Report of Progress from the commencement of the Survey to the termination of the year 1862.

In the investigation of the Geology of the Province, I have been aided in the field-work, not only by the Government-appointed officers of the Survey, but by explorers who have received their training from me, and have acted under my instructions. The results obtained by some of these have in part, appeared as separate Reports, addressed to me as Director of the Survey, and have been transmitted to the Government, and published with my own. In the present volume however no separate mention is made of the special labors of my colleagues or assistants; and it is but due to them to state, in this place, the part which each one has taken in the investigation.

The explorations of my colleague Mr. Murray have extended over most of the settled parts of western Canada, and over a large portion which is still in forest; and he may be said to have blocked out nearly all that is known of the distribution of the rocks in that division of the province; while, in respect to the limits of some of the formations, the investigation has been carried into farther detail by others connected with the Survey. He has also examined several parts of Gaspé, where his explorations include surveys of the Rivers Matanne, Ste. Anne, St. John or Douglastown, and Bonaventure, and the examination of parts of the Shickshock Mountains.

Mr. James Richardson, formerly a farmer settled in Beauharnois, has been in the employ of the Survey nearly from its commencement, and has become a most valuable and indefatigable explorer, capable of mapping accurately his survey of rivers, lines of traverse through the forest, and outcrops of rocks; but he requires aid in working up his materials into a report. His labors, following preliminary explorations by myself, have shown, in considerable detail, the distribution of the Lower Silurian rocks for a moderate distance on each side of the Ottawa, from Pembroke to Grenville; and on the north side of the St. Lawrence between Montreal and the St. Maurice; as well as on its south side from St. Regis to Phillipsburgh and Laprairie. On the south side of the St. Lawrence he has farther partially traced out the rocks of the Hudson River formation and of the Quebec group, in some of the seigniorial lands, and in several parts of the Eastern Townships. In the Quebec group his explorations have embraced a portion of the country from St. Nicholas to St. Thomas, and have extended almost continuously along the south bank of the St. Lawrence from Rivière du Loup to the Marsouin, including a breadth of from five to fifteen miles. He has examined a section across the Silurian rocks from the St. Lawrence to the Restigouche, by the Great Metis and Patapedia Rivers; and another from the Marsouin across the Shickshock Mountains, to the neighborhood of the Great Cascapedia. He has surveyed the Quebec group on the Magdalen, and explored the Gaspé limestones and sandstones on a line of country from this river, by the Dartmouth, to Gaspé Basin. He has partially traced out the distribution of the Lower Silurian and Laurentian rocks about Lake St. John on the Saguenay; and of the Lower and Middle Silurian around the Island of Anticosti in the Gulf of St. Lawrence. His examination of the Lower Silurian series has been continued in the Mingan Islands, and of the Laurentian system along the north shore of the Gulf between the Mingans and the Strait of Belle Isle; where finally, by his examination of the fossiliferous rocks on both sides of the strait, and the specimens which he has there collected, he has afforded the means of establishing pretty clearly that the Quebec group is of Lower Silurian age, and younger than the Potsdam.

The work of Mr. Robert Bell, a young civil engineer, whose connection with the Survey as an explorer is comparatively recent, comprises an examination of some parts of the Gaspé peninsula, in which he has added to our knowledge of the distribution of the Gaspé limestones and sandstones on the Dartmouth, York, Malbay, and Grand Rivers, and of that of the Bonaventure formation behind Percé; as well as an examination of portions of the western peninsula of western Canada, where he has traced out in greater detail the limits of the Middle Silurian rocks, of which Mr. Murray had previously ascertained the general outlines. In his explorations, Mr. Bell has devoted a good deal of attention to the phenomena of Superficial Geology; and he has aided in collecting the facts on this subject which have been ascertained by others connected with the Survey, and by various investigators who have elsewhere published their observations.

Mr. J. De Cew, a provincial land-surveyor of Decewville, Cayuga, who has been occasionally employed for short periods on the work of the Survey, has added many details to Mr. Murray's lines along the contiguous limits of the Onondaga, Oriskany, and Corniferous formations, from Middleton to Bertie on the Niagara River.

Mr. James Lowe, a farmer settled in the township of Grenville, after acquiring sufficient experience by accompanying me as assistant in my explorations in his own neighborhood, has been employed in tracing out, under my direction, the distribution of the crystalline limestones interstratified in the Laurentian system, and of the intrusive masses which intersect this, in the counties of Ottawa, Argenteuil, Two Mountains, and Terrebonne. In this intricate investigation, in a district almost wholly covered with forest, he has accumulated a great number of valuable facts, which, joined to my own labors in these counties, have enabled me to prepare a detailed map of the geology of this interesting region.

Mr. Richard Oatey, a practical Cornish miner, residing in Montreal, has from time to time been entrusted with the examination of metalliferous lodes and deposits, particularly those holding lead, copper, silver, and gold, with a view of ascertaining their economic value.

The Rev. L. T. Wurtele, formerly of Lennoxville, and now of Actonvale, has on several occasions volunteered short explorations on behalf of the Survey; and we are more particularly indebted to him for information, and for specimens procured on an excursion up the St. Francis River from its mouth to the neighborhood of Drummondville.

My own researches embrace explorations of Lake Superior, of the north shore of Lake Huron, and of the valley of the Ottawa for about 300 miles, with the valley of the Mattawa to Lake Nipissing. They include also the study of the Laurentian rocks on the lower part of the Ottawa, and on its tributaries the Rouge and North Rivers; investigations of the geology of the valley of the St. Lawrence at various points from Malden and Windsor, by Niagara, Toronto, Belleville, Kingston, Brockville, Cornwall, and Montreal, to the St. Maurice; a continuous examination of the distribution of the Lower Silurian rocks from the St. Maurice by Quebec to Cape Tourmente; and examinations of the same series at Bay St. Paul and Murray Bay, as well as among the Mingan Islands. They comprehend also a preliminary exploration of the Gaspé peninsula, by an examination of the whole coast from the Restigouche, by Port Daniel, Percé, and Cape Gaspé, to Cape Chatte; and by two transverse lines of examination, one of them along the valleys of the Chatte and Great Cascapedia, to the Bay of Chaleurs, and the other by the Matapedia and Kempt road to Metis. In this region they farther include a survey of the St. John, and of its tributary the Black River, as well as of a transverse line of section by the Madawaska River, Temiscouata Lake, and Temiscouata Portage, to Rivière du Loup; and an examination of the country along the coast from Rivière du Loup, by Kamouraska, Ste. Anne, and L'Islet, to St. Thomas, comprehending a breadth of from five to ten miles. Among these researches there is embraced a detailed, but still incomplete, examination of the rocks of the seigniories and townships between the Chaudière and Lake Champlain. These include the strata of the Quebec group on the southeast, and those of the Hudson River formation on the northwest of the great break or overlap which follows the valley of the St. Lawrence from Lake Champlain to Cape Rosier. There is included also, along the western side of this break, an examination of the Chazy formation, and of the Trenton group, from St. Dominique to Farnham, continued by Highgate Springs and Swanton, to St. Alban's Bay; and on the east of the break an investigation of the Phillipsburgh series of the Quebec group from the centre of Stanbridge, across St. Armand, to the road between Highgate Springs and Highgate Falls; with an examination of the Potsdam group still farther eastward. In the above investigations of the Ottawa, the Eastern Townships, and Gaspé, the explorations of Mr. Lowe, Mr. Richardson, Mr. Bell, and Mr. Murray have been important auxiliaries.

The labors of my colleague Mr. T. Sterry Hunt comprehend all that has been done in connection with the Survey in the chemical analyses of mineral species and mineral waters, of rocks, and of minerals capable of useful applications. His researches have also been devoted to the study of rock-metamorphism. The principal results of his investigations are given in his own words in the four chapters, xvii–xx; while many of them are interwoven with the matter of other parts of the volume, particularly that of chap. xxi, which treats of Economic Geology. The chemistry of sedimentary rocks is discussed at some length in the introductory portion of chap. xix, where the theory of metamorphism is also considered. It is there asserted that heated alkaline waters have produced the alteration of sediments; but, in opposition to the view of Daubrée, who supposes that thermal springs acting near the surface have been the agents in producing this change, it is maintained that, except in local and comparatively rare cases, the process has only taken place in sediments so deeply buried as to be directly affected by the internal heat of the earth. The ingenious experiments and observations of

Daubrée have thrown great light upon that production of crystalline minerals in which metamorphism consists; but it must be remarked that the effect of alkaline waters in producing these changes was pointed out and insisted upon, as the efficient agent of metamorphism, in the Reports of the Geological Survey, some time prior to the first publication of Mr. Daubrée's views. (See Report of Progress for 1853–56, pages 479, 480). In addition to his researches in the laboratory, Mr. Sterry Hunt has aided the Survey by explorations among the metamorphic rocks of the Laurentian series on the north and south sides of the Ottawa, and the north side of the St. Lawrence, as well as of the Silurian series in the Eastern Townships; and he has extended his examinations to the gypsiferous and oil-bearing rocks of the western peninsula of Canada.

Mr. Billings was appointed Palæontologist to the Survey in 1856, and since then his unremitting attention has been devoted to the study of the Palæozoic fossils of Canada, of which very considerable collections have been made in our various explorations. Of these fossils he has described in the publications of the Survey, and in the scientific journals of the province, 526 species; of which 395 are Lower Silurian, 67 Middle and Upper Silurian, and 64 Devonian. He has thus greatly facilitated the means of determining with precision the limits and distribution of our geological formations, and of the economic substances which they contain. In order to insure uniformity in the palæontological part of this work, all the palæozoic fossils mentioned in it have been submitted to the inspection of Mr. Billings, and the species are therefore all given on his authority. Of the described Lower Silurian species found in Canada, not including those of the Quebec group, he has prepared a catalogue, showing their vertical distribution, and referring to the publications in which the descriptions and figures will be found. This catalogue has been introduced into the Appendix to this volume.

The age of those rocks which are now termed the Quebec group, was, from an early period of the Survey, a subject of considerable difficulty. In a preliminary Report made to the Government in December 1842, and, with others, published by authority in 1845, it was stated as my impression that the contorted strata of Point Lévis, which form a part of the group in question, came from beneath, and were older than the flat limestones of the Trenton formation on the opposite side of the St. Lawrence. It was found however on subsequent examination, that the black shales which overlie these limestones, and hold fossils of the Hudson River and Utica formations, passed, with apparent conformity, beneath the Point Lévis rocks. The only fossils which had at that time been met with in these last, were a species of *Leptæna*, and an *Orthis;* since then named *L. decipiens*, and *O. Electra*. These are so like *L. sericea* and *O. testudinaria*, that they were by me mistaken for them; and had it not been for the discovery of their interior structure in silicified specimens, dissolved out from masses of limestone by the aid of an acid, they might still have passed for these species. With this apparent superposition of the strata, seemingly uncontradicted by fossils, as the only evidence before me, I felt constrained to relinquish my first impression; and in 1848 and 1849 enunciated the opinion that the whole series composing the Quebec group was subordinate to that of the Hudson River, and to its succeeding formation, the Oneida conglomerate. But the discovery in May 1860 of the Point Lévis fossils at once enabled Mr. Billings to conclude that the rocks of the Quebec group must be placed near the base of the second fauna of Barrande,* or about the horizon of the Calciferous and Chazy formations. This opinion, our subsequent investigations in the neighborhood of Lake Champlain, and of the Strait of Belle Isle, have completely borne out; and there now remains little doubt that the attitude of the rocks in question in the vicinity of Quebec is due to a great overlap, which runs from southwest to northeast through the whole length of the eastern part of the province, and extends in both directions far beyond it. Dr. Emmons in 1842 stated his conviction that rocks in Vermont, which have since been ascertained to be equivalent to those of the Quebec group, were older than the Birdseye and Black River formation; but his view of the structure of that region made a large part of them older than the Potsdam sandstone. In eastern Canada we have as yet no proof that any great series of strata to the southward of the St. Lawrence is of higher antiquity than the Potsdam group, to which that sandstone belongs. The country through which the rocks in question extend is still however under investigation; and the structure which has been assumed for the purpose of conveniently describing this metalliferous region, which appears to be one of great economic importance, must for the present be considered as in some degree provisional.

Before the Geological Survey of Canada was commenced, the investigations of Emmons, Mather, Vanuxem, and Hall, the four geologists to whom

* This opinion of the age of the Point Lévis limestones was communicated to Mr. Barrande by Mr. Billings in a letter dated 12th July 1860. Specimens of trilobites from the slates of Georgia in Vermont were received from Col. E. Jewett in the latter part of 1858, and pronounced by Mr. Billings to belong to primordial types; but he then thought it possible that these, with the several species of *Triarthrus* of the Utica slate, and those referred, in the first volume of the Palæontology of New York, to *Olenus* and *Agnostus*, might constitute a colony of primordial forms (or something analogous to the colonies of Barrande), in the upper part of the Lower Silurian series. This view was also transmitted to Mr. Barrande in a letter written in March or April 1860; but the great amount of palæontological evidence furnished in the following month by the Point Lévis fossils, rendered it necessary to seek for some other explanation. The supposed age of these fossils was first stated, as already said, in Mr. Billings's letter of the 12th July; and the explanation of the structure, which brings the Quebec group into the place now assigned to it, was given in my letter of the 31st December 1860. (See Canadian Naturalist and Geologist, v, 472; and American Journal of Science [2], xxxi, 216).

was entrusted the survey of New York, had correctly established the sequence in that state of all the palæozoic formations which lie to the west of the great overlap that has just been mentioned. It is therefore scarcely necessary to do more than allude to the great advantage which has been derived from their labors in following out the same formations through western Canada. But in addition to the general benefit obtained from the investigations of Professor Hall in his own division of the state of New York, we have to express our obligations to him for the assistance rendered to Mr. Murray in 1856, in tracing out the boundary of the Upper Devonian rocks in a part of the western peninsula. The Survey will be farther benefited by the labors of this distinguished naturalist in his description of the compound graptolites obtained from the Quebec group at Point Lévis. This work was kindly undertaken by Professor Hall before the appointment of Mr. Billings as palæontologist to the Survey, and it will shortly appear as the second Decade of Canadian Organic Remains. A list of the species to be described in it has been introduced into the Appendix.

Amidst his many arduous duties connected with the University of McGill College, Dr. J. W. Dawson has still found time to devote attention to many points in Canadian geology. His investigations into the character of our Post-tertiary deposits have greatly extended our knowledge of the subject; while his study of the land-plants of the Devonian rocks of North America has given a new interest to this series of deposits. He was first incited to an examination of this flora by the numerous specimens which he found ready for examination in the collection of the Survey from the Gaspé sandstones; and the species found in Gaspé, although few in number, naturally suggested inquiry into the vegetable remains of equivalent rocks in other parts. Goeppert, in his memoir on the flora of the Silurian, Devonian, and Lower Carboniferous rocks of Europe and America, enumerates in 1860, fifty-nine species as known in the Devonian series up to that date. In 1859, Dr. Dawson described six species from specimens collected by himself, and by the Geological Survey, in the Devonian rocks of Gaspé. In 1861, he added fifteen other species from Perry in Maine, and from St. John in New Brunswick. In 1862, having had placed in his hands the collections of the New York Survey, and those made by Messrs. Matthew and Hartt at St. John in New Brunswick, he raised the number of American species to sixty-nine; and in a paper read before the Geological Society of London, in May 1863, he has added to these, thirteen more, including two from Gaspé; making the whole number of species in the Devonian flora of eastern North America, eighty-two, belonging to thirty-five genera. Of these species eight had previously been recognized in Europe, and about ten of them had been more or less perfectly noticed or figured in reports on American geology. On the subject of the Post-tertiary deposits, we have availed ourselves not only of Dr. Dawson's published observations, but of various manuscript notes which he has kindly placed in our hands. In his investigations of these deposits, Dr. Dawson has more than doubled the number of species of invertebrate animals previously known in them; and Mr. J. F. Whiteaves, so well known as a naturalist, has kindly aided in preparing a catalogue of these fossils.

Mr. Sandford Fleming of Toronto has communicated to the Canadian Journal several interesting papers upon points connected with the lacustrine deposits of Lakes Ontario and Huron, of which use has been made in describing our Superficial Geology. We have also given the ancient water-margins occurring between Lakes Ontario and Simcoe, as described by the late Mr. Thomas Roy of Toronto; and we are indebted to Mr. A. Dickson of Pakenham for various facts relating to the Post-tertiary formation, and for specimens from this, and from the Lower Silurian rocks.

Admiral Bayfield's excellent maps of the lakes, river, and Gulf of St. Lawrence have always been of the utmost aid to the Survey in such explorations as came upon the great water-lines of the province. Their value however is not confined to the indication of geographical features. There is registered upon his charts, a considerable amount of accurate geological information, in the form of notes, which he has in many places given of the character of the rocks forming the coast. These notes have on some occasions immediately directed attention to points of interest, and at other times have saved much labor in tracing out the distribution of formations. It is understood that Admiral Bayfield, in his surveys of the St. Lawrence, made, with the aid of Dr. Kelly, a considerable collection of organic remains, which were presented to various societies and institutions of natural history. It is much to be regretted that these had not been figured and described before they were thus distributed, as we should thus probably have long ago obtained a knowledge of many fossils, the descriptions of which have been only recently published from specimens in the collections of the Survey. Admiral Bayfield has communicated to the Literary and Historical Society of Quebec, and to the Geological Society of London, various interesting papers on subjects connected with Canadian geology, with the facts in which it will be found that we have on several occasions availed ourselves.

Among the pioneers in Canadian Geology, no observer was more accurate than Dr. J. J. Bigsby, secretary to the Boundary Commissioners under the Treaty of Ghent. His range of investigation extended from Quebec to Lake Superior, and beyond the limits of the province in that direction; and he has accumulated and published a great store of facts, upon the exactness of which the greatest reliance can be placed. He is in consequence frequently quoted in this volume as an authority.

Lieutenant, now Major-General Baddeley, of the Royal Engineers, when in Canada, now nearly forty years since, was an ardent promoter of geological inquiry, and his services were made available to the Provincial Government in explorations in the region of the Saguenay, and in the peninsula of Gaspé. To him we are indebted for the first published notice of the Lower Silurian limestones on Lake St. John, Bay St. Paul, and Murray Bay, as well as of the existence of gold in the drift of the Eastern Townships. Lieut. F. L. Ingall was another explorer, who about that time did good mineralogical service on government expeditions; the district to which his attention was directed being the country between the St. Maurice and the Ottawa. Captain R. H. Bonnycastle, R.E., at a somewhat later period interested himself in the examination of various mineralogical and geological phenomena, more particularly in the neighborhood of Kingston, where his military duties had placed him. The results of his observations were given in Silliman's Journal in 1831, and in other publications, and have been cited in this Report.

Although Dr. James Wilson, who practised during many years as a physician at Perth, in the county of Lanark, has personally communicated little to the public, he has devoted considerable attention to the natural history of the district in which he resided, and has enriched the mineralogy of the province by the discovery of several very interesting species. To him we are indebted for pointing out the sandstone bed near Perth, from which were obtained the specimens of *Climactichnites Wilsoni;* and we have on several occasions, received from him information regarding the occurrence in his own neighborhood of minerals capable of economic application. With the *Climactichnites* at Perth, there occurs also the *Protichnites* of Owen, the first discovery of which at Beauharnois was made by the late Mr. Robert Abraham, then editor of the Montreal Gazette, in which he gave an interesting description of these curious foot-prints.

The late Dr. A. F. Holmes of Montreal, long a diligent collector of minerals, was instrumental in bringing several Canadian species or varieties into notice, by transmitting them for analysis to Dr. Thomas Thompson of Glasgow. His cabinet has now become the property of the University of McGill College, and we have on several occasions been favored with authentic specimens from it, for the purpose of comparative analyses.

The late Reverend Andrew Bell of L'Orignal, from about the time the Geological Survey commenced, devoted a portion of his attention to the collection of fossils from the Lower and Middle Silurian rocks of Canada, and at the time of his death bequeathed his cabinet to the University of Queen's College, Kingston. In addition to a large number of organic remains, it contained many of the mineral species of the province, and now forms the nucleus of the museum of that university, to which Drs. Williamson and Lawson have since made many additions. The authorities of the university have, on several occasions, kindly permitted to Mr. Billings the use of specimens from their museum for the purpose of comparison. We are besides indebted to Dr. Lawson for several facts connected with the drift.

Professor E. J. Chapman, of Toronto University, so favorably known for his contributions to mineralogy, has advanced the science of geology in the province, not only by his lectures in connection with the University, but by such field explorations as he has had an opportunity to make; by his collections and descriptions of Canadian fossils; and by his communications to the Canadian Journal on various points relating to his investigations of the Drift and the Silurian formations of western Canada, of which we have availed ourselves. We are indebted to him for important mineralogical observations; and to Professor Henry Croft, of the same university, for several chemical analyses. Through Professor Chapman, Mr. Billings has been permitted the use, for the purpose of description, of some of the corals from the Corniferous formation of western Canada, which are preserved in the collections of the Canadian Institute of Toronto. Professor Hind, of Trinity College, Toronto, has also favored the Survey with fossils for description, from collections made by himself for the museum of his college. By his excursion up the Moisie River, in Eastern Canada, Professor Hind has added to our knowledge of the distribution of the anorthosite rocks; and by his explorations in the Red River region he has shown the extension in that direction of the Lower Silurian and Devonian series, without the intervention of the Middle and Upper Silurian.

We are indebted to the late Mr. John Head for specimens from the Corniferous formation of western Canada, and for aid in the examination of the rocks of Point Lévis. In our investigations in the vicinity of Phillipsburgh, both Mr. Billings and myself have on several occasions been favored with the assistance of Dr. P. J. Farnsworth; and in the neighborhood of Swanton we have been indebted for guidance and kindly aid to the Rev. J. B. Perry and Dr. G. M. Hall, who have devoted much attention to the geology of their own district. By these three gentlemen the Survey has been supplied with several new species of fossils from the Quebec group, which have been described by Mr. Billings.

I have in addition to express our obligations to many persons who have either presented specimens of Canadian organic remains to the Survey, or lent them to the palæontologist for comparison or description. Among these contributors are Mr. T. Devine and Mr. E. Cayley of the Crown Lands Department, Quebec, the former of whom has described two new species discovered by himself; Mr. G. Barnston, Mr. H. G. Vennor, Dr. W. Fraser, Mr. T. Peel, Mr. W. Bulmer, and Mr. N. S. Whitney, of Montreal, as well as the Montreal Natural History Society; Mr. T. E. Blackwell and Mrs. A. M. Ross, formerly of Montreal;

Dr. J. A. Crevier of Ste. Cesaire; Mr. Brown of Hawkesbury; Dr. E. Vancortlandt, Dr. James Grant, and Mr. J. Mackinnon, of Ottawa; the Rt. Rev. Dr. Horan, R. C. Bishop of Kingston; Mr. A. T. Drummond of Kingston; Mr. W. M. Roger of Peterborough; Mr. J. F. Smith of Toronto; Mr. W. Saunders of London, C. W.; Mr. J. Dalgleish of Galt; Judge W. B. Wells of Chatham; Mr. A. D. Hager of Vermont, Col. E. Jewett of Albany, N. Y., and Mr. W. Denton of Ohio.

For the localities and modes of occurrence of several mineral deposits of economic importance, more particularly of copper ores, we have been indebted to Mr. Charles Robb and Mr. J. L. Willson, mining engineers of Montreal; to Mr. Herbert Williams, manager of the Harvey-Hill mine, Leeds, C. E.; and to Mr. R. H. Fletcher of Sault Ste. Marie, C. W. Mr. T. Macfarlane, formerly of Actonvale mine, and now of the Wickham mine, C. E., has also furnished valuable information, and has published in the Canadian Naturalist and Geologist several interesting papers on the mineralogy and geology of the province. Among these is a comparative view of the rocks of Canada and Norway, in which latter country Mr. Macfarlane resided for several years.

For the purpose of representing correctly the geological features ascertained in the explorations of parts of the country which had not been previously delineated topographically, it became necessary for the officers and assistants of the Survey, from the very commencement of their operations, to measure carefully many of the rivers and other geographical lines. The amount of work of this description has been very considerable; but it will be more particularly alluded to in describing the map which has been constructed to show the distribution of our geological formations. This map has been compiled on a scale of twenty-five miles to an inch, by Mr. Robert Barlow, aided by his son Mr. Scott Barlow. A reduction of it to 125 miles to an inch, with other maps, on a larger scale, showing the distribution of small typical portions of the Laurentian and Huronian rocks, will be given in a separate Atlas, which will accompany the present volume, and be of a uniform size with it. The Atlas will contain in addition one or two plans, and a series of sections illustrating the geological structure of different parts of the province.

One of the duties imposed by the Government upon the Survey, at the time of its institution, was the formation of a Provincial Museum, which should illustrate the geology and the mineral resources of the country. This object has been constantly kept in view; and since a suitable building has been placed at the disposal of the Survey, the Museum has gradually assumed a value and importance which at the present time render it second to few on the continent for the special purposes to which it is devoted. The Museum is separated into two parts. One of these is devoted to Economic Geology, and in it are displayed specimens of such rocks and mineral substances as can be applied to the useful purposes of life. These are subdivided into two classes; one of them containing the more important metals and their ores, and the other what may be termed the non-metalliferous mineral substances. These various materials are again classified technically, pretty much in the way in which they are described in the twenty-first chapter of this volume; each specimen being placed under a label giving its locality, and the geological formation to which it belongs. The various substances are as much as possible reduced to forms showing their uses, thus at once making the design of the arrangement intelligible. In this division of the Museum there is a classified collection of all our mineral species; and another of our rocks, more particularly those of a metamorphic or of an intrusive character. This part of the Museum it is proposed to illustrate farther by geological maps, sections, and models.

The geographical distribution of any series of formations can scarcely be followed out correctly over a large area without a preliminary knowledge of the true geological superposition, or the natural order in which these formations have been deposited. It is now well established that throughout a very large proportion of the whole series of rocks composing the earth's crust, the best means of determining their succession is by their fossils; it being a fundamental principal of geology that different formations are characterised by different groups of organic remains. The study and determination of fossils thus becomes an indispensible part of a geological survey. But these organic forms are so many and so various, and pass into one another by such insensible gradations, that to make them truly available requires the special attention of a person versed in natural history, and indeed of one who pursues an uninterrupted study of that department of natural history which is devoted to these ancient forms. Hence the necessity of attaching a palæontologist to every important geological survey; and hence no geological museum can be complete without a full and properly classified collection of described organic remains from the fossiliferous rocks of the area which it is designed to illustrate.

The second division of the Museum is thus devoted to the palæontology of our formations. In this division the fossils are displayed in groups, which succeed one another in the order of the formations, beginning with the most ancient. In each group the specimens are arranged in a natural-history order, commencing with the simplest or lowest forms, and rising to the highest; and to each specimen there is attached a label giving the generic and specific names of the fossil, with its geological formation and locality. In order that there may be no mistake as to the fossil indicated by the label, the specimens are freed as much as possible from all other fossils. In order at the same time to save space, the specimens have been as much as possible reduced in size. In this operation the services of Mr.

T. C. Weston, a lapidary, have been made available; and his skill has also been applied to slitting many of the cephalopods and other fossils, and rocks, for the purpose of showing their internal structure. By this reduction in the size of the specimens we have been able to arrange a much greater number in our limited space than would otherwise have been possible.

The number of species of fossils displayed in the Museum is about 1500. Figures engraved on wood of 543 of the more characteristic of these, are given in the present volume. These are chiefly by Mr. J. H. Walker of Montreal, with a few by Mr. A. W. Graham and Mr. G. G. Vasey: the whole from excellent drawings by Mr. H. S. Smith. With a few exceptions, the species here figured are distinct from those which have already been given in the Decades of Canadian Organic Remains, published by the Survey. Of these, I, III, and IV have appeared, and it is expected that Decade II, already referred to, will shortly be published. For the descriptions of Decade I we are indebted to Mr. J. W. Salter, palæontologist to the Geological Survey of the United Kingdom. It contains twenty-one species from the Birdseye and Black River formation, the figures of which are drawn by Mr. C. R. Bone, and engraved by Mr. W. Sowerby. Decade II will contain fifty-one species of graptolitidæ, by Prof. James Hall of Albany. Decade III contains twenty-nine species of Lower Silurian cystideæ and asteridæ, described by Mr. Billings, and one species of cyclocystoides, by Messrs. Salter and Billings; with fourteen species of Lower Silurian bivalved entomostraca, by Mr. T. Rupert Jones, of the Geological Society of London. The figures are drawn on stone by Messrs. C. R. Bone, J. Dinkle, Tuffen West, G. West, and H. S. Smith. Decade IV contains forty-three species of Lower Silurian crinoidea, described by Mr. Billings; the figures drawn on stone by Mr. H. S. Smith, and printed by Mr. G. Matthews of Montreal. As already stated, Mr. Billings has described altogether 526 species of fossils. Those not included in the Decades have been published in the Canadian Journal of Toronto; the Canadian Naturalist and Geologist of Montreal; in the Annual Reports, and in the volume entitled Palæozoic Fossils of Canada, published by the Survey.

In the collection of the Survey there are probably at the present time about 500 species of fossils still remaining undescribed. The publication of these will be an additional contribution to the general fund of palæontological knowledge; to which, as it has been of great utility in our own investigations, we are bound to add what we can for the benefit of others. But independent of the instruction derived from fossils as guides to ourselves, and proofs to others in regard to the succession of our rocks, there is a higher consideration attached to them than their mere utilitarian application. For, as remarked by Conybeare, they bring us supplementary information of numerous species which have long vanished from the actual order of things; and by their resurrection they unexpectedly extend our views of the various combinations of organic forms. In many instances they supply links otherwise wanting, in uniting the different terms of the series in an unbroken chain, and thus aid in the elucidation of those general laws of natural history, the investigation of which is always of so much interest to enlightened minds.

W. E. LOGAN.

OFFICE OF THE GEOLOGICAL SURVEY,
Montreal, May 1863.

GEOLOGY OF CANADA.—1863.

ERRATA.

The reader will please to make the following corrections :

Page 11, line 6 from the foot, for Henley's read Healy's.
" 29, " 10 " " " supply the figure 2.
" 162 ; the numbers of the woodcuts, 161 and 162, are to be transposed.
" 268, line 19 from the foot, for *Stromatopora* read *Stenopora*.
" 420, " 20 from the head, for Devonian read Upper Silurian
" 718, at the top, for fifteenth read fourteenth.
" 734, line 12 from the top, for Devonian read Silurian.

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GEOLOGY OF CANADA.

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GEOGRAPHICAL DESCRIPTION.—ST. LAWRENCE BASIN.—LAURENTIDE AND NOTRE DAME MOUNTAINS; THEIR LAKES AND RIVERS.—RAPIDS AND CANALS OF THE ST. LAWRENCE.—LOWER SILURIAN REGION OF WESTERN CANADA.—MIDDLE AND UPPER SILURIAN REGION.—SURFACE OF THE WESTERN PENINSULA; ITS WATER-SHED AND RIVERS.—PENINSULA OF MICHIGAN.—THE GREAT LAKES.—AMERICAN COAL FIELDS.—MISSISSIPPI AND RED RIVER VALLEYS.—ROCKY MOUNTAINS.

Basin of the St. Lawrence.

The hydrographical basin of the St. Lawrence and its estuary as far as the lower end of the island of Anticosti, comprises an area of about 530,000 square miles. In form it presents an irregular parallelogram, running nearly S. W. for about 900 miles, with a pretty uniform breadth of 250 miles; the southern side, in its farther progress, sweeping round in a rude semicircle, the diameter of which extends about 900 miles to the N. W. The great lakes into which the river expands, with its estuary, have an area of about 130,000 square miles; leaving for the land drained by the river a superficies of 400,000 square miles. More than eight tenths of this, or about 330,000 square miles, belong to Canada, while the remainder constitutes a part of the United States. With the exception of about 50,000 square miles (including the whole of the Gaspé peninsula) in the eastern part of the province, the Canadian portion lies wholly on the north side of the river, while the only part of the United States which does so is situated at the west end of Lake Superior.

Mountain Ranges.

A range of mountainous country rises on each side of the estuary of the St. Lawrence,—the Laurentides on the north, and the mountains of Notre Dame on the south. The opposing flanks of these ranges keep close on the margin of the water for a considerable distance up the river. That of the southern range begins to leave the margin in the neighborhood of Kamouraska, nearly a hundred miles below Quebec, where the river is fifteen miles wide. Opposite to Quebec the range is thirty miles distant from the river, and opposite to Montreal about fifty miles, where it enters the State of Vermont to form the eastern limit of the valley of Lake Champlain. From the province line south-westward, the range is known as the Green Mountains and the Alleghanies, and constitutes the Appalachian chain. The flank of the northern range diverges from the St. Lawrence at Cape Tourmente, about twenty miles below Quebec, and at Montreal is distant from the river about thirty miles. Beyond this it extends up the Ottawa on the north side, for about a hundred miles, and sweeps round thence to the Thousand Islands, near Kingston; from which it gains the southern extremity of Georgian Bay, and continues along the eastern and northern shores of Lake Huron and Lake Superior. It then turns up to the north-westward, and ultimately reaches the Arctic Ocean; the distance of the whole course of the range from Labrador being about 3500 miles.

Notre Dame Mountains.

The southern range separates the tributaries of the river St. Lawrence from those of the Gulf, as well as from those of the bay of Fundy and the Atlantic, as far as Canada is concerned; but is broken through by the Hudson, the Delaware, the Susquehanna, and other Atlantic rivers farther westward. The northern range gives the water-shed separating the tributaries of the St. Lawrence from those of Hudson's Bay; but beyond the basin of the St. Lawrence it is traversed by two of the affluents of this bay, the Saskatchewan and the Churchill, the former taking its source in the Rocky Mountains; while still farther on, the range again becomes the limit of the Hudson's Bay rivers, dividing their sources and those of the Back and other streams, for 800 miles, from the tributaries of the Mackenzie.

Laurentides.

Judging from the facts obtained in Canada, each of these ranges is composed of sedimentary rocks in an altered condition; those of the north presenting the more crystalline character. The rocks of the northern range are also the more ancient, being of the azoic era; while those of the southern are palæozoic, though the fossils in a large portion of them appear to have been obliterated through molecular movements.

Structure of Notre Dame Mountains.

The strata of both ranges are very much corrugated. In the southern mountains the axes of the folds run parallel with the range, and the hills and valleys for the most part coincide with these bearings. Some of the axes have been traced considerable distances, and though parallel with one another they do not appear to maintain straight lines, but assume, as they proceed, great sinuous sweeps. Following them from the extremity of Gaspé, they strike into the land with a north-west bearing, which gradually rounds to west in the vicinity of Ste. Anne des Monts and the Chatte. Farther on, they by degrees assume a nearly south-west course, and again turn more west for a short distance, after passing the Chaudière; but once more bending to south-west, their course becomes nearly south as they quit the province amid the Green Mountains, beyond which their course has been described by Professor Rogers as being marked by sinuosities of a similar character as far as Alabama. In one part or other of the range, rocks of all the divisions of the palæozoic period, from the Lower Silurian to the Carboniferous, appear to be involved in the folds, and though in some places there is a want of conformity between the Lower and the Upper Silurian, and between the Devonian and the Carboniferous, there is no want of parallelism in the axes of the folds throughout the whole; showing that the forces which produced them continued in operation in the same directions during nearly the whole of the palæozoic period.

Age of rocks of these Mountains.

In the Canadian part of the range, it is the inferior deposits of this period that present the highest peaks. To these deposits appear to belong the Shickshock Mountains, which, in ascending the St. Lawrence towards Quebec, are the highest that are displayed to view on the south side. The whole of the Gaspé peninsula may be considered a block of table-land of about 1500 feet in height, in which the river-courses are deep and narrow excavations. Upon this the Shickshock Mountains are a conspicuous range of highlands, extending about sixty-five miles from the east side of the Ste. Anne des Monts to the Matanne. They stand on a breadth of from two to six miles, at a distance of about twelve miles from the St. Lawrence, and rise into points, attaining heights of between 3000 and 4000 feet. But though the highest land, they do not form any part of the water-shed of the peninsula; for the Ste. Anne des Monts, the Chatte and the Matanne, taking their sources on lower land to the south, cut gorges through them so deep that their channels, where they cross the range, are not more than between 500 and 600 feet above the St. Lawrence. The waters of one branch of the Matanne have their source on lower land on the north side of the range, and flow south through a profound gap to join the main stream, thus crossing the range twice in their course to the great river.

Heights of Mountains.

In the same part of the geological series are St. Ronan's Mountain in Buckland, and White Mountain in Coleraine, each about twenty-five miles from the Chaudière on opposite sides, and about forty miles from its mouth, as well as Ham and Orford or Victoria Mountains, some twenty or twenty-five miles from opposite sides of the St. Francis, with Owl's Head and Sutton Mountains, the whole being the highest series of summits along the range to the province line, some of them supposed to equal in elevation the peaks of Gaspé. As in the case of the smaller streams cutting the Shickshock Mountains, the Chaudière and the St. Francis, which are two of the largest tributaries on the south side of the St. Lawrence, traverse this portion of the range; gathering the chief part of their waters from lands to the south, through valleys running with the strike.

Except near the water-shed, the valleys of the principal streams do not attain a greater elevation than from 500 to 900 feet above the St. Lawrence. They present but few abrupt cascades, and though no less than sixteen ponds and larger sheets of water are included in the panorama

Lakes of Notre Dame Mountains.

Their heights and areas.

from the top of Orford Mountain, it cannot be said that on the whole the Canadian part of the southern range abounds in lakes. The greatest of these, with their areas and approximate heights above the sea, are:—

	HEIGHT. *Feet.*	AREA. *Square Miles.*
Memphramagog	756	37
Aylmer	795	9
St. Francis	890	12
Megantic	?	17
Temisconata	467	24
Matapedia	480	12

The hills, exclusive of the summits of the highest ridge, seldom exceed from 1000 to 1500 feet, and the country connected with the Canadian part of the range, presenting a rolling rather than a rugged mountainous surface, is for the most part, particularly in what is called the Eastern Townships, capable of tillage or pasturage, and will in general be found to constitute a useful agricultural area.

Structure of Laurentides.

While the corrugations of the Laurentides appear to be more complicated than those of the southern range, they have not yet received the same amount of investigation. It would be hazardous therefore to express any very confident opinion in regard to their general bearings. The northern range, belonging, as has already been stated, to the azoic period, is composed in Canada of two series of rocks, which have been termed the Huronian and the Laurentian, the former overlying the latter. The Huronian strata are met with on the north shore of Lake Huron and the east and north shores of Lake Superior, and the axes of the folds which these strata present appear to trend north-west on the former lake and gradually turn round to south-west on the latter. The Laurentian folds which have been investigated appear to hold courses wholly independent of these, the chief part of them being north or a few degrees removed from it. The plications appear to be sharp and numerous; and as the bearing of their axes would be transverse to the general bearing of the range, while supposed equivalent rock-masses belonging to it are nevertheless found towards both extremes of the province, as well as in intermediate parts, it seems probable that the outcrops of the strata will exhibit a very deeply serrated or zigzag arrangement in their geographical distribution, and that the bearings of the mountains and valleys will conform to them.

The largest rivers issuing from the Laurentides in Canada are the Ottawa and the Saguenay, the former between 500 and 600 miles, and the latter between 300 and 400 miles in length. They take their sources very nearly together, upwards of 200 miles north-west of the St. Lawrence, and, after running for some distance parallel with it in opposite directions, turn and flow nearly parallel with one another to join it; their distance apart being about 300 miles. Almost all the streams in the intermediate country—the Gatineau, the Lièvre, and the St. Maurice being the largest three—run very nearly from north to south, and it is upon some of those which are tributary to the Ottawa that the axes of the folds have been found to coincide with the rivers; while the Ottawa itself, skirting the Laurentides for a considerable distance in the lower part of its course, cuts the folds transversely. From the upper end of Lake St. John to Chicoutimi, sixty miles in a bearing south of east, the Saguenay appears to run with the strata; but from Chicoutimi to the mouth, seventy miles more in the same bearing, it appears to cut them transversely. For some distance below the Saguenay the streams flow nearly parallel with it, becoming however more north and south approaching the Gulf. The largest of these rivers appear to be the Betsiamite, the Outarde or Bustard, the Manicouagan, and the Moisie; but what relation their courses bear to the strike of the strata has not been ascertained.

Rivers of the Laurentides.

Between Lake St. John and Murray Bay the main ridge of that part which is cut transversely by the Saguenay is stated to attain 4000 feet above the sea, while peaks in parallel ridges nearer the St. Lawrence may exceed half that height. Bayfield gives 2547 feet to Mont Eboulemens, between Murray Bay and Bay St. Paul; and farther up the St. Lawrence, among the summits that lend such majesty to the view from Quebec, he states Cape Tourmente to be 1919 feet, and Mount Ste. Anne 2687 feet. In the country north of the Ottawa the most elevated summits seen by the officers of the Survey are those of the Trembling Mountain in Argenteuil. One of its peaks is estimated to be 2060 feet, while few hills in the next gradation of heights in the same neighborhood exceed 1000 or 1200 feet. In the country between the Ottawa and Lake Huron the highest summits do not appear to exceed 1500 or 1700 feet, though one near the sources of the Muskoka and the Petewahweh probably attains 2300 feet: those on the northern tributaries of Lake Nipissing and the French River are from 1400 to 1600 feet. To the Lacloche Mountains on the north side of Lake Huron, belonging to the upper division of the azoic rocks, 1000 feet have been given, and to hills farther north in this part something less, while some of the summits of the same deposits on Lake Superior attain 2000 feet.

Heights of the Laurentides.

As the various heights mentioned belong to points more prominent than the country surrounding them, it may not be giving too low an estimate of the general elevation of the Laurentide range in Canada to call it from 1500 to 1600 feet. The surface which the range presents is of a mammillated character, its hills being worn by glacial action into round-backed forms, in general thickly clothed with wood, the prevailing trees on the summits being evergreens, in some parts chiefly pine, and in others spruce, while hardwood sometimes abounds on the lower elevations and in

Lakes of the Laurentides.

the valleys. The valleys are in general not very wide, and many are worn into deep pits holding ponds and lakes: some streams indeed are nothing more from their sources to their mouths than a chain of such quiet expansions united by short discharging channels. The prodigious number of these sheets of water, great and small, bespangling the whole area, is one of its most remarkable features, and when looked upon as displayed on a map, they appear so scattered at random over the surface as to contradict almost any supposed law of distribution. Some of the clusters however that have been examined in connection with their geology are most beautifully explained by the peculiar geographical distribution of the strata, which results from their very corrugated condition, combined with the unequal wear occasioned by the hardness and toughness of some parts, and the softness of others, in the sequence of the metamorphosed deposits. In the Laurentide district a straight line can scarcely be followed in any direction for a great distance without the occurrence of one of these expansions; and it frequently happens that it will present a considerable area even where discharging by a very slender outlet. The profusion in which the lakes exist, with in some instances only a short interval of land between them, though they may belong to different river-systems, affords, with the aid of birch-bark canoes, a ready means of passing from one navigable stream to another, in whatever part an explorer may be; and thus, if he is well acquainted with the country, he can reach almost any position he may wish to attain without any very great deviation from a direct route. Although a large number of the rivers of the Canadian portion of the Laurentides is still unknown, or only partially explored, upwards of a thousand of these lakes are represented on the published maps of the country. It is only a few of them however that are sufficiently large to deserve especial mention. The following six are the best known, with their areas and their elevations above the sea:—

Their heights and areas.

	HEIGHT.	AREA.
	Feet.	*Square Miles.*
St. John	300 ?	360
Grand Lac........................	700 ?	560
Temiscamang......................	612	126
Keepawa	760	92
Temagamang	800 ?	330
Nipissing...........................	639	294

Plain between Laurentide & Appalachian Mountains.

From the opposing flanks of the two mountain ranges which have been described, there extends a vast intermediate plain, the limit of which westward is the Rocky Mountains. In addition to six or seven isolated trap mountains in Eastern Canada, varying in height from 500 to 1800 feet, (all visible from the hill near Montreal, which is one of them,) and the Adirondack Mountains, a nearly isolated mass of Laurentian rocks rising in

New York to the height of 5000 feet between Lake Champlain and Lake Ontario, there are few sudden inequalities to break the smoothness of the general surface of the plain, with the exception of abrupt descents through the drift to river courses, and an escarpment forming that step in the country which produces the world-renowned cataract of Niagara. The summit of that escarpment is of the Middle Silurian period, and tracing it from west to east, it is known to form the two horns separating Green Bay from Lake Michigan: thence running along the south front of the northern peninsula of the state which takes its name from that lake, and the south half of the Manitoulin range of islands, it reaches Cabot's Head, and composes the chief feature of the promontory separating Georgian Bay from the main body of Lake Huron. From this it constitutes the summits of the Blue Mountains, and, rounding the western extremity of Lake Ontario, it forms St. Catherine Ridge and Queenston Heights. It thence follows at a short distance the south side of Lake Ontario and of the valley of the Mohawk, and sweeps round into the valley of the Hudson. By the addition of terrace above terrace of Upper Silurian and Devonian age, the step farther on rises into the Catskill mountains; beyond which it becomes entangled in the folds of the Appalachian chain and is lost. Niagara Falls.

In so far as relates to Canada, nothing can better shew the character of this plain than a comparison between the surface of the land and the levels of the great fresh-water seas that spread out on it. The following are the areas of these lakes and their heights above tide-water:—

	HEIGHT.	AREA.
	Feet.	*Square Miles.*
Ontario	232	7330
Erie	565	10030
Huron	578	23780
Michigan	578	25590
Superior	600	31420

The distance from Quebec to the western extremity of Lake Superior is about 1200 miles, so that the average ascent of the valley of the St. Lawrence does not exceed six inches in a mile. But if we take the ascent of the lower plain to the foot of the Niagara escarpment, and that of the upper one from the edge of it, we have about six inches in the mile for the former and only about three quarters of an inch in the mile for the latter; the difference of level between Lakes Erie and Superior being only thirty-five feet. The land on the banks of the St. Lawrence and its lakes, either immediately near the margin or at no very great distance removed from it, rises in general to the height of from fifty to one hundred and fifty feet; and although, as has been said, no sudden important inequalities present themselves on its surface with the exceptions mentioned, there are occasionally gentle swells of ground, which, when extending over considerable areas, Great Western Lakes.

St. Lawrence valley.

attain greater heights than would be suspected without careful admeasurements. There are few of these between Quebec and Montreal, and it is not probable that in this part of the plain any point on either side of the river rises beyond 300 feet above the sea. Above Lake St. Peter, a considerable tract of country on the south-east side of the river, with a very fruitful soil, is lower than the land on the opposite side. It is occupied by the valleys of the Richelieu and the Yamaska, two parallel streams, not far distant from one another, which run in the strike of the formations, on two low anticlinal forms with a third between, all belonging to the Appalachian system of folds. The Richelieu is the outlet of Lake Champlain; the surface of which, with an area of 450 miles, is eighty-eight feet above the sea. The Hudson River flowing in the same valley as Lake Champlain, but in an opposite direction, approaches to within twenty miles of the lake, with a height of land between them of one hundred and twenty feet above the sea; so that were the continent depressed a little over that amount, there would be a continuous salt-water communication between the Gulf of St. Lawrence and the Atlantic by this channel, and the states of New England, with Nova Scotia, New Brunswick, and nearly all that part of Canada on the south-east side of the St. Lawrence, would be converted into an island.

Plateau between the St. Lawrence and the Ottawa.

A triangular portion of the plain, still largely covered by forest, lies between the Ottawa and the St. Lawrence, and abuts against the Laurentian range where this sweeps round from the Lac des Chats to the Thousand Islands. In the whole of this triangle, comprising about 10,000 square miles, it may be said that there is only one exception to its general horizontality. This is found in the mountain of Rigaud, one of the trappean hills which have been already alluded to. Its summit is 538 feet above the Rivière à la Graisse at its foot, where this stream joins the Lake of Two Mountains, or 600 feet above the sea, while the land for nine miles southward from the summit maintains an elevation which overlooks the comparatively level tract beyond, up and across the St. Lawrence; one point of view in Lochiel, commanding the country around it for a considerable distance, being about 280 feet above the sea. To illustrate the near approach of the district to horizontality, it may be stated that the South Petite Nation, which drains a large part of it, takes its source in the townships of Edwardsburgh and Matilda, within a mile and a half of the St. Lawrence, in a water-shed which is only thirty feet above the surface of the great river, or 252 feet above the sea, and falls but 144 feet in a hundred miles before reaching the Ottawa in Plantagenet; while on the Ottawa and Prescott railroad, which crosses the Petite Nation in Edwardsburgh, the two highest levels are 362 feet ten miles from the Ottawa, in West Gloucester, and 358 feet about ten miles from the St. Lawrence, in Edwardsburgh. The Rideau, discharging at Ottawa, is another stream which drains a considerable part of the triangle. Where this issues from amidst the Laurentian hills at Rideau Lake its surface is about 400 feet above the sea, and between the valley of this stream and the Lac des Chats the highest levels belonging to the plain range from 330 to 410 feet above the same base.

This triangular plateau is of a good agricultural character where it is cleared, and has produced much heavy pine timber from its forests. It is underlaid by rocks of the Lower Silurian age, reaching nearly to the summit of the group. They lie in the form of a trough, the breadth of which reaches across the St. Lawrence into the State of New York, where the inferior members of the group occupy a margin of from fifteen to twenty-five miles, and rest upon the azoic strata of the Adirondack Mountains. To the south of the eastern apex of the triangle, at the junction of the Ottawa and the St. Lawrence, these strata turn sharply round to the valley of Lake Champlain, making an elbow which corresponds with a more obtuse form of the same character north of the Ottawa, opposite the upper end of the island of Montreal. The two pointing to one another indicate the existence of a low transverse anticlinal arch, which nearly isolates the Silurian triangle by leaving but the lowest Silurian formation to conceal the azoic strata, and that only partially, since a dome of azoic rock protrudes through the Silurian in Mont Calvaire, situated on the left bank of the Ottawa, in the intermediate space. A longitudinal fold of some importance in the triangular trough divides it into two synclinal forms, of which the northern one is the deeper; the deepest part being near the north-west corner of Russell, about fifteen miles from Ottawa City. The effect of this fold is traceable all the way from the Lac des Chats to the trap mountain of Rigaud, and it is probably connected with those of Montreal, Montarville, Rouville, Rougemont, Yamaska and Shefford, all of which, being the chief part of the trappean masses already alluded to, stand pretty nearly in a straight line, shewing the disturbance to extend 180 miles across from the Laurentian to the Appalachian range.

Undulations and intrusive rocks.

The Lac des Chats and Lake Ontario are very nearly on a common level, and the channels of the Ottawa and the St. Lawrence descending from them are worn out of equivalent strata on opposite sides of the triangular trough. The former river leaves the Chats by a single leap of fifty feet over Laurentian strata, and makes a plunge of upwards of sixty feet more at Ottawa City in the Chaudière falls; which, though they break the navigation of the river, give inexhaustible water-power for manufacturing purposes, and, with the aid of the horizontal limestone strata piled up into crags and abrupt eminences over the river, combined with the Laurentide mountains some few miles to the north, invest the scenery of the neighborhood with much picturesque beauty. From the foot of the Chaudière falls, where the river is 118 feet above the sea, it is of easy

Rapids and canals of the Ottawa.

navigation for steamboats for nearly sixty miles, to Grenville, between which and its junction with the St. Lawrence two interruptions from rapids occur. These are obviated between Grenville and Carillon, where the difference of level is forty-seven feet, by a canal capable of navigation by barges and propellers of eighty tons, and at Ste. Anne by a lock enabling steamers of 300 tons to overcome a fall of three feet between the Lake of Two Mountains and Lake St. Louis.

Of the St. Lawrence.

Lake St. Louis is fifty-seven feet above the sea. The descent to it from Lake Ontario is therefore 175 feet, and to the head of sea navigation in the harbor of Montreal there is an additional descent of forty-five feet in the Lachine Rapids. The whole distance from Lake Ontario is between 140 and 150 miles, so that the inclination would be about eighteen inches in a mile. In this there are no vertical falls, but several interruptions from violent rapids. These do not impede the downward navigation of vessels drawing nine feet; but to enable such vessels to ascend the river, a magnificent system of canals has been built by the provincial government. These canals are nine in number, and their total length forty-two miles. The number of locks is twenty-seven, obviating 205 feet of the fall, and permitting the passage of vessels of 800 tons burden.

Adirondack Mountains. Thousand Islands.

This part of the St. Lawrence, it would appear, does not exhibit so continuously deep an excavation in the rocks of the country as the Ottawa below the Chats. As in the case of the Lac des Chats, an exposure of azoic rocks crosses the St. Lawrence at the outlet of Lake Ontario. It unites the azoic mass of the Adirondack mountains with the main body of the Laurentian range, and gives origin to the much-admired scenery of the Thousand Islands. The exposure appears to be a part of an ancient ridge in the bottom of the Lower Silurian sea, by the sediments from which this low ridge was gradually covered up. Again denuded at a comparatively recent period, the resistance which the hard gneiss composing it has offered to the erosive forces excavating the valley has rendered it a barrier to keep up the waters of the lake, and to produce between it and Montreal the steepest part of the river in the lower plain. The width of the denuded ridge at the narrowest part does not apparently exceed five miles.

From the point where the azoic ridge is thus traversed by the St. Lawrence, the junction of the azoic and palæozoic rocks on the lower side runs north of east down the river on the one hand, and west of north across to the Ottawa on the other. On the upper side it runs north of west to Georgian Bay in Lake Huron, and east of south along the valley of the Black River to the valley of the Mohawk. The whole azoic mass in immediate relation with the Adirondack mountains has an area of about 10,000 square miles. Its most southern part in the valley of the Mohawk is near Johnston, where it approaches to within twenty miles of the Middle

Silurian escarpment. This escarpment in a gently sinuous line runs very nearly due west to Hamilton, whence it proceeds west of north to Owen Sound in Georgian Bay. It will be observed from the bearings given, that the Lower Silurian plain on the upper side of the Thousand Islands presents the form of a rude east and west parallelogram, with the addition of a truncated triangle based on the east end and applied to a prolongation of the south side. The area of this figure comprises about 23,000 square miles; of which Lake Ontario, with an extreme length of 200 miles and an extreme breadth of fifty miles, occupies about one third.

Lower Silurian region of Western Canada.

The terrestrial portion appertaining to Canada, exclusive of a small strip bordering the south side of the lake between Hamilton and Queenston, presents the form of a triangle, whose base is the escarpment between Hamilton and Owen Sound, and whose apex is at the outlet of the lake among the Thousand Islands. The area comprises about 16,000 square miles. The chief streams by which it is drained are the Salmon, the Moira, the Ottonabee or Trent, the Humber, and the Credit, which are tributary to Lake Ontario, and the Severn and the Nottawasaga, tributary to Lake Huron. The first two streams, which are not of great importance, have their sources a considerable distance among the Laurentian rocks: the Ottonabee, as it is called in its upper, and the Trent in its lower part, is the principal river of the area. Its valley is wide and its course very crooked. Following the main stream, its whole length is about 170 miles, while a straight line from its source to its mouth is only about ninety miles. The difference arises from six sharp turns, in the stretches between which the stream flows alternately westward of south and northward of east before it is discharged into the bay of Quinté; in which bay the same alternate courses, always giving angles less than ninety degrees, are repeated three times to the open lake. The main stream and its northern tributaries for sixty-five miles of longitude have their sources in the Laurentian range, while the southern tributaries rise in a ridge of drift removed but from seven to fifteen miles from Lake Ontario. The main stream flows among the Laurentian hills for about thirty miles, and leaves them just before entering Balsam Lake; though it still continues to skirt the range at a variable distance, through a succession of lakes, for upwards of forty miles to Salmon Trout Lake. Here making the second of the acute turns mentioned, it arrives by a stretch of thirty miles to within ten miles of Lake Ontario in Rice Lake, and by another stretch of about the same distance returns to within five miles of the Laurentian range at Henley's Falls, above the junction of Crow River. In the lakes skirting this range the fall is about eighteen inches in a mile, but about four times as much to Rice Lake. The following are the heights of the lakes above the sea:—

Its rivers.

The lakes, their sources.

Balsam Lake	820 feet.
Cameron Lake	815 "

Sturgeon Lake	793 feet.
Pigeon, Buckhorn, and Chemung Lakes	788 "
Deer Bay Lake	785 "
Stoney and Salmon Trout Lakes	758 "
Rice Lake	596 "

The distance from Salmon Trout Lake to the junction of Crow River is about nineteen miles in a straight line, and the height of the Trent there is 542 feet. Belmont Lake, which is surrounded by Laurentian strata, is about eight miles to the north on Crow River, but not more than eleven miles from Salmon Trout Lake, and is 599 feet above the sea; by which it appears that on the west side of Crow River, which has its source forty miles north of Belmont Lake, there is a considerable rise in the land. The main tributary on the south side of the Trent is the Scugog; in Scugog Lake it approaches to within seventeen miles of Lake Ontario. The height of Scugog Lake is 797 feet above the sea, and as Sturgeon Lake into which it is discharged is only a few feet lower, it is evident that the summit of the drift for twenty-five miles northward must be nearly horizontal. This horizontality is preserved twenty-five miles eastward to the neighborhood of Peterborough on the Ottonabee, so that while the latter stream flows southward, there are two additional parallel tributaries between it and the Scugog which run northward.

Water-shed between Huron and Ontario.

A very narrow water-shed, bearing nearly north and south, separates the tributaries of the Trent from those of Lake Simcoe and the Severn, while the dividing line on the drift ridge between the tributaries of Lake Huron and those of Lake Ontario is nearly east and west. Between the Holland and the Humber, Mr. Tully, in his report on the proposed Georgian Bay Canal, states the height of the ridge to be 904 feet above the sea. To the east of this the ridge is crossed by the Toronto and Simcoe railroad, in the Township of King, at a height of 987 feet; while to the west, where it abuts against the Upper Silurian escarpment on the line between the townships of Adjala and Albion, and separates the Humber from the Nottawasaga, its height is 950 feet. As shewing the slope of the drift northward, it may be here stated that Lake Simcoe, occupying 283 square miles, is 704 feet above the sea; and though this lake is tributary to Lake Huron, the depression in which it lies is a continuation of the valley of the Trent, which can thus be traced from Georgian Bay to Kingston.

Except on or not very far from the shore of Lake Ontario, there are no exposures of palæozoic strata between Peterborough and the Niagara escarpment for a breadth of forty miles, so that the deposit connected with the drift ridge would appear to have an area of between 3000 and 4000 square miles. If the palæozoic surface beneath presents the same character that it does in other parts of the plain, it seems probable that it will rise with a pretty even slope from the exposures on the lake to those north of it, and that a depression would accompany the softer deposits of the period from Georgian Bay to Lake Ontario. This would give a probable depth of 400 feet to the drift along the chief part of the ridge, with a still greater depth over the depression.

In that part of the Lower Silurian plain which lies between Lake Ontario and the Hudson River, Lake Oneida, discharging into Lake Ontario by the Oswego river, occupies a position in the same valley as the Mohawk, which flows in a contrary direction to join the Hudson at Troy. Lake Oneida, with a height of 400 feet above the sea, is only fifteen miles removed from the Mohawk at Rome, and the height of land between them is forty-two feet above Oneida; so that a depression of the continent of 442 feet would bring the ocean into Lake Ontario by the valleys of the Mohawk and the Hudson, as well as by that of the St. Lawrence. It would drown all the Lower Silurian plain in Eastern Canada, as well as the triangular portion between the St. Lawrence and the Ottawa. It would convert the latter river into an inlet as far as Roche Capitaine, upwards of 200 miles above Montreal, and carry the present inlet of the Saguenay beyond Lake St. John. The waves of such an ocean would wash the base of the Middle Silurian escarpment from the valley of the Hudson to the upper end of Lake Ontario. If the drift were removed from the supposed valley in the surface of the palæozoic rocks between Georgian Bay and Lake Ontario, a depth of 136 feet in this valley beneath the level of Lake Huron would so far lower the surface of Georgian Bay as to constitute it a part of the Ontario sea, and cause the emergence of the sub-aqueous ridge of the Middle Silurian escarpment between Cabot's Head and the Great Manitoulin Island, making dry the narrow channels on each side of Lacloche Island. Lakes Huron and Michigan, lowered to a level beneath the bed of the St. Clair River, would escape by a cascade into Georgian Bay through the deepest part of the Manitoulin Strait; or if any part of the strait were sufficiently profound, the lakes would be lowered equally with Georgian Bay and communicate directly with the Ontario sea, while Lake Erie would be left to escape by its present exit.

Relative levels.

There are no evidences that this condition of circumstances has existed, and the statement is made merely to illustrate relative levels; but the face of the Middle Silurian escarpment in some parts appears to shew traces of having suffered the operation of destructive causes greater than those now existing, perhaps when the continent was even more deeply submerged than would be sufficient to bring the ocean through the valleys of the Hudson and Mohawk. The waters of the Nottawasaga and the Humber, flowing in the same line in opposite directions, are separated, as has already been said, by the central drift ridge. The valley of the former river is broad, and on the west side it is bounded by an escarpment of red marl and sandstones, with a strongly marked band of grey sandstone above them, and crowned by the Middle Silurian

Middle Silurian escarpment.

limestone, which constitutes the summit. From the margin of the stream in the centre of the valley, a gentle rise over a breadth of twelve or thirteen miles reaches the foot of the escarpment, and after a short and sharp ascent over a portion of the red and grey strata, the solid limestone presents precipices rising at once or in successive steps to the summit. From the west side of the valley the main trunk of the river is supplied by many tributaries, and the west branch of the main stream itself takes its origin upon it. But though the summit or edge of the escarpment exhibits the range of highest points on the valley, and the dip of the strata is westward,—a direction opposite to the flow of the tributaries,—the water-shed which divides these from the streams that empty themselves into Lake Erie and the southern part of Lake Huron is from three to nine miles west of the escarpment, lying on the back of the calcareous strata, which form its upper part. It is by these ravines, cut clean through the solid limestone and far down into the softer red marls below, that the waters of the intermediate land find an outlet to the valley. These ravines afford scenes of the wildest and most picturesque confusion. Great blocks and fallen masses of the limestone, which in many places is seen towering 200 feet above, lie scattered over the bottom of the gorge, while others constitute a talus at the base of the precipice, as if to form it a whole cliff had been shaken into mighty fragments, among which are holes and interstices so numerous, large, and deep, that it is dangerous to pass along. Great impending masses of the perpendicular cliffs themselves, comprising occasionally an acre, cracked off from the main body of the rock, dip slightly in towards the ravine, and the rents which separate them from the strata in place, with a width of from twenty to thirty feet, are sometimes so profound, that a great pine tree, 120 feet in length, which, blown over by the wind, has fallen obliquely into the crevice, will be seen hanging head downwards, still attached by some unbroken part of its roots to the edge of the chasm, the bottom of which is hid in darkness below the other extremity. The rents appear to be generally in the natural joints of the rock; their sides are quite smooth and even, and while a main one will separate an acre from the mountain, many minor ones running parallel, usually in two directions, will divide the area into several rhomboidal parts. Some of the tributaries may run through ten miles of their course in these ravines, and though their turbulence and velocity is usually so great during freshets that one of them is appropriately termed the Mad River, the quantity of water which they convey cannot be considered sufficient to have produced the effects observed; and this is corroborated by the circumstance that dislocated masses are not wanting in those parts of the escarpment which exist between the tributaries and face the general valley. Not only in the valley of the Nottawasaga, but in many other parts, the escarpment has the aspect of an ancient sea-cliff, and when the plain at its foot is seen

Its ravines and gorges.

from a favorable spot on the summit, the great extent of surface over which the eye wanders without perceiving any undulation, and the even unbroken straight line of the distant horizon, almost deceive the imagination into the belief that they still belong to a sea instead of to a fertile wooded land.

From the summit of the escarpment, the surface has a general slope to Lakes Erie and Huron, in a curve corresponding with their positions. *Rivers of Western Peninsula.* The highest part appears to be the Blue Mountains in the neighborhood of Melancthon, and from the back of them descend three of the principal rivers that drain the area, the Saugeen, the Maitland, and the Grand River; the first two running generally transverse to the stratification into Lake Huron, and the last into Lake Erie, following the strike and curving round the extremity of Lake Ontario. Another of the principal streams is the Thames, which has its main sources west of the valley of the Grand River, on the axis of the turn alluded to, and flows between Lakes Erie and Huron, and parallel with the nearest coast of both, into Lake St. Clair. The bearing of the Thames and the curve of the Grand River are both related to the same geological form. The turn in the stratification is due to a low anticlinal arch, a shallow valley on the crown of which guides the course of the Thames: the course of the Sydenham, a stream running parallel with the Thames at a short distance northward, is influenced by the same anticlinal. The effect of this anticlinal is traceable for nearly a thousand miles, in the course of which it runs under the city of Cincinnati on the Ohio.

The plains which stand between the valleys of these rivers keep a pretty uniform level of about 1200 feet above the sea for a considerable distance westward, in the latitude of Toronto. *Heights on Grand Trunk railway.* The Grand Trunk railway from Toronto to Sarnia rises to the upper plain through a breach in the escarpment, forming a valley for a tributary of the Credit, and, after passing over the water-shed and reaching to within nine or ten miles of the base of the Middle Silurian shield near Georgetown in Esquesing, the level of the road at Rockwood is 1200 feet above the sea; at Guelph (thirty-five feet above the Speed, a tributary of the Grand River) it is 1057 feet; crossing the Grand River it is 997 feet, and near Petersburgh in Wilmot 1235 feet; but northward of this, between the Canistaga and Smith rivers, both tributary to the Grand River, there is said to be a ridge 200 feet higher. At Hamburgh and Stratford the road is 1207 feet, and continues at this level to St. Mary in Blanchard, on the west branch of the Thames; at London it is 802 feet, and the land is not higher than this at any place between London and Sarnia. The Buffalo and Goderich railway, which crosses the Grand Trunk at Stratford, rises to a summit-level of 1209 feet in Fullarton; and on the dividing line between the townships of Tucker-Smith and Hibbert, where it is about seventeen miles from the nearest coast of Lake Huron, the road is 1050 feet above the sea. The line of these two roads from Rockwood to Hibbert sweeps partially round the Blue Mountains in Melancthon in an irregular curve, at a distance varying from fifty to seventy miles, and the curve would be still farther continued were a line of equal elevation followed from Hibbert northward. From this curved line the surfaces of the interspaces on the one hand appear to ascend gradually with the beds of the streams, though rather more slowly, until they culminate in a flat broken-edged semi-dome 1600 feet above the sea, to the highest point of which allusion has already been made as overlooking the valley of the Nottawasaga; while on the other hand the land descends rather more rapidly towards the lakes, and to that part lying between them which extends from the neighborhood of London to the entrance of the Detroit River into Lake Erie. The rocks of this lower portion of the area are in part softer than those of the higher country; they are of the Devonian period, and it is chiefly out of them that have been excavated the depressions which hold Lake Erie and the main body of Lake Huron.

Surface of the Western Peninsula.

It would appear from what has been said that though the Canadian part of the upper plain, occupying about 10,000 square miles, has a general smooth surface, it swells into a height which is not inferior in elevation to some of the highest points in the more rugged Laurentian country between Lake Huron and the Ottawa. Its palæozoic strata have a dip conforming in direction with the general slope of the geographical surface, and though the inclination of the strata is greater than that of the surface, it is still so small that by the eye it cannot be distinguished from horizontality. As in the plain to the east of the escarpment, this part is thickly covered with drift, largely derived from calcareous rocks; and both areas, possessing soils of remarkable fertility, are endowed with great agricultural capabilities. From its relation to the great lakes nearly surrounding it, that portion of the country west of a line between Toronto and Georgian Bay is appropriately called the Western Peninsula. It has a coast line of about 800 miles in extent; the only natural impediment to the intercommunication of all the ports of which with one another, by vessels capable of navigating the ocean, is the fall occasioned by the Middle Silurian escarpment. This obstacle is obviated by the Welland canal, extending from the mouth of the Grand River on Lake Erie to Port Dalhousie on Lake Ontario. It has a length of twenty-eight miles, and by means of twenty-seven locks, accommodating vessels of 350 tons burden, it overcomes a total difference of level of 333 feet. By its establishment, and that of the various railroads which within a comparatively recent period have been carried through the country, the western peninsula has advanced in improvement with a truly wonderful rapidity.

The southern peninsula of Michigan, lying between Lake Huron and Lake Michigan, and comprising an area of about 40,000 square miles, though in part composed of rocks of a different epoch, (about one third of it in the centre being of the Carboniferous age,) offers no contradiction to the general horizontality of the upper plain. As described by Dr. Houghton, its rocks consisting for the most part of nearly horizontal strata of sandstones, limestones and shales, give character to a beautifully varied succession of hills and valleys, as also to a soil admirably adapted to the purposes of agriculture. It is surrounded by a belt of nearly level country, varying in width from five to twenty-five miles, which gradually obtains a greater elevation as we proceed to the interior. The rise culminates in a water-shed, attaining in some parts a height of 1200 or 1300 feet above the sea, and separating the streams flowing in opposite directions to the two great lakes. From the manner in which the main streams interlock, it seems probable that the differences of level on the plateau are not very sudden or very considerable. The width of the peninsula, excluding the indentation made by Saginaw Bay, may be considered about 180 miles; and the winding character of the water-shed is such that while a portion of the streams which discharge into Saginaw Bay take their source about sixty miles from Lake Michigan, some of those emptying themselves into the southern part of Michigan rise about sixty miles from Lake St. Clair. Three lines of railroad cross the water-shed in a breadth of nearly eighty miles, and the following are the heights which they indicate: the Detroit and Milwaukee, the most northern, gives 765 feet near Corunna in Sheawassee; the Michigan Central, 1023 feet between Chelsea and Grass Lake; and the Michigan Southern, 1105 feet at Osceo in Hillsdale.

Peninsula of Michigan. **Its waters.**

The rocks of the peninsula lie in the form of a basin; so that the same formations which constitute the bottom of Lake Huron crop out under the waters of Lake Michigan, and these same formations give to a portion of the country south of the peninsula a surface somewhat lower than its more northern centre. The distribution of the whole series of palæozoic rocks in their relation to the great lakes of the St. Lawrence presents one of the grandest instances to be met with of the guiding influence of geological structure in producing geographical peculiarities. The arrangement of the lakes is traceable to the arrangement of two distinct parallel zones of strata, the softer members of which have yielded with comparative facility to the wear producing the excavations holding the water. Erie, the main body of Huron and Michigan, may thus be termed Devonian lakes, while Ontario, Georgian Bay, its continuation in the channel north of the Manitoulins, Green Bay, and the expansion of Superior, are Lower Silurian lakes, while the land which separates the two aqueous ranges from one another is a Middle and Upper Silurian ridge.

Its rocks. **Geology of the Western Lakes.**

It has been mentioned above that the shielding limestone of this ridge composes the horns of Green Bay. In its progress southward from them it constitutes the west side of Lake Michigan, and sweeps round the coal basin of Michigan to the western part of Lake Erie; forming a

American coal fields.

rim to the basin, which, though but slightly raised, is sufficient to constitute a water-shed between tributaries of the St. Lawrence and others of the Mississippi. A little south-west of Lake Michigan it bends over a flat anticlinal arch, which separates the Michigan basin from the great basin of Illinois and that of Iowa farther west, as it does at the upper end of Lake Erie over the Cincinnati anticlinal, which runs between the Michigan basin and the great basin of Appalachia, the Iowa, Illinois and Appalachian depressions containing three of the largest coal areas of the world. The Appalachian coal measures are separated from Lake Erie by the upper members of the Devonian series, as are the Michigan measures from Lake Huron on one side and Lake Michigan on the other; and on the south side of Lake Erie, within but a few miles of its margin, these upper Devonian rocks give origin to the northern tributaries of the Ohio. This river drains nearly all the plain between Lake Erie and the Appalachian range, and with its affluent the Alleghany runs for about 300 miles with the Appalachian coal measures, and then about 400 more transverse to the stratification to the Mississippi, crossing the Cincinnati anticlinal and the south part of the coal basin of Illinois.

Mississippi, Red River, etc.

Some of the eastern tributaries of the north part of the Mississippi take their sources almost as near to the margin of Lake Superior as those already mentioned do to the Devonian group of lakes; so that from almost the very margin of the whole of these great lakes, excluding Ontario, there is a gradual descent in the general surface to the Gulf of Mexico, with but few elevations, excepting perhaps near Lake Superior, exceeding 1000 feet above the sea. The source of that branch of the Mississippi which goes by this name is nearly in the latitude of the west end of Lake Superior, and the source of the Red River is in the same vicinity. These two streams, flowing in opposite directions, preserve a general line parallel with the Rocky Mountains from the northern end of Lake Winepeg to New Orleans, nearly twenty-five degrees of latitude. The Missouri however is in reality the main trunk of the Mississippi. It also for 700 miles of its course, from about the forty-eighth parallel to the Kanzas, flows parallel with the upper Mississippi, with a breadth of 250 miles between them in which all the main streams have pretty much the same bearing. But the upper part of the Missouri and all the western tributaries of the river, and the main western affluent of Lake Winepeg descending from the Rocky Mountains almost at right angles, shew the gradual rise of the land to this great dominant ridge of the continent. The whole surface of the North American continent on the east side of this great dominant ridge has been described by Sir John Richardson with considerable truth to be a vast inclined plain, in which the Laurentide and Appalachian ranges are mere roughened parts, presenting but a few points rising to a sufficient height to disturb its uniformity.

Rocky Mountains.

CHAPTER II.

GEOLOGICAL NOMENCLATURE.

DIVISIONS OF THE NEW YORK ROCKS; THEIR NOMENCLATURE.—PARALLELISM WITH EUROPEAN ROCKS.—AZOIC ROCKS OF NORTH AMERICA; THEIR NAMES.—TABULAR VIEW OF CANADIAN ROCKS.

Rocks of New York.

In the nomenclature which has been adopted for the geological formations of Canada, the system of local designations has been resorted to as the one generally considered to be most convenient. In the names used we have been desirous of availing ourselves as much as possible of those which have been applied to well established groups of strata elsewhere, with a view of at once facilitating comparisons of equivalent masses, and of rendering homage to those whose labors have aided us in understanding our own rocks. The investigations which had already been made in the state of New York, when the Canadian Survey commenced, had in some degree rendered the stratigraphical nomenclature of that state classic in America, and, while the undisturbed condition of the masses in that part of the state which furnished the local names rendered the sequence certain, the formations passed from New York into Canada in such a manner that there was no doubt of their equivalence on the opposite sides of the boundary. For the subordinate groups of fossiliferous strata it thus became extremely convenient to adopt the nomenclature of New York.

As nearly all the designations of the fossiliferous groups are derived from local names, it has not been deemed expedient to make any change in respect to the few exceptions in which they are founded upon lithological characters; and it is only when a group has not been recognized among the rocks of New York, or when a mass there destitute of organic remains is replaced in Canada by one marked by fossils, that a Canadian name is introduced.

The rocks met with in the Canadian portion of the area comprehended in the topographical description of the previous chapter are designated as follows in descending order:—

CARBONIFEROUS.

20. Bonaventure formation.

DEVONIAN.

19. Portage and Chemung group.
18. Hamilton formation.
17. Corniferous " } Upper Helderberg group.
16. Oriskany " }

UPPER SILURIAN.

15. Lower Helderberg group.
14. Onondaga formation.

MIDDLE SILURIAN.

13. Guelph formation.
12. Niagara " }
11. Clinton " } Anticosti group.
10. Medina " }

LOWER SILURIAN.

9. Hudson River formation,
8. Utica "
7. Trenton "
6. Birdseye and Black River formation.
5. Chazy = Sillery ? " } Quebec group.
4. Calciferous = Lévis " }
3. Potsdam group.

AZOIC.

2. Huronian series.
1. Laurentian system.

Rocks of Great Britain. The equivalent lines of demarcation between the great divisions of the fossiliferous rocks being now sufficiently well established on the opposite sides of the Atlantic, the European designations are applied to them as used by the Geological Survey of the United Kingdom, except in the case of the term Middle Silurian, applied to designate an intermediate series of rocks, which are not well defined in Great Britain. Systems of nomenclature, different from the one here adopted, have been used in Pennsylvania and in other parts of North America. A table showing these, and setting forth at the same time the sub-divisions of the palæozoic rocks in various parts of the world, and their relation to the Canadian series, will be given as a sequel to the description of our rocks, where it will be more intelligible.

To the azoic rocks no local names have yet been applied in any part of America except in Canada, and as these rocks are here more extensively exposed than anywhere else on the continent, while it would be very inconvenient to describe the geology of the province without the use of special designations attached to them, the names of the Laurentian and the Huronian systems or series, which we have been accustomed to apply to them, are allowed to remain unchanged, particularly as they have been recognized abroad, and have been made by other geologists a standard of comparison both in America and Europe. Azoic Rocks.

With each local designation it will be perceived that we have associated the term series, group, or formation, in place of the lithological distinction which usually accompanies the local designation in the New York nomenclature, such as sandstone, limestone, slate, or shale. The reason for this is, that in a country extending like Canada for a thousand miles in the strike of the strata, the mineral character of any division may differ very much in different localities, and the lithological term become inapplicable in some particular case.

CHAPTER III.

THE LAURENTIAN SYSTEM.

LAURENTIAN SYSTEM.—THE OLDEST KNOWN STRATIFIED ROCKS.—ORTHOCLASE GNEISS.—LIMESTONES AND THEIR ASSOCIATED MINERALS.—IRON ORES.—CONTORTED STRATA.—MADAWASKA SECTION.—CONGLOMERATE BEDS.—ANORTHOSITES; THEIR FELDSPARS AND ASSOCIATED MINERALS.—VEINS OF SEGREGATION CONTAINING PYROXENE AND FELDSPAR.—METALLIFEROUS LODES.—INTRUSIVE ROCKS; DOLERITE, SYENITE, QUARTZIFEROUS PORPHYRIES.—CHERT VEINS.—DISTRIBUTION AND STRUCTURE OF THE LAURENTIAN SYSTEM; ITS PROBABLE THICKNESS.—SUPPOSED FOSSILS IN THE SYSTEM.

The rocks which compose the Laurentian Mountains were shown by the Geological Survey, in 1846, to consist of a series of metamorphic sedimentary strata underlying the fossiliferous rocks of the province. They have since been recognized by Sir Roderick Murchison, as forming the so-called fundamental gneiss of the Western Islands of Scotland and parts of Ross-shire and Sutherlandshire, and the name of the Laurentian system, first applied in Canada, has now been extended to them in Great Britain, where as well as in this country they are the oldest rocks known, and lie at the base of the sedimentary series. They are altered to a highly crystalline condition, and are composed of feldspathic rocks interstratified with important masses of limestone and quartzite. Great vertical thicknesses of the series are composed of gneiss containing chiefly orthoclase or potash feldspar, while other great portions are destitute of quartz and composed chiefly of a lime-soda feldspar, varying in composition from andesine to anorthite, and associated with pyroxene or hypersthene. This rock we shall distinguish by the name of anorthosite.*

Anorthosite.

Orthoclase gneiss.

The orthoclase gneiss is generally of some reddish tint, arising from the prevailing color of the feldspar, which varies from very pale to very deep flesh-red, though it is often white and frequently of a bluish-grey. This rock has in no instance been found destitute of quartz: hornblende is seldom absent, and mica very often present. The quartz is generally white,

* Since all these varying triclinic feldspars are anorthic in crystallization, and approach more or less to anorthite in their composition, Delesse thus proposed to designate them by the common name of anorthose, as distinguished from orthose or orthoclase, and the rocks characterised by their presence as anorthosite. In accordance with this we have adopted the generic name of anorthosite for these rocks.

but often colorless and translucent; the hornblende is usually black, but sometimes green; the mica is often nearly black, frequently brown, and generally of some dark color. A great portion of the rock is fine grained, and, though the constituent minerals are arranged in parallel layers, no one constituent predominates in any layer to the exclusion of others; but even in their subordinate arrangement there is an observable tendency to parallelism. A thick bed of reddish feldspathic rock, for example, will in vertical section present a number of short dashes of black hornblende or black mica all drawn in one direction, and apparently destitute of arrangement except in regard to parallelism. The continuation of these lines will be interrupted irregularly, and before one ends another will commence above or below it, the lines interlocking among one another. Sometimes these continuous black bands will run in the rock for considerable distances, or the rock will be barred by parallel streaks of white quartz or white feldspar, in which as well as in the red part the dark and dotted lines will continue. The same description of arrangement will be found when the whole ground of the rock is white instead of red, and then the red feldspar will occasionally constitute streaks. There is no end to the diversity of arrangement of the component minerals, but there is a never failing constancy in respect to their parallelism, which, however, though never absent, is sometimes obscure.

Very large masses of this rock are frequently coarse grained. These are usually very feldspathic, the feldspar being in cleavable masses often attaining an inch and sometimes more in diameter, while the mica and the quartz, often accompanied by hornblende, and the former sometimes replaced by it, are distributed among the feldspar in such a manner as to give a reticulated aspect to the surface of the rock. Beds of this character are sometimes thin, but when thick, which they usually are, might on first inspection be mistaken for intrusive igneous instead of altered sedimentary masses. Upon a careful study of any such mass however it will be perceived that this reticulated structure is accompanied by an obscure arrangement of the meshes of the network into parallel lines, which will be found conformable with the more distinctly banded portion of the strata. Granitoid gneiss.

There is as great a diversity in the arrangement of the masses as in the minerals composing them. The greatest masses appear to be formed of the coarse grained porphyroid gneiss above described. These rise into the highest ridges and peaks of the orthoclase region, and generally constitute the main body of rock separating one important band of limestone from another. They appear sometimes to attain several thousand feet in thickness, divided however at unequal intervals by thinner and less feldspathic masses in which the stratification is more distinct. The quartz occasionally presents masses of considerable volume, two of which, nearly pure, occur in the district of the Rouge, a tributary of the Ottawa, one 400 and the Quartzite.

Hornblende and mica schists. other 600 feet thick. The hornblende often forms a massive rock: a band of it in Blythfield has a thickness of 200 feet. Mica associated with hornblende and with quartz characterises great thicknesses of hornblende and micaceous schists.

Though there does not appear to be any special order in which the masses succeed one another, beds of hornblende rock and hornblendic schist seem often to be more abundant near the interstratified bands of limestone than elsewhere, and in the same neighborhood there usually occurs a more frequent repetition of beds of quartzite than in other parts. Pyroxene and garnet rocks. Near the limestones, pyroxene, which in other parts does not appear to be very abundantly disseminated, is occasionally met with, forming massive beds. Pink or raspberry-red garnets are often thickly disseminated in bands of micaceous or hornblendic gneiss and quartzite. Although these are not confined to the immediate proximity of the limestones, they are more commonly met with there than elsewhere, and it generally happens that the limestone masses are limited on the one side and frequently on both, by garnet-bearing rock. Near the Three Mountains, about fifty miles up the Rouge, pink garnets are disseminated through a gneiss consisting chiefly of a pure white crystalline orthoclase feldspar, producing a rock of striking beauty. It is about 150 feet thick, and runs along the upper side of one of the bands of limestone for a considerable distance. A few miles from this, however, the bed passes into a reddish and more quartzose garnet-bearing gneiss, and in a third position becomes a garnetiferous quartzite.

Limestones. The masses of limestone are in general crystalline in a high degree; occasionally they are composed of an aggregation of rhombohedral crystals of calcspar with faces an inch square. They are usually coarse grained, but sometimes saccharoidal; though it rarely happens that they are so fine in texture as to be entitled to the designation of compact. Their general color is white; they are often barred with grey in the direction of the strata, and are occasionally wholly grey. They are sometimes partially salmon or flesh-red; but this tinge has not been seen diffused throughout a bed, or extended to any great distance in it. It is seldom that beds are composed of pure carbonate of lime: several accidental minerals are usually associated with this, and they may vary in quantity and kind in different parts of a group of strata both horizontally and vertically. The most frequent minerals imbedded in the limestones are serpentine, pyroxene, tremolite, hornblende, wollastonite, mica, graphite, apatite, chondrodite, quartz, scapolite, iron pyrites, specular iron, with more rarely zircon, spinel, fluor spar, idocrase, tourmaline, corundum, and copper pyrites.

Dolomites. Carbonate of lime and dolomite are frequently met with mechanically mingled, giving rise to more or less magnesian limestones; they often, however, compose distinct beds interstratified with one another; and in some parts great masses of nearly pure dolomite occur. The dolomite is usually finer in texture than the limestone; very little of it can be called coarse grained. On Mazinaw Lake, in the township of Barrie, great masses of it are saccharoidal and sufficiently pure to yield statuary marble, and in Madoc and MacNab it is often compact. Its color is generally white, but it is sometimes of a pale yellowish-red tinge, and when compact it has a waxy lustre. The rock often weathers to some tinge of yellowish-brown.

It is not quite certain whether the accidental minerals characterise the pure limestone and the dolomite equally, or whether there are marked distinctions in the groups prevailing in each rock. Most of those which have been mentioned however appear to be more abundant in the limestone than in the dolomite. Serpentine is found associated with both rocks. It is frequently disseminated in grains varying in size from the tenth to the fourth of an inch: among these are occasionally scattered masses of from six to ten inches in diameter, and sometimes the mineral forms interstratified beds. When it occurs in grains and larger scattered masses, the grains, more or less closely aggregated, usually run in bands parallel with the beds, and clearly mark the stratified character of the rock. The colors of the serpentine are usually some tinge of green from leek-green to oil-green and pale greenish-yellow; sometimes the mineral is resin colored, and occasionally masses of a pale yellowish-green are spotted with crimson or blood-red patches from disseminated peroxyd of iron. Serpentine.

Another silicate of magnesia, which is met with in patches and occasionally in interstratified massive beds in the limestone, is pyrallolite or rensselaerite, a mineral closely allied to talc in composition. The color of the mineral hitherto observed in Canada is usually a pale greenish-yellow, but in the Laurentian series of New York, according to Emmons, it shews various tints of grey and is occasionally black. It appears in general to occur in the neighborhood of beds marked by serpentine, and aphrodite, an allied mineral, is sometimes associated with it. Pyrallolite.

The limestone beds are sometimes characterised by grains of pyroxene disseminated in the rock in the same banded arrangement as the serpentine, but not in such abundance, and occasionally there run with the stratification masses composed of cleavable pyroxene associated with several other minerals, making a very coarsely crystalline rock; but these may sometimes perhaps constitute veins of segregation, rather than beds. Pyroxene.

Hornblende, in addition to being found in disseminated crystals, is sometimes met with, more particularly in the form of tremolite, constituting beds in the limestone and dolomite. These beds are sometimes many feet thick, and the mineral occurs in them in parallel or radiating fibrous masses, sometimes attaining eighteen inches in length, the interstices among them being filled with the limestone or dolomite. Hornblende.

Mica and graphite.

Mica and graphite very generally accompany one another in the calcareous beds, and some of these for many hundreds of feet in thickness are seldom without them. It appears to be finely disseminated graphite that occasionally gives to great masses of the limestone a grey color, and the greater and less accumulation of it in different layers produces the bands of darker and lighter grey that have been mentioned. Both the graphite and the mica appear to be present in the dolomite as well as the limestone, although perhaps not in so great abundance, and there are important masses of dolomite which are almost wholly free from them. The chief colors of the mica are blackish-brown and brownish-yellow; but it is often golden or brass-yellow, sometimes steel-blue, and frequently silvery or pearl-white. The chief part of both the graphite and the mica occurs in small scales. The graphite however is sometimes met with in patches or nests subordinate to the stratification; and when the mineral is found in quantities available for economic purposes, it appears usually to be connected with beds. Very large crystals of mica sometimes occur in abundance, enclosed in pyroxene rock, accompanied with calcspar, apatite, iron pyrites, and other minerals, the whole forming masses of a very coarse texture running with the stratification.

Pyrites.

Crystals and grains of iron pyrites are often thickly disseminated in both the limestone and the dolomite, and very frequently accompany the mica and the graphite, arranged like them in parallel bands holding a greater or less abundance of the mineral. Pyrites often characterises large nodules and lenticular masses of gneiss or gneissoid pyroxenic rock subordinate to the calcareous and dolomitic beds; and strata of this description, weathering to a rusty brown, and holding disseminated graphite, very often limit the great masses of limestone and dolomite, and afford a useful guide in tracing out their distribution.

Chondrodite, apatite, fluor.

Chondrodite, apatite, and most of the other accidental minerals belonging to the limestones and the dolomites, present the same banded arrangement as those already mentioned. The chondrodite in grains is often mingled with grains of serpentine and pyroxene. The apatite, which is seldom wholly absent from any great mass of the limestone, is generally in small quantity, though it is found in some of the limestones of Elmsley, Burgess, and Ross, in such proportions as may be economically available. In Ross it is accompanied by purple fluor spar.

Oxyds of iron.

Specular and magnetic oxyds of iron are disseminated in scales and grains both in the gneiss and the limestone; but there are also important interstratified beds of these iron ores varying in thickness from a few feet up to several hundreds, those of the magnetic oxyd being the thicker and more numerous. Some of the thickest of these beds are interstratified with layers of limestone, and as far as known most of them appear to be either associated with the great limestone bands, or to be not far removed from them in stratigraphical place.

Contorted gneiss in limestone.

Some of the bands of limestone are of great thickness, and passing to them from the gneiss there is occasionally an interstratification of smaller calcareous beds. When one of these calcareous beds or a collection of them is traced to some distance and then compared with the gneiss, the stratigraphical relation of the two is readily made out, and it is perceived that the limestone as a whole is conformable with the beds of gneiss and parallel with those bands and streaks with which they are marked. This relation however is not so evident when only small portions are compared; for it often happens that while an overlying or underlying mass of gneiss will exhibit very regular and even lamellation, the subordinate layers of it dividing the calcareous bed will display contortions of the most complicated description, which appear more important in proportion to the mass of limestone in which they occur. Where this is great, the gneissoid beds, of several inches or a foot thick, which form the subdivisions, will be bent and folded in a very extraordinary manner, or, partially broken up into fragments, will be surrounded by the limestone.

The accompanying wood-cut (1) represents a section in the strike of a calcareous bed between two and three feet thick occurring at the Ragged Chute on the Madawaska, in Blythfield. The bed is inclosed between masses of evenly laminated hornblendic gneiss, and is one of several that succeed each other with considerable regularity, separated by intervening layers of gneiss. Most of them present thin subordinate layers consisting of quartz associated with feldspar and hornblende or mica, being in fact nothing more than thin layers similar to the enclosing rock.

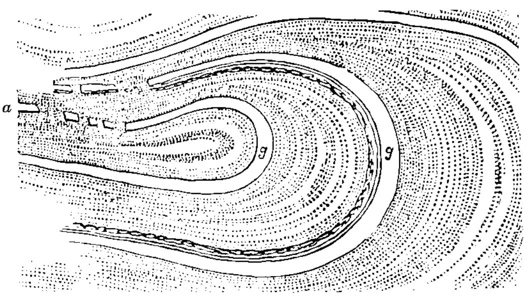
1.—CONTORTED GNEISS BANDS IN LIMESTONE. SCALE ABOUT $\frac{1}{10}$.

l, *l*, Limestone including thin layers of gneiss. *g*, *g*, Gneiss above and below limestone.

These thin divisions are all more or less corrugated, while the thicker masses above and below are comparatively even. The portion selected for representation is somewhat more corrugated than the others, and the folds very much resemble such as might be produced in parallel layers of paper, were they placed in a viscid fluid to which some gentle movement should be communicated.

Near the timber slide at the Chats two beds of gneiss of from six inches to a foot thick, in limestone, shew a fold (2) which is supposed to be similarly related to the gneiss limiting the mass. At *a* both of the beds become broken into fragments, which are surrounded by the limestone.

2.—GNEISS BANDS IN LIMESTONE. SCALE ABOUT $\frac{1}{140}$.



g, g, Bands of gneiss in the limestone. *a,* Broken parts of the gneiss bands.

Nodules in limestone.

Fragments have occasionally been met with in the limestone which appear to shew that thin quartzite beds have been folded and then twisted spirally until one portion separated from another. Sometimes large disjoined masses eight or ten feet in diameter, of a gneissoid character, assuming somewhat the aspect of vast nodules, with parallel layers of the constituent minerals, and much charged with pyrites, will be surrounded by the limestone; and several of these masses succeeding one another will be found in the continuation of a bed of the same description. One instance has been observed, where the limestone of a bed marked with grains of serpentine appeared to have an uninterrupted connexion with rock of identical character filling up a crack or fault in the gneiss at right angles to the general direction of the strata. Notwithstanding these irregularities however, it appears to be the case that the calcareous strata taken in the large are parallel to the gneissoid beds, and alternate with them in a well marked system of stratification.

Limestone filling fissures in gneiss.

Section on the Madawaska.

As an instance of the mode in which the beds succeed one another, the following section may be given, as measured at the High Falls on the Madawaska, a tributary of the Ottawa, where the dip of the strata is pretty constant in direction, being from twenty-five to forty-five degrees east of north, and varying in inclination from fifteen to thirty degrees.

The beds are given in descending order :—

	Feet.
Grey speckled hornblendic gneiss of a schistose character, occasionally striped with darker and lighter colors, caused by a greater or less preponderance of black hornblende and blackish-brown mica; some of the beds have long white dashes on them, arising from the presence of white feldspar; towards the bottom some of the layers have thin lines of a reddish color, occasioned by flesh-red feldspar, ...	32
Grey speckled micaceo-hornblendic gneiss of much the same character,........	26
Grey hornblendic gneiss in three bands of five feet each, and reddish gneiss in three bands of two feet each, ...	21
Measures concealed, with the exception of some reddish gneiss at the top,......	23
Reddish micaceo-hornblendic gneiss, with black hornblende and brownish-black mica,....	3
White crystalline limestone,...	3
Grey hornblendic gneiss,...	15
Measures concealed,..	34
Reddish hornblendic gneiss not well displayed,.............................	20
Measures concealed, ...	37
Reddish hornblendic gneiss composed of red feldspar, translucent colorless quartz, and black hornblende, forming dotted lines upon the red feldspar; there are occasional layers of red feldspar without black dotted lines, and there are a few irregular layers more large grained than the rest,..................	51
Reddish hornblendic gneiss; black layers of an inch are of occasional occurrence, the color being derived from the presence of hornblende; the rock splits in the direction of these layers; iron pyrites occurs irregularly in patches composed of groups of crystals, giving by its decomposition a rusty-brown color to a portion of the beds,..	84
Reddish hornblendic gneiss of much the same character as the last, ...	105
Black hornblendic gneiss and white crystalline limestone in alternating layers; the gneiss is composed of black hornblende, blackish-brown mica, and greenish-white feldspar and quartz; the limestone holds graphite and golden-yellow mica in small scales; the beds are irregularly arranged, and there are occasional lumps weathering into knobs on the surface,.................	3
White crystalline limestone, much of it consisting of transparent colorless calc-spar, with graphite and golden-yellow mica in small scales; lumps of a rusty-brown color holding mica are irregularly displayed in the bed, and in the weathering of the rock there appear raised lines of very small grains of serpentine and tremolite; these dotted lines run above and below the rusty-brown lumps, giving place to and enclosing them,.......................	2
Dark grey hornblendic gneiss with limestone similar to the last; this and the two previous beds come to a point in the direction of the dip, and appear to be part of a lenticular mass filling up a hollow in the bottom of the reddish hornblendic gneiss previously mentioned,.................................	
Dark grey hornblendic gneiss with white crystalline limestone, as before,......	4
Grey hornblendic gneiss with greyish-white bands of a quartzose character and two bands of limestone with much black mica, ...	2
White crystalline limestone with bands of rusty-brown hornblendic gneiss in the middle from six to eight inches thick; there is more mica in the limestone than before, and the upper surface of the bed is uneven,.................	4
Grey thin bedded schistose gneiss with more translucent colorless quartz and more black mica than before; the beds are separated by thin layers of limestone, and there is a considerable amount of hornblende on the surfaces upon	

	Feet.
which the limestone rests, which is made perceptible by being weathered into relief in exposed parts, ...	12
Grey thin-bedded schistose gneiss, ...	12
Reddish hornblendic gneiss similar to that previously mentioned, ...	139
White crystalline limestone holding scales of mica and graphite, and having at the top a layer of dark mica two inches thick, and another near the bottom, with a layer of green fibrous actynolite above and another below; the layers of actynolite are each two inches thick, and the fibrous structure is transverse to them; massive pyroxene is associated with one of the layers, ...	1
Reddish micaceo-hornblendic gneiss, ...	15
Grey schistose gneiss with more mica and quartz than the last,...............	34
Grey schistose gneiss, in some parts of the vertical thickness nearly black from hornblende and mica; a layer or two of white quartz is present in the mass, and two or three feet at the top are composed of limestone, which disintegrates rapidly, probably from the presence of iron pyrites; there are many lumps of a harder description than the rest in the decomposing mass, and much mica in its ruins, ...	33
Light grey gneiss dividing into beds of from three to eight inches; it appears to be more quartzose than usual, and some of the beds are nearly altogether composed of translucent colorless quartz, ...	31
At this point there appears to be a disturbance of some kind; approaching it there is a mass of very large-grained rock with red orthoclase feldspar and translucent colorless quartz without hornblende or mica; it indistinctly crosses the beds, the ends of which become lost in it.	
Measures concealed by soil and herbage, ...	49
Dark grey gneiss obscurely exposed, ...	21
White crystalline limestone with very few scales of mica and graphite, ...	6
Dark grey quartzite separated into layers by partings of mica,................	10
Dark grey micaceous gneiss with two small bands of crystalline limestone,.....	13
Dark grey schistose gneiss with black bands, the color of which is derived from the presence of much black hornblende; mica prevails where the rock is most fissile, ...	25
Black schistose gneiss with much hornblende; the lower part has much black mica, with layers composed of white feldspar and translucent colorless quartz,	51
Grey micaceo-hornblendic gneiss with black streaks composed of mica, and black patches of the same,..	42
Measures concealed by soil and vegetation,.................................	80
Light grey hornblendic gneiss; the beds, which are from two to six inches thick, are very quartzose, and have a few specks of green hornblende and black mica with opaque white feldspar, and some few streaks showing red feldspar,	10
Measures concealed by trees and moss, ...	63
Reddish hornblendic gneiss,...	39
Grey hornblendic gneiss interstratified with crystalline limestone,.............	15
White crystalline limestone, containing abundant small scales of mica and graphite, and interstratified with irregular corrugated layers, of which some are very quartzose and some dotted with lines of black hornblende, ...	19
Reddish hornblendic gneiss of much the same character as that previously described, ...	56
Measures concealed by the river, ...	7
Reddish hornblendic gneiss, ...	17
Reddish hornblendic gneiss not well exposed, ...	18
Dark grey or nearly black thin layers composed chiefly of black hornblende, with some black mica and some crystals of white quartz and feldspar; interstratified with limestone having corrugated layers and many patches	

	Feet.
and spots, displaying tremolite and serpentine, as well as some with hornblende and mica. Near the bottom there is an irregular layer of limestone from one to two feet thick, ...	25
White crystalline limestone with a few dark corrugated bands of gneiss,.......	12
Dark grey gneiss, consisting of black hornblende, black mica, and white feldspar and quartz,..	25
	1351

In this section the gneiss preponderates over the limestone, and none of the calcareous beds are of great thickness; but a little higher in the series on Calabogie Lake, on the fourteenth lot of the first range of Blythfield, a bed of white crystalline limestone upwards of a hundred feet thick is seen, with hornblendic gneiss above and a mass of very black hornblende rock below. The upper portion of this is schistose, and contains yellow mica between the layers, while the lower portion is highly crystalline. This mass of hornblende rock, which in some parts has the aspect and composition of fine greenstone, and in others has a small quantity of quartz in it, may be upwards of 200 feet thick, and is again underlaid by limestone.

Thickness of the limestones. In other instances the amount of calcareous rock greatly surpasses the gneiss. At the Chenaux, for example, a succession of white crystalline limestone strata on the left bank of the Ottawa, near the boundary line between Clarendon and Litchfield, presents a breadth of 600 yards, with but a moderate interstratification of harder rock. The dip is about N. 15° E. $< 10° — 20°$, giving a thickness of 400 feet and upwards, of which not much more than one fifth consists of gneiss; and it is probable that the section is but part of a larger series of the same rocks interstratified with one another much in the same proportion. On the twenty-fourth lot of the first range of Clarendon there is a considerable display of similar rocks, the breadth of which, unless there be sharp undetected folds, would give a thickness of 4000 feet, about two thirds of which consists of crystalline limestone.

Conglomerate beds. Notwithstanding the general highly crystalline condition of the Laurentian rocks, beds of an unmistakeably conglomerate character are occasionally met with among them. Limestones similar to those which have been described are extensively exposed in Bastard and South Crosby; their color is usually white, but sometimes greenish-white, or white with grey bars or stripes. Small scales of graphite are invariably disseminated through the rock, with serpentine, mica, and iron pyrites, and in the twenty-seventh lot of the third range of South Crosby chondrodite is of frequent occurrence, the disseminated mineral alternating with bands containing mica. **Section in Bastard.** On the twenty-fourth lot of the tenth range of Bastard a bed of conglomerate is interstratified between two of the beds of limestone. The dip of the strata at the spot is N. 50° E. $< 30°$, and the following ascending section shows the character and relations of the beds:—

	Ft.	in.
Pure white highly crystalline coarse grained limestone, with small disseminated scales of graphite running in the layers, and grains of mica, ...	5	0
Coarse colorless translucent granular quartzite, containing cleavable masses of white feldspar, readily decomposing by the action of the weather into kaolin, with patches of greenish chloritic limestone containing brown mica; in some parts the feldspar is replaced by a soft greenish-white sub-translucent unctuous mineral having a somewhat columnar structure and a waxy lustre, resembling indurated talc, and there are present occasional scales of graphite and grains of copper pyrites with blue carbonate,...............	0	4
Finer and more calcareous granular quartzite, with cleavable masses of feldspar and calcspar and scales of graphite; green stains occur in patches,.......	0	2
Coarse conglomerate, of which the matrix is a fine grained quartzose sandstone, somewhat calcareous, containing white feldspar, which occurs in the form of grains and pebbles, associated with large and small well defined pebbles of vitreous, milk-blue, translucent, and sometimes opalescent quartz. There are also pebbles of fine grained homogeneous greyish sandstone more calcareous than the matrix; some similar to these, but nearly white and more pulverulent, afford to chemical tests a small quantity of phosphate of lime, and others of yellowish-grey sandstone are finely but distinctly laminated, the laminæ being shewn by intervening bands of a white color; one of the laminated pebbles is characterised by a layer of coarser pebbles in one of the bands. The sandstone pebbles are flat, and lie on their flat sides in the general plane of the stratification. Mica is disseminated in considerable abundance, and there are a few scales of graphite,......................	1	6
Fine grained calcareous sandstone, ...	0	2
Fine grained, very hard, crystalline arenaceous bluish-grey limestone, weathering reddish, with a few scales of graphite, ...	0	4
Pure white, highly crystalline, coarse grained limestone, with scales of graphite in some abundance, and rounded grains of mica, besides small amber-yellow grains of chondrodite running in layers,.........................	6	0
	13	6

On the bridge-island in Hog Lake, on the eleventh lot of the thirteenth range of Huntingdon, calcareous mica schist is seen dipping to the north-westward; and on the road in the same lot, farther north, there is white crystalline limestone with mica and graphite. The observed strike of these strata north-eastward would carry them into the lake. On the north side of the lake, in a position which would appear to overlie the previous mentioned exposures, are contorted gneiss and micaceous schists cut by red syenitic veins. The dip of the stratification is north-westward.

Conglomerates in Madoc.

Proceeding northward, gneiss occurs on the first lot of the sixth range of Madoc, and white crystalline limestone beyond it in the same numbered lot in the sixth and seventh ranges. In a field a little way north from the village of Madoc, still in ascending continuation of the section, a ridge of a somewhat micaceous schist occurs; it is slightly calcareous, of a bluish color, weathering greenish, and holds numerous fragments of rock different in character from the matrix, all being without calcareous matter, and some of them resembling syenite or greenstone. North from this ridge another succeeds, consisting of micaceous schists, beyond which, for 300 yards, ridges of a decided conglomerate, with distinctly rounded pebbles enveloped in a matrix of micaceous schist, alternate with ridges of schist containing few or no pebbles. The exact dip of the strata has not been satisfactorily ascertained; but crystalline calcareous beds, portions of which appear to be pure dolomite, with small scales of mica, a few small grains of serpentine, and thin reticulating strings of magnetic iron ore, are found at the village on the south side of the ridge, while black or dark bluish calcareous and pyritiferous schist is found to the north of them, both of these usually exhibiting a northward dip.

On the fourth and fifth lots of the fifth range, still farther north, another band of conglomerate occurs, associated with fine grained soft micaceo-siliceous feldspathic schist. The matrix of the conglomerate weathers white, and appears to be a dolomite. The pebbles, of which the largest may be six inches in diameter, are chiefly quartz, but there are also pebbles or masses of feldspar, and a few of calcspar. The quartz pebbles are for the most part distinctly rounded, and their colors various, some being internally bluish, some white, and others pinkish. The feldspar is red and white, and the calcspar white. The dip of this rock appears to be southward of east, but the slope is irregular, and may probably be thirty-five or forty degrees. The beds may be a repetition of the conglomerate of Madoc village on the opposite side of a synclinal.

Anorthosite rocks.

It has been stated above, that in great vertical thicknesses of the Laurentian rocks the chief constituent mineral is a triclinic feldspar, varying in composition from andesine to anorthite. These anorthosite rocks in general weather opaque white, and they are usually marked by the presence of hypersthene and ilmenite. Sometimes, as in the township of Morin, they consist chiefly of labradorite. In this locality the rock is composed of a fine grained white-weathering feldspathic paste, of a purplish grey, and holding cleavable masses of a lavender-blue feldspar several inches in diameter. Many of these exhibit a fine golden-green and deep blue opalescence, and the same hues occasionally emanate from points in the paste. The rock is generally massive, and it is occasionally very difficult to find any indication of those parallel planes which are so generally present in the orthoclase gneiss. The large cleavable masses of labradorite, however, as well as the hypersthene and ilmenite which occur in the rock, are found to prevail in belts that appear to be parallel with one another, and garnetiferous and pyroxenic micaceous bands occasionally indicate the same arrangement. To these anorthosites belongs the hypersthene rock of northern New York and of the isle of Skye. The hypersthene is however often replaced by ordinary pyroxene, or is wholly wanting in the Laurentian system, giving rise to a purely feldspathic rock.

Triclinic feldspars, labradorite, hypersthene, and ilmenite.

At St. Jerôme a belt of the crystalline limestone was found to exist on the west side of the river. It was traced along its bank for a distance of a mile and a half, bearing N. 12° E., with a breadth of apparently about 200 yards. The rock on the east side of it is composed to a large extent of triclinic feldspar; but holding a considerable admixture of other minerals, it is not of so conspicuous a character as the anorthosite of Morin. The minerals have a reticulated arrangement, as in the case of the porphyroid orthoclase gneiss. Darker and lighter bands run parallel to one another, the shades being occasioned by the greater or less abundance of a fine grained greenish feldspar, weathering opaque white, which occurs in spots surrounded by a darker colored net work, consisting of dark green pyroxene and magnetic iron ore, with small disseminated clusters of yellowish-red garnets. In this mixture large and small masses of labradorite, some of them two or three inches in diameter, are irregularly disseminated, and irregular veins or apparent segregations occur here and there, composed of flesh-red orthoclase and translucent colorless quartz.

St. Jerome: anorthosite and orthoclase gneiss.

On the west side of the river, rock of a similar character is met with; but there is also seen an interstratified mass of reddish hornblendic gneiss, the feldspar of which is orthoclase. The breadth of the mass is 200 yards, and it is marked by bands darker than other parts, from the presence of more hornblende. Iron pyrites and molybdenite are observed in the rock. On the west side of this mass of orthoclase gneiss, smaller bands of a similar nature seem to alternate with those containing a triclinic feldspar, indicating a passage between the anorthosite and the orthoclase gneiss. Beds of quartzite are also interstratified, and some of these were in one place so filled with small garnets as to form a fine granular garnet rock. The strike of the masses on each side of the limestone runs with it N. 12° E., and all dip to the westward at a high angle.

Terrebonne.

An anorthosite rock, resembling that of Morin in its opaque white massive aspect, occurs at New Glasgow on the Achigan, in Terrebonne seigniory; the stratification, however, is well marked by bands of garnets and pyroxene, and on the west side, by alternations of the rock with orthoclase gneiss. The strike is a little eastward of north, with a dip to the westward, and the breadth which has been observed is about three quarters of a mile, without, however, attaining the eastern limit of the belt. Similar rocks have been observed in Rawdon and Chertsey, where they appear to have a breadth of twelve miles.

Chateau Richer; andesine.

A large development of triclinic feldspar rock occurs on the Sault à la Puce, in the parish of Chateau Richer (Montmorenci), where it covers a breadth of two or three miles across the strike, bounded by crystalline limestone on one side and a quartzo-feldspathic rock on the other, resembling the orthoclase gneiss. In this region there are several varieties of the feldspar, in which the composition varies much, being sometimes that of labradorite, andesine, and intermediate varieties, and at others approaching that of anorthite. Hypersthene is met with throughout the rock in broad lamellar masses, which, though variable and irregular in their distribution, exhibit a general parallelism. They are occasionally four or five inches in diameter, by an inch or more in thickness. Titaniferous iron ore is also found in the rock in grains and lenticular masses, occasionally an inch or more in thickness. These occur in the granular base, generally near the hypersthene; but grains of the ore are occasionally found in the crystalline feldspar. The hypersthene does not exceed a half per cent. and the titaniferous iron one per cent. of the mass. The latter mineral, however, in other localities, may present a much larger proportion. In the parish of St. Urbain, near Bay St. Paul, there is a mass of it ninety feet in width by about 300 feet in length, in a rock which is probably a continuation of that of Chateau Richer.

St. Urbain, ilmenite.

Such are the chief varieties of rock composing the strata of the Laurentian series as far as known; there are other varieties to be noticed, constituting veins and intrusive masses. The rocks composing the veins are in general much more coarsely crystalline than those of the strata; but some of the more coarsely crystalline masses appear to coincide with the strata, and it cannot yet be stated with certainty whether they are not to be considered as part of them. Some of them have been casually alluded to already in the description of the stratified masses, being those composed of large cleavable masses of pyroxene, orthoclase, calcspar, and mica, with apatite, sphene, and pyrites. There are masses however of a somewhat similar character, which run transverse to the strata, and there can be no doubt that these are to be considered veins of segregation.

One of this description occurs at the Ragged Chute, near the High Fall, on the Madawaska, in Blythfield. It has a breadth of not less than 150 feet; its course is about N. 40° E., being transverse to the strata, which consist of crystalline limestone, alternating with orthoclase gneiss. The vein appears to be chiefly composed of pyroxene of a dull whitish-green, associated with dark green hornblende, calcspar, mica, orthoclase, quartz, and black tourmaline. The pyroxene constitutes the great body of the vein; its crystals are confusedly aggregated, and sometimes radiating smooth cleavage faces, six inches in breadth, may be followed for a length of fifteen inches or two feet. In the vicinity of Grenville there occurs in a micaceo-graphitic limestone, a coarsely crystalline rock composed of orthoclase, wollastonite, dark green pyroxene, sphene, graphite and quartz, with small quantities of serpentine, zircon, idocrase, and mica.

Veins of pyroxene and hornblende.

Grenville, wollastonite, graphite, &c.

Veins are frequently met with composed chiefly of orthoclase in large cleavable masses, mingled with quartz, constituting a pegmatite, which, by an admixture of mica, often passes into granite. One of this kind occurs on Allumette Lake, at Montgomery's clearing, about five miles above Pembroke. The feldspar is a brownish-red orthoclase, and the quartz, which is white, is in some parts so disposed in the feldspar as to imitate the

Granite veins with mica, tourmaline and zircon.

characters of Hebrew writing, making a graphic granite. Large crystals of brown and black mica occur in the vein, but they are rare. The breadth of the vein is from fifty to one hundred feet, and its course N. 70° W., which is transverse to the strike of the strata.

In the Roche Fendue channel of the Ottawa, in the township of Ross, at the mouth of a deep recess, a vein of a similar character occurs. Crystals of tourmaline were observed in parts of it, but no mica. Its breadth is nine feet, and it stands up like a wall above the gneiss, nearly in the direction of the strike, its course being N. 13° E., with an underlie to the eastward. The dip of the strata is about S. 80° E. < 16°. Another instance of a granite vein holding crystals of tourmaline occurs at Carrying-place Bay, on Charleston Lake, in the northern concessions of Escott and Lansdowne.

On the west side of the river, at St. Jerôme, interstratified orthoclase and labradorite rocks are cut by veins of a granite composed of very pale flesh-red orthoclase, weathering white, and translucent colorless quartz, with occasional crystals of dark brown mica. One of the veins is large and very coarse grained, and they are all more or less characterized by the occurrence of black tourmaline, and small zircons.

Albitic granite.

Other veins intersecting the Laurentian rocks are composed of an albitic granite. One of these occurs on the nineteenth lot of the ninth range of Bathurst, where the albite in part is that highly beautiful opalescent variety which constitutes the peristerite of Thompson. A mixture of colorless transparent quartz is disseminated through a large portion of the albite, which still so far predominates as to give a distinct feldspar cleavage to considerable masses.

Another vein of this description is met with at Eel Creek, on the north side of Stoney Lake, in Dummer, where the strata consist of white crystalline limestone, alternating with blackish-grey schistose gneiss, dipping S. 87° W. < 18°. The strata are intersected by a set of parallel dykes or veins of pale flesh-red syenite, the largest about three feet thick; their general course is about N. 18° E., and their underlie S. 72° E. < 45°. These are again cut by veins of a fine grained mixture of quartz and reddish-white albite, some of the albite being in large cleavable masses, exhibiting a bluish opalescence. The vein holds occasional masses of fine granular tourmaline, and is slightly calcareous in parts.

A third locality, presenting a rock of this description, probably in a vein, is at the head of the Lake of Three Mountains, about forty miles up the River Rouge, where masses of pure white albite, several feet in diameter, and showing large striated cleavage surfaces, are mingled with masses of translucent colorless quartz, some of them a foot in diameter, and large crystals of greenish-brown and black mica. None of this albite was observed to be opalescent. The strata in contact with the mass are crystalline limestone. In some localities orthoclase and albite are associated in the same mass of granite. We conceive these feldspathic veins to be segregated and not intrusive.

Pistachio-green epidote very frequently runs in thin reticulating veins in the orthoclase gneiss; and when the feldspar of the gneiss is red, the mixture produces a beautiful ornamental stone. A locality of such gneiss occurs in Ramsay, near Carleton Place, and another at the lowest fall of the Mingan River, on the north shore of the Gulf of St. Lawrence. Where veins of this description occur, the rock of the country appears to be slightly shattered for a certain breadth in a particular direction, but its fragments are very little displaced, and the epidote, without any other mineral, runs in a net-work through the part affected by the disturbance. Epidotic gneiss.

Metalliferous lodes are occasionally found intersecting the Laurentian rocks. The ores which have been met with in them are those of lead and copper, in the forms of galena and copper pyrites. These veins have usually been found to intersect the crystalline limestones, in bearings approaching northwest and southeast. The gangue, which holds the ores, is usually either calcspar or barytes, or a mixture of both. The quantity of copper in these veins appears as yet to be but small; but the lead in some of them may be found profitable. Instances of those holding traces of copper ore are met with in crystalline limestones, in the townships of MacNab and Bastard, and in the augmentation of the seigniory of Lanoraie and d'Autraye on the Assumption River, where the rock of the country is micaceous gneiss. Veins holding lead ore are known in Bedford, Lansdowne, and Fitzroy. They all intersect the crystalline limestone; but it has recently been ascertained that the age of these veins is much more recent than the Laurentian epoch. Metalliferous lodes.

Some veins containing the magnetic and others the specular oxyd of iron have been met with in the Laurentian rocks, but they are of little importance. One of the former occurs in Ross, opposite Portage du Fort, in which the magnetic oxyd appears in reticulating strings, transverse to the strata of the crystalline limestone at the spot. The micaceous specular oxyd occurs in what appears to be a vein at Hudson's Wharf, on the Lac des Chats, at the junction of limestone and gneiss. The great iron deposits of the system are in beds. Iron ores.

The intrusive masses of the Laurentian series consist chiefly of syenite and greenstone. They occur in many parts of the country, but their relative ages have been ascertained almost altogether by investigations in the counties of Ottawa and Argenteuil. What appear to be the oldest intrusive masses are a set of dykes of a rather fine grained dark greenish-grey greenstone or dolerite, which weathers greyish-white, and consists of greyish-white feldspar mixed with pyroxene, occasional scales of mica, and grains of pyrites. Their width varies from a few feet to a hundred yards, Intrusive rocks.

and they possess a well marked columnar structure. Their general bearing appears to approach east and west, but the main dykes occasionally divide, a branch striking off at an angle of from twenty to forty degrees.

Dolerites of Grenville.

One of these dykes cuts crystalline limestone on the thirteenth lot of the fourth range of Grenville. Its breadth is about thirty yards, and it has been traced across the limestone and gneiss for a mile and three quarters, in which, with a few moderate zig-zags, it maintains a course of N. 85° E., until it is interrupted by a mass of syenite on the eighth lot of the range already mentioned. Across the limestone it forms a ridge ; but across the gneiss it is usually found in a depression, sometimes a very deep one. When it mounts the side of any hill which runs with the stratification, the columnar structure gives it the aspect of a flight of gigantic steps, well presenting the character from which the Swedish name of *trap* is derived. The columns are so truly at right angles to the plane of the dyke that they are a sure means of determining the underlie, which is towards the north. A branch strikes off from the dyke on the eleventh lot of the range, and, after proceeding about a quarter of a mile in the direction S. 30° E., it turns S. 50° E., and continues for three quarters of a mile more, chiefly across limestone, in a remarkably straight line, to the eighth lot, where, having gradually diminished from the width of eighteen yards to five, it seems to split up into a brush-like arrangement of small dykes, and is lost. In a westerly direction from the thirteenth lot of the fourth range, the main dyke has been traced between four and five miles, and in its whole course from the syenite the bearing is about five degrees north of west.

Another dyke of the same character, with a width of twenty-five yards, occurs in the eleventh lot of the fifth range of Grenville, and runs for about a mile in the bearing N. 67° E., when it is interrupted by the same mass of syenite as before, on the eighth lot of the same range. A probable continuation of the dyke in an opposite direction is seen crossing the gneiss on the fifth range, reaching the seventeenth lot, with a bearing N. 75° W., and thence crossing the River Rouge.

From the sixth lot of the fourth range of Chatham Gore, where it cuts the crystalline limestone, another of these dykes has been traced for upwards of two miles to the first lot of the third range of Wentworth. Its width varies from fifty to a hundred yards, but it appears to maintain a very uniform course, and though an interval of seven miles is a long one at which to recognise it again, yet an exposure of greenstone on the front of the first range of Wentworth on the division between the twentieth and twenty-first lots is sufficiently near the line to make it probable that it is a continuation of the same dyke. At the latter spot it is from 110 to 120 yards wide, and about eleven chains to the westward it is cut off by the syenite. It has been met with again, however, on the western side of it, and traced across the north-west corner of Chatham into Grenville, and is probably continued to the twelfth lot of the ninth range of the latter township, where there is a dyke of the same character. The whole distance from Chatham Gore is about fifteen miles, and the bearing about five degrees south of west.

Still another of these dykes has been observed in the seigniory of Argenteuil, about a mile and a half from the North River, on the road from Lachute to Chatham Gore. It appears to be about twenty-five or thirty yards wide, and it bears N. 80° W. for about a mile and a half to the town line of Chatham, which it crosses towards the rear of the ninth range; and although it would require a change in its course to bring it to a dyke seen on the road between the seventh and eighth ranges on the ninth lot, it appears probable that the two will be found to be the same. Running westward from the latter spot, it comes against the syenite in the eleventh lot of the seventh range, and is there cut off.

Dolerites cut by syenite.

These greenstone dykes being always interrupted by the syenite when they have been found to come in contact with it, it is plain the syenite must be of posterior date. This mass of intrusive syenite occupies an area of about thirty-six square miles in the townships of Grenville, Chatham, and Wentworth, and a glance at the accompanying map, shewing the distribution of the crystalline limestone in the counties of Ottawa and Argenteuil, will shew its shape and distribution. In its lithological character the rock is very uniform, being composed for the most part of orthoclase, either of some tinge of flesh-red or a dull white, with black hornblende, and a rather sparing quantity of greyish vitreous quartz. The red tinge prevails more on the west side, the white on the east. In the spur which runs into Wentworth, mica is occasionally found accompanying the hornblende. The rock is rather coarse grained in the main body, but dykes of it are sometimes observed cutting the limestone and gneiss, in which the grain is finer: these have not as yet been traced to any great distance from the nucleus.

Felsite porphyry cutting the syenite.

The syenite is cut and penetrated by masses of a porphyritic character, which are therefore of a still later date. These masses belong to what has been called felsite porphyry, hornstone porphyry, or orthophyre, having a base of petrosilex, which may be regarded as an intimate mixture of orthoclase and quartz, colored by oxyd of iron, and varying in colors from green to various shades of black, according to the oxydation of this metal. Throughout the paste, which is homogeneous and conchoidal in its fracture, are disseminated well defined crystals of a rose-red or flesh-red feldspar, apparently orthoclase, and, although less frequently, small grains of nearly colorless translucent quartz. The larger masses of this porphyry have a fine grained reddish-buff base, in which well defined crystals of flesh-red feldspar of various sizes, from one-eighth to three-eighths of an inch, are thickly disseminated. In addition to the crystals of feldspar, the base often contains a multitude of fragments of gneiss, greenstone, and syenite. varying in size from small grains to masses several feet in diameter. These are occasionally so abundant as to give to the rock the character of a breccia. When the base is green it is rather more compact, and it does not usually contain so many imbedded crystals of feldspar.

Porphyritic nucleus and dykes.

The principal nucleus of this porphyry occupies a pear-shaped area, the small end pointing south, on the third and fourth lots of the fifth and sixth ranges of Grenville, from which, on the eastern side, a portion projects into the second lot of the fifth range. This mass is wholly surrounded by syenite, and a large part of it constitutes a mountain or group of hills intersected by one or two ravines. In about the centre of the mass on the summit of one of the hills, there is a circular depression of about a hundred yards in diameter, nearly surrounded by a tufaceous porphyritic rim of about thirty feet in height. In this depression there is a turf bog supporting a grove of good sized evergreen trees. On sounding the depth of the bog with a boring rod, the rock beneath was found to present the shape of a cup, with the depth of twenty-five feet in the centre; so that, including the rim, the depression would be about fifty feet deep, with the exception of a break down to the level of the bog on the east side. The nature of the rock constituting the rim gives to the depression in some degree the aspect of a small volcanic crater. But if it be the remains of one, it can only represent some deep-seated part of the vent; for there can scarcely fail to have been here a great amount of denudation of the ancient Laurentian surface, while the ice grooves in the neighborhood shew that there has been much erosion over the whole country in comparatively recent times. In this vicinity some entangled beds of gneiss occur, one of which, running N. 80° W. for upwards of a hundred yards, is completely surrounded by the porphyry.

From this porphyritic nucleus one or two porphyritic dykes can be traced cutting the syenite for short distances, and some of a similar character are met with at such a distance as to make it probable that there are other porphyritic nuclei. One of these dykes about seven yards wide, containing beautiful red feldspar crystals set in a black base, occurs on the south side of the road, between the seventh and eighth ranges of Chatham, on the eighth lot. Its bearing S. 85° W. would carry it to the south of the porphyritic mass above described, from which the position in which the dyke cuts the gneiss is removed seven miles, though it is not more than one mile from the syenite.

Another dyke of this aspect is seen in the ninth range near the line between the thirteenth and fourteenth lots, but in addition to the elements mentioned it holds disseminated grains of transparent colorless quartz. Its course appears to be S. 44° W., and it intersects a mass of porphyritic rock of the same color and texture as the porphyry of the pear-shaped nucleus, which, however, like the dyke, contains grains of vitreous quartz. Grains of this mineral are also observed in another porphyritic mass, whose course is N. 10° W., about a quarter of a mile from the front of the twenty-fifth lot in the seventh range. A porphyritic dyke is observed on the road between the sixth and seventh ranges on the twenty-third lot. It encloses grains of quartz and crystals of flesh-red feldspar, some of them half an inch in diameter, in a reddish finely granular base. Of the tufaceo-porphyritic rock a lenticular mass crosses the seventh and eighth lots close upon the rear of the fifth range of Grenville. It has a length of nearly half a mile by a breadth of about 150 yards in the middle, and lies between gneiss on the north and syenite on the south.

In the vicinity of the pear-shaped porphyritic intrusion there are met with two veins of a special character, cutting the syenite, that deserve to be noticed. They consist of a white, yellowish-brown or flesh-red cellular chert, the colors in some cases running in bands parallel to one another, and sometimes being rather confusedly mingled, giving the aspect of a breccia. The cells are unequally distributed, some parts of the veins being nearly destitute of them, while in others they are very abundant, and of various sizes from that of a pin's head to an inch in diameter. On the walls of some of these cells small transparent crystals of quartz are implanted, and in some there are the impressions of cubical forms, resulting probably from crystals of fluor spar which have disappeared. The stone has the chemical characters and the composition of flint or chalcedony. Veins of chert in syenite.

One of these veins is on the north half of the first lot of the sixth range of Grenville, where it was traced for about a hundred yards running about east and west, and the other in the south half of the first lot of the sixth range, belonging to Mr. James Lowe, who was the first person who drew attention to it as affording buhrstone. On his ground the vein has been more examined than elsewhere; it appears to run in a very straight nearly east and west bearing, and stands in a vertical attitude, while its breadth varies from about four to seven feet. Where the vein is banded the colors run parallel with the sides. The attitude and associations of the mass clearly shew it cannot be of sedimentary origin, and its composition, taken in connection with the igneous character of the district, suggests the probability that it is an aqueous deposit which has filled up fissures in the syenite, and is similar in its origin to the agates and chalcedony which, in smaller masses, are common in various rocks.

For a distance of perhaps 200 yards on each side of these veins of chert, while the quartz of the syenite remains unchanged, the feldspar has been more or less decomposed, and been converted into a sort of kaolin. As this process involves a separation of silica from the feldspar, it is not improbable that it has been the source of the veins of chert.

Ages of these intrusive rocks.

The intrusive rocks which have been described have a date anterior to the deposit of the Silurian series. None of a similar character have been met with breaking through this series, and the relations of the base of the Lower Silurian group along the foot of the hills composed of the syenite are such as to make it evident that the Silurian beds in some places overlie eroded portions of the intrusive rock. But all these intrusive masses are cut by a set of dykes whose relations to the Silurian series are not so certain. These dykes are composed of a finely granular base, with an earthy fracture, consisting of feldspar and pyroxene, and having a dark brownish-grey color. In this base are imbedded rounded masses of black cleavable augite, varying in size from a pin's head to several inches in diameter. These are associated with various sized nodules of calcspar filling cells that do not attain the diameter of the largest masses of augite, and with small scales of mica, grey in fresh fractures, but weathering brass-yellow on the sides of cracks and joints. Small crystals of sphene and grains of titaniferous iron occur in the rock.

One of these dykes, having a width of from three to ten feet, is traced from the first lot of the sixth range of Grenville, near Mr. Lowe's buhrstone, where it cuts the syenite, to the third and fourth lots of the same range, where it cuts the pear-shaped mass of porphyry; thence it crosses to the eighth lot of the fifth range, where it cuts both syenite and porphyry, and farther to the tenth lot of the same range, where it intersects the quartzite and the limestone. The whole distance is upwards of two miles and a half, and the bearing S. 82° W. Another dyke of this description intersects the limestone on the thirteenth lot of the same range, and is traced for half a mile, running east. These dykes bear a striking resemblance to some of the dolerites which intersect the Lower Silurian group in the neighborhood of the mountain of Montreal, and may possibly be of the same age, but none of them have yet been traced continuously from the Laurentian into the Silurian rocks.

Extent of Laurentian system.

The description which precedes will give some notion of the chief rock masses of the Laurentian series. Stretching on the north side of the St. Lawrence from Labrador to Lake Huron, this series occupies by far the larger portion of Canada, and its strata probably possess a very great thickness. To determine the superposition of the various members of such an ancient series of rocks is a task which has never yet been accomplished in geology, and the difficulties attending it arise from the absence of fossils to characterise its different members. Bands of the crystalline limestone are easily distinguished from bands of the gneiss, but it is scarcely possible to know from local inspection whether any mass of limestone in one part is equivalent to a certain mass in another. They all resemble one another lithologically, and, although masses dipping in the same direction are met with running for considerable distances rudely parallel with one another, it is scarcely ever safe to take for granted that they are stratigraphically distinct. The dips avail but little in tracing out the structure; for in the numerous folds of the series the dips are frequently overturned, and the only reliable mode of pursuing the investigation and working out the physical structure is patiently and continuously to follow the outcrop of each important mass in all its windings as far as it can be traced, until it becomes covered up by superior unconformable strata, is cut off by a great dislocation, or disappears by thinning out. A labor such as this, in a district without roads and the topography of which is yet little known, with a surface much broken by the unequal wear of its rocks, and still covered by forest, must necessarily require much time. Structure of the Laurentian region.

An attempt has been made to work out the structure of a small portion of the Laurentian country in this way. It comprehends a part of the counties of Ottawa, Argenteuil, Montcalm, and Two Mountains, and the accompanying map displays the distribution of the limestones in that area, as far as known. In this investigation a single band of limestone, which has been termed the Grenville band, varying apparently in thickness from 60 to 1000 feet, and averaging perhaps 750 feet, emerging from beneath the Silurian rocks, has been traced from Grenville to the Iroquois Chute, fifty miles up the valley of the Rouge. It presents the general form of a trough, but its distribution is so complicated by subordinate undulations that in a triangular area, of which the base extends about twenty-five miles between the Petite Nation seigniory and Lachute, and of which the apex is at the Iroquois Chute, the line of calcareous outcrop measures upwards of 200 miles. The arrangement presented by the outcrop appears to depend upon two sets of undulations, the axes of the one running in bearings approaching north and south, and of the other in bearings nearly east and west, the latter apparently related to the oldest system of dykes. Map of the limestones.

The north and south undulations appear to be the more important and the more numerous of the two, giving to the lines of outcrop in that direction the greater number of repetitions and the longer stretches. For about twenty-five miles from the Ottawa and North Rivers the bearing of these axes is about N. 10° E., and they preserve a considerable degree of parallelism; but the investigation has not yet been sufficiently extended to determine whether they continue in that direction, or whether they turn a little to the westward of north for some distance in their farther progress, nor is it yet certain in what positions will be found the main axes of the series. The most important anticlinal observed appears to start in Chatham from the intrusion of syenite which has been mentioned, and, crossing the town line of Chatham and Wentworth about half-way between Lake Louisa and the west branch of the North River, to gain a position towards the west side of Howard; but beyond this its course has still to be ascertained. Ottawa and North River District.

The deepest part of the trough to the westward of this anticlinal, as far as the investigation has proceeded, appears to be around the point where the line between Wentworth and Harrington comes upon the south side of the township of Montcalm. In this neighborhood a bed of limestone, passing through Proctor's Lake, overlies the Grenville band; but being only fifteen feet thick, it has been traced out no more than two or three miles. On the east side of the axis this bed has not been observed; but a more important one, supposed to be higher in the series, and to average 500 feet in thickness, has been followed through Howard, Morin, and Mille Isles to St. Jerôme, where it sinks beneath the unconformable Silurian strata. What is supposed to be the same band again emerges about twenty miles to the north-eastward in Rawdon, and runs northward obliquely across the township.

Rawdon and Mille Isles.

The synclinal between Rawdon and Mille Isles appears to be occupied by the anorthosite rocks already described as made up of triclinic feldspars, associated with more or less pyroxene or hypersthene, and gneissoid in their structure. Of this anorthosite there is probably a great vertical thickness; for although it has been traversed at about right angles to the strike for nearly twelve miles in Rawdon and Chertsey, the summit of it has not been ascertained, nor is it yet known whether it is succeeded in ascending order by limestone or by orthoclase gneiss. Between St. Jerôme and the most eastern exposure of the Grenville band of limestone at Lachute, the anorthosite appears gradually to pass into orthoclase gneiss, and this in its various lithological modifications is the only rock met with above and below the Grenville band of limestone in the triangular area explored up the valley of the Rouge to the Iroquois Chute.

It has been stated above that for twenty-five miles from the Ottawa the bearing of the axes of the northward anticlinals and synclinals is about N. 10° E. The bearing of the most important synclinal form examined beyond this distance is about N. 10° W. Upon it runs a trough-shaped development of the Grenville limestone from the north part of Arundel to the Iroquois Chute, where the limestone seems to come to a point. The widest part of the trough is at Hamilton's farm, on the plain of the Three Mountains, where a section at right angles to it shews two important bands of crystalline limestone coming from beneath the Grenville band on each side, with heavy masses of orthoclase gneiss between. The outcrop of the lower of these two sheets runs through Trembling Lake on the east side and through three small lakes on the west. The upper one passes through Long Lake and Great Beaver Lake on the east, and Green Lake on the west, and it is divided into three subordinate sheets by the interposition of two bands of garnet-bearing gneiss and quartzite. In this part garnet-bearing gneiss overlies the Grenville band, and above it a great bed of quartzite, 600 feet thick, which has already been alluded to, forms Quartz Mountain, an isolated hill which rises from the plain of the Three Mountains. Orthoclase gneiss rises from beneath these three bands of limestone on each side of the trough, and on the east side it constitutes Trembling Mountain, the highest hill for some distance around, being, as mentioned in a previous chapter, about 2060 feet above the sea.

From what has been said, it will be observed, that in the present state of the investigation, without counting the Proctor's Lake bed, which is too small for separate consideration, there appear to be four important bands of crystalline limestone in the Laurentian area of which the structure has been partially examined. The wrinkled condition of the strata is such that there are in some parts four and five anticlinals in the breadth of a mile, the effect of each of which is perceptible in the geographical distribution of the strata, and this renders it very difficult to determine with precision the volume of rock in which the four calcareous bands are inclosed; but according to the best estimate arrived at, it appears probable that the following would be an approximation to the thickness of the various constituent parts of the mass arranged in ascending order:—

Four limestone bands.

Section.

	Feet.
1. Orthoclase gneiss composing Trembling Mountain; though the mass has not been especially examined nor any geographical position shewing its inferior limit ascertained, yet the general aspect of the mountain induces the supposition that it must be of great thickness, and it is presumed that it will exceed the volume here given,........	5000
2. Crystalline limestone of Trembling Lake, ...	1500
3. Orthoclase gneiss between the limestone of Trembling Mountain and that of Great Beaver Lake,........	4000
4. Crystalline limestone of Great Beaver Lake and Green Lake, including two bands of interstratified garnetiferous rock and hornblendic orthoclase gneiss, which may equal half the amount,........	2500
5. Orthoclase gneiss intermediate between the limestone of Great Beaver Lake and Long Lake, and the Grenville limestone on the Rouge at the Iroquois Chute, the lower part having several bands of garnetiferous gneiss and quartzite, and the upper part much coarse grained porphyroid orthoclase gneiss,........	3500
6. Crystalline limestone of Grenville, in some parts interstratified with a band of gneiss. The thickness appears to vary from about 1500 feet to 60 feet, and may be estimated at about	750
7. Orthoclase gneiss between the limestone of Grenville and Proctor's Lake limestone, ...	1580
8. Proctor's Lake limestone, ...	20
9. Orthoclase gneiss passing gradually into anorthosite between Proctor's Lake limestone and the Morin band. This would probably include the quartzite of the Quartz Mountain, the orthoclase gneiss above it, and the gneiss of passage, ...	3400
The nearest geographical approach of the Grenville and Morin limestones that has been ascertained is about two miles; the present estimate of their stratigraphical separation is 5000 feet, which is not perhaps extravagant.	
10. Anorthosite above the Morin band of limestone; the thickness is wholly conjectural, ...	10000
	32750

Anorthosites of the Saguenay and Lake St. John.

How this portion of the series is related to the rocks displayed in other parts of the Laurentian area, is yet unknown. As already stated, a considerable breadth of anorthosite rock occurs at Chateau Richer. This rock has also been met with in the parish of St. Urbain in the seigniory of Beaupré, and it appears to be largely developed on the Saguenay between Chicoutimi and Lake St. John. Its strike there coincides with the bearing of the river, and its breadth extends to the valley of Lake Kinogami. Much of this rock in the immediate vicinity of Lake St. John and in its tributary the Peribonka is of a dark violet-blue color, approaching to black, and is almost entirely made up of a cleavable triclinic feldspar, often having the characters of labradorite. This species takes its name from Labrador, where it was first discovered, and appears to characterize portions of the Laurentian series across the whole breadth of the province to Parry's Island on Lake Huron, where labradorite rock was observed in place by Dr. Bigsby. Anorthosite rocks were observed by Prof. Hind forming a range of hills on the Moisie River, and, from the specimens brought thence by Mr. Cayley, appear to constitute a part of the Seven Islands, where they were long ago remarked by Bayfield; but whether in any or all of these localities the strata are equivalent to the anorthosite rocks of Mille Isles and Rawdon, can for the present be only conjectural.

Labrador.

Lake Huron.

Crystalline limestone is interstratified with orthoclase gneiss at the Falls of St. Féréol on the Ste. Anne (Montmorenci), and at Cape Tourmente. Exposures of the rock are said to continue for fifty miles up the valley of the Rouge above the part examined and described. On the north side of the Ottawa the rock is met with in many places in considerable masses as far as the Deep River, but none of it has been seen between that and Lake Temiscamang. In the rear of Kingston a thick band of it, associated with dolomite, and including orthoclase gneiss, has been traced northward for twenty miles through the townships of Loughborough and Bedford, and partial examinations have been made of exposures of the rock occurring at intervals all the way from Loughborough to Balsam Lake. Between the Ottawa and Lake Huron, crystalline limestone is largely developed on the Mississippi, the Madawaska, and the Bonnechère, but none of it was seen on an exploration up the Muskoko and down the Petewahweh. The garnet-bearing gneiss, however, so frequently found in the vicinity of the limestones, occurred in several parts of the Muskoko; but on the Petewahweh the most conspicuous masses, independent of orthoclase gneiss, consisted of intrusive syenite, which in many parts appeared to be decomposing into a brick-red soil. A band of crystalline limestone crosses the Meganatawan about thirty-five miles from its mouth, and has been traced for about two miles in a northerly bearing. Limestone occurs at the exit of Lake Talon on the Mattawa, and in two places on Lake Nipissing; one in a group of islands at the extreme eastern end of the lake, and the other in Iron

Laurentian limestones in Western Canada.

Island, where the limestone is associated with specular oxyd of iron in considerable quantity, accompanied by fluor spar. On the other hand the Laurentian limestones have been observed by Mr. Blaiklock on the Mistiashini more than 100 miles north of Lake St. John. North of the Mattawa, Lake Nipissing, the French River, and the shore of Lake Huron to Shebahahnahning, the country has not yet yielded any exposures of crystalline limestone, and all its Laurentian rocks appear to be varieties of orthoclase gneiss. At the falls of the Recollet on the French River there occurs an intrusive syenite, weathering to a brick-red earth similar to the rock on the Petewahweh; but the extent of the area which it occupies has not been ascertained.

Area and distribution of the Laurentian system.

The area occupied by the Laurentian series in Canada, as already stated, is supposed to be about 200,000 square miles. Its northern limit has not yet been satisfactorily ascertained, though it is supposed, from Lake Nipissing eastward, to be beyond the boundary of the province. The southern limit is well known: with the exception of a narrow border of Silurian strata on the strait of Belle Isle, another at the mouth of the Mingan River, and a third near the Seven Islands, with the addition of two narrow Silurian strips running a few miles up the Murray Bay River and the Gouffre, the north shore of the St. Lawrence is the southern boundary of this ancient series of deposits from Labrador to Cape Tourmente. The distance is about 600 miles: in the first half the bearing is about west, and in the second about south-west. In the next 200 miles the boundary runs about west-south-west, and is distant from the St. Lawrence about thirty miles in the rear of Montreal. Beyond this for a hundred miles it follows the Ottawa, in a bearing more nearly west, with a narrow strip of Silurian rocks between it and the margin of the river for the chief part of the distance. Turning southward at the upper end of Lac des Chats, it runs in a very irregular line between that lake and the St. Lawrence, which it again reaches at the Thousand Islands, presenting in the interval several points projecting into the Lower Silurian plain to the eastward. From the Thousand Islands the Canadian part of the boundary runs in a pretty straight line a little north of west to Matchedash Bay on Lake Huron, but, as has already been stated, from the Thousand Islands the formation expands into an area of 10,000 square miles in New York, the boundary of which has been given. From Matchedash Bay the east and north shores of Lake Huron complete the southern boundary, which terminates at Shebahahnahning. The western boundary, which is but imperfectly known, runs about north-east from the place last named, and reaches the Wahnapitae River about forty miles north of Lake Huron, from the mouth of the French River. It follows the upward course of the Wahnapitae for about fifteen miles, and continues its north-eastward course to the Sturgeon River, reaching it at its junction with the Maskanongi. From this it gains Lake

Temiscamang, three miles below the united mouths of the Metabechouan and Montreal Rivers, and follows the west side of the lake for fourteen miles; it gains the east side about three miles above the point opposite to those rivers, and follows this side to the head of the lake. How far north it may run from this is not yet ascertained.

Gneiss of Lake Superior.

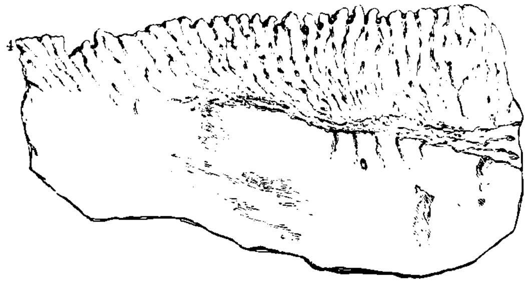
Orthoclase gneiss, resembling that of the Laurentian series, is spread over an area occupying a breadth of about four or five miles on the north shore of Lake Huron, between the Mississagui and Thessalon Rivers. It appears also to come upon a considerable portion of the coast of Lake Superior, giving place there to higher rocks between Gros Cap and Mamainse, at Cape Gargantua, Cape Choyye, and for some distance on each side of the Michipicoten River, as well as for some distance up the stream. Newer rocks run in a narrow strip on the coast a few miles south of Otter Head, and occupy about twenty miles on each side of the bight of Peninsula Bay, as well as about twenty miles up the Pic River. From this the gneiss continues along the coast of the lake to Neepigon Bay, on the north side of which it leaves a narrow border for the overlying strata. Crossing Neepigon River about seven miles above its mouth, the limit of the gneiss runs in a nearly straight line to the lower part of Thunder Bay, leaving to higher strata the peninsula between Neepigon and Black Bays, and between Black and Thunder Bays. From Thunder Bay it strikes into the land a little north of the Kaministiquia River, and keeps on the north side of it as far as Dog Lake, which is as far as the river has been examined.

Supposed fossils in the Laurentian limestones.

Although the Laurentian rocks have hitherto been considered azoic, certain forms strongly resembling fossils were discovered three years since by Mr. John McMullen, then attached to the Geological Survey as an explorer, in one of the bands of limestone belonging to this series at the Grand Calumet. Any organic remains which may have been entombed in these limestones would, if they retained their calcareous character, be almost certainly obliterated by crystallization, and it would only be through the replacement of the original carbonate of lime by a different mineral substance that there would be some chance of the forms being preserved. The specimens obtained from the Grand Calumet present parallel or apparently concentric layers, resembling those of the *Stromatopora rugosa*, except that they anastomose at various points. The layers are composed of crystalline pyroxene, while the interstices are filled with crystalline carbonate of lime. These specimens have called to recollection others which were some years ago obtained from Dr. James Wilson of Perth, and then regarded merely as minerals. They came from loose masses of limestone, in that vicinity, and exhibit similar forms to those of the Calumet composed of dark green concretionary serpentine, while the interstices are filled with crystalline dolomite. If both are to be regarded as the results of unaided mineral arrangement, it would seem strange that identical forms should be derived from minerals of such different composition. If the specimens had been obtained from the altered rocks of the Lower Silurian series, there would have been little hesitation in pronouncing them to be fossils. Their resemblance to *Stromatopora rugosa* from the Birdseye and Black River limestone, where this fossil has been replaced by concretionary

3, 4.—SUPPOSED FOSSIL FROM LAURENTIAN LIMESTONE, GRAND CALUMET.

3.—Weathered surface of a specimen, natural size.



4.—Vertical transverse section of 3.

silica, is very striking. In the specimens from the Calumet the pyroxene and the carbonate of lime being both white, the forms, although weathered into strong relief on the surface, are not perceptible in fresh fractures until the fragments are subjected to the action of an acid, the application of which shews the peculiar structure throughout the mass.

CHAPTER IV.

THE HURONIAN SERIES.

SLATE CONGLOMERATE.—QUARTZITE.—DIORITE.—SECTION ON LAKE HURON.—SLATES OF LAKE SUPERIOR.—ROCKS OF THE THESSALON.—JASPER CONGLOMERATE.—INTRUSIVE GREENSTONE AND GRANITE.—METALLIFEROUS LODES.—DISTRIBUTION OF HURONIAN ROCKS.—THESSALON BASIN AND FAULT.—ROCKS OF THUNDER BAY AND THE KAMINISTIQUIA.—CONTACT OF LAURENTIAN AND HURONIAN ROCKS.

Slate conglomerate, Lake Temiscamang

On Lake Temiscamang the Laurentian orthoclase gneiss is followed by a slate conglomerate. The finer parts of this rock are dark grey, weathering to dark green; they are of a uniform grain, and, being at the same time argillaceous and silicious, they present the characters of a hard compact slate. Some parts not so fine in texture are a hard dark grey sandstone, weathering to a dingy olive-green. In both cases the rock frequently exhibits the character of a compact conglomerate, holding pebbles and boulders, sometimes a foot in diameter, of the subjacent gneiss, from which they appear to be principally derived. The boulders display red orthoclase feldspar, translucent colorless quartz, green hornblende, and brownish-black mica, arranged in parallel layers which have a direction according with the attitude in which the boulders were accidentally enclosed. Some of the pebbles consist of a dark green feldspathic rock shewing no crystallization, not so hard as most of the others, and giving a white streak. Occasionally thick beds are composed of these green pebbles, enclosed in a fine grained matrix of the same description of material. Sometimes the rock has the semblance of porphyry, appearing to contain opaque white crystals of feldspar; but these are probably small angular fragments of the mineral.

In the finer parts of the rock the bedding is sometimes indicated by thin differently colored layers cemented together, without the slightest tendency to cleavage in the bedding. The colors are usually different shades of green, with sometimes the addition of reddish-brown or deep flesh-red and black, giving a very beautiful and regularly striped rock. Another form which the finer parts present is that of a very close grained, compact, dark grey mica slate, cleavable with difficulty in the direction of indistinct lines, and exhibiting on the planes of division, which are not very even, a surface glimmering from the effect of very minute and closely adhering scales of mica. A transverse fracture shews thin interrupted whitish streaks interlocking among one another, and arising from the presence of quartz.

Where there is a cleavage or jointed structure in the rock, the planes of division cut evenly and smoothly through the pebbles of the conglomerate without the slightest deflection; and the pebbles are so thoroughly and intimately united with the matrix, and so similar in hardness, that the blow of a hammer never displaces them, but breaks through them and the matrix as if the rock were perfectly homogeneous. The action of the weather and friction also appear to wear both equally.

In no part where the rock was observed on the lake is there any cleavage of that perfect kind which would render it fit for roofing slates; but specimens said to be obtained about five miles up the Montreal River make it probable that it must have such a cleavage in some parts of its geographical distribution. The thickness of the rock has not been ascertained: with a dip of eight or nine degrees it rises into hills of about 400 feet in height, and its volume is very probably much more than 1000 feet.

To this succeeds a quartzite which appears to be of pretty uniform character throughout the whole mass. It is in general of a pale sea-green or greenish-white, weathering to a light yellowish-brown to a depth seldom exceeding a quarter of an inch from the surface. Sometimes it is brownish-green within, and in a few instances of a light grey with spots of green. It appears to be composed of quartz and feldspar, with occasional scales of silvery mica. This rock is in general moderately fine grained, but coarse grained beds are now and then interstratified, which approach the character of a fine conglomerate, with pebbles of white translucent quartz. It is a strong and solid rock, resisting well the general influences of the weather, and is generally thick-bedded. The total volume seen of the deposit, as determined by the height of hills which it composes in nearly horizontal layers, is between 400 and 500 feet. Quartzite.

On the Sturgeon, Wahnapitae, and Whitefish Rivers, there is usually interposed between the Laurentian gneiss and the recognised Huronian rocks, a mass of rather coarse grained greenstone or diorite; but whether this is an overflow constituting the base of the upper formation, or an eruptive mass in the form of a dyke intruded at a later period, has not been ascertained. The Huronian masses which follow the greenstone are frequently found to be interstratified with igneous rocks of a similar character, which are sometimes seen to cap the hills where the strata below are nearly horizontal; but there are also vertical intrusive masses of greenstone which apparently differ from the intercalated layers only in being generally of a somewhat finer grain. Independent of the greenstones, the members of Diorite.

Section on Lake Huron. the Huronian series on and near the three rivers mentioned, appear to be as follows in ascending order :—

1. Fine grained green silicious strata with thin bands of greenish quartzite interstratified; these appear to be associated with fine grained bluish or black slates, weathering very black, and occasionally with layers of a reddish color. In all these slates copper pyrites and iron pyrites are frequently present.

2. Slate conglomerate, of which the matrix is always greenish in color; sometimes the matrix has a regular slaty structure, while at other times it resembles a massive fine grained diorite; it holds pebbles of whitish and red syenite in great profusion, with occasional masses of green, brown, and red jasper, all rounded in form; toward the base of the conglomerate there appear green slates in very regular laminæ, cleaving with the bedding, and usually cut by two sets of parallel joints, dividing the rock into rhomboidal forms.

3. A band of limestone usually much shattered and disturbed, and in general associated with greenstone; the prevailing color of the limestone when found in mass is a pale whitish-grey, sometimes passing into a dark blue; the band is frequently brecciated, and often displays rough jagged edges, which appear to belong to layers of hornstone; portions of the band appear to be indurated calcareous shale, and these occasionally contain fine grained silicious pebbles.

4. Slate conglomerate resembling that on the other side of the limestone; with this is associated green silicious slate, similar to that already mentioned, with some tolerably strong bands of quartzite towards the top.

5. White and very pale sea-green or greenish-white, close grained quartzite, with beds of quartz conglomerate interstratified, and layers of talco-quartzose slate, sometimes of a dark green color, but more frequently of a pale flesh-red. The pebbles of the conglomerate are chiefly small white opaque rounded masses of quartz, but these are occasionally mixed with rounded masses of red and green jasper.

Slates on Lake Superior. On Lake Superior the Laurentian gneiss is succeeded by slates, generally of a dark green without, and often dark grey in fresh fractures, which at the base appear occasionally to be interstratified with beds of a feldspathic character, of the reddish color belonging to the subjacent gneiss. Sometimes these beds are a combination of feldspar and quartz, occasionally with the addition of hornblende, and in some of the beds the hornblende, preponderating, gives them a general green color. Some of the beds have the character of diorite; others that of mica slate, and a few present that of quartzite. Rising in the series the dark green slates become interstratified with layers, holding a sufficient number of pebbles of different kinds to constitute conglomerates. The pebbles appear to be all derived from altered rocks; they greatly vary in size in different places, and occasionally measure a foot in diameter. Where the slate conglomerates have been worn by the action of the water, the pebbles are generally worn down equally with the rest of the surface; and though a very distinct picture of them is presented on such a surface where the water or weather appears to have had an influence in bringing out a well defined contrast in colors between the pebbles and the slate, at the same time producing a contrast between parallel bands of the slate on the terminal edges of the laminæ, it yet often happens, unless the pebbles are of white quartz, that they are very obscurely distinguishable on fracturing the rock, both the pebbles and the matrix having a grey color, and showing very little apparent difference in mineral character. On some of these pictured surfaces small opaque white feldspathic crystals occasionally spot the whole surface of the rock, the pebbles equally with the slaty matrix. The rock has nowhere on the lake been observed to display true slaty cleavage independent of the bedding; but it often exhibits a jointed structure, and the divisional planes cut through the pebbles without the smallest deflection.

Section of the slates.

A considerable thickness of these conglomerate or pebbly slates is exposed at the mouth of the river Doré, near Gros Cap, about five miles above the mouth of the Michipicoten River. The strike of the rock is very regular, being about east and west, while the dip is very highly inclined, the beds being not more than from ten to fifteen degrees from a vertical attitude; but the slope is for part of the distance to the north and for the remainder to the south; there is not however supposed to be any repetition of the measures, which are here given in descending order:—

	Feet.
Green slate rock, with a few scattered pebbles through some parts of it, becoming in other parts sufficiently abundant to entitle the rock to the appellation of a conglomerate slate: the sedimentary layers are not distinctly marked; the rock has a jointed structure, and the planes of division, which are very even, cut clean through the pebbles without any deflection,...............	40
Green pebbly slate; the edges of the laminæ are better marked than in the preceding mass by different shades of green and grey or black, giving the rock a ribbon-like aspect; the pebbles, which appear to be chiefly gneiss, granite, or syenite, are worn smooth with the rest of the surface; they are more numerous at the top than at the bottom,..........................	300
Green slate rock, with a considerable number of pebbles towards the top, and fewer in the lower part; several hollows are worn at intervals running in the strike, which are covered with sand; the rock is probably softer in those parts, and may be partially talcose,..................................	550
Green pebbly slate, with large and small boulders of the same character as before; some of the boulders may be a foot in diameter; iron pyrites is disseminated in some parts of the mass, ...	170
Measures not seen, being covered by sand,.................................	90
Green slaty conglomerate with large pebbles of igneous or altered rock; the colors of the edges of the slate layers are green, black, and red, and are very distinctly marked,..	15
Green slate rock with many pebbles; the arrangement of the different colors of the thin edges of the laminæ sometimes partially conforming to the pebbles, and running round them, gives to the smooth surface a lignoous aspect, like a planed surface of wood, shewing its fibres and knots, ...	30
Green slate rock with fewer pebbles, ...	40
Green slate rock with scattered large pebbles,...............................	10

	Feet.
Green slate rock of the same character as before, with sometimes a greater and sometimes a smaller number of pebbles, but all shewing some,....	130
Green slate conglomerate, containing a collection of boulders, some of them a foot in diameter, in the same slaty matrix as before, ...	5
Measures concealed by sand,.......................................	30
Green slate rock with many pebbles, some of them six inches in diameter; some of granitic character have a red hue; the edges of the slate laminæ are green, black, and red; many of the pebbles are of the same green as the slate; they appear of various shades of grey when fractured,..	30
Green slate rock containing a larger number of pebbles in the middle than at the top and bottom, ...	30
Measures concealed by the sand, ...	20
Green slate rock of a more pebbly character than before; some of the pebbles are six or eight inches in diameter; the sedimentary layers are finely waved, and the surface of the rock near the water's edge is very much pitted, yielding in some parts to the action of the water more readily than others, ...	30
Green slate rock; the bedding is very even and regular, and well marked by different shades of black and green; the character of the rock appears to be somewhat talcose towards the top, but harder towards the bottom, and when unweathered the laminæ are very difficult to separate, ...	20
Green slate rock of much the same character as before, but perhaps somewhat harder, ...	15
Green slate rock with even and regular bedding, slightly unctuous, and talcoid in several of the divisions; in general however the rock is very hard, and splits with difficulty in the direction of the layers,........................	20
Green slate rock; some parts of it have a few scattered pebbles, which are in general flat or elongated in the direction of the strata; ribbon-like stripes in the direction of the laminæ are very regular, and in some parts the rock splits into rude slates, but on the whole it is very hard and close; some parts are unctuous on the surface; the dip is here S. < 75°, ...	90
Green slate rock with large pebbles and small boulders of granite or gneiss, quartz, and a chert-like stone; the general color gives to the rock a chloritic or epidotic aspect; crystallized epidote appears in some of the cracks of the rock, ...	35
	1700

At the Doré a much larger amount of the slate formation than is here given comes in behind the preceding section: but it was so covered with trees and moss at the time of the examination, that it was found impossible to follow out the details. Towards the lower part it assumes more the character of the gneiss which usually succeeds it, and becomes interstratified with reddish-yellow feldspathic layers; but sufficient data have not yet been ascertained to determine what may be the total thickness of the slate rock in this part, though it must probably attain several thousand feet.

Reddish-yellow feldspathic masses occasionally traverse the slate as they do the gneiss beneath, and it is not quite certain how the similar masses mentioned above as forming layers may be related to them. Though running with these apparent layers, it is possible they may not belong to the sedimentary portion of the rock, and their relation to the strata may be merely accidental. Masses of translucent white quartz varying in thickness from a few inches to several feet are found running both with the strata and transverse to it. These appear more particularly to belong to the slate formation, but they are supposed in both cases to be veins.

In that part of the country on the north shore of Lake Huron which lies between the Mississagui and St. Mary Rivers, where the Huronian series has been more completely examined than elsewhere, the immediate contact of the gneiss with the overlying rocks has not been observed. On the coast line between the Mississagui and Thessalon Rivers, a distance of about twenty-five miles, the gneiss extends from within about four miles of the former to within about the same distance from the latter; but it is very much disturbed by intrusive granite and greenstone, and, although there are great exposures of rock, it is very difficult to make out how the stratified portions are related to one another. The gneiss extends to the vicinity of a small stream about a mile and a half above Les Grandes Sables, and what is supposed to be the lowest Huronian mass of that part occurs about half a mile above the stream. It consists of a grey quartzite which abuts against one mass of gneiss and runs under another, and appears to be much broken by and entangled among the intrusive rock; but judging from a transverse measure in one part, its thickness would not be far from 500 feet. Farther west, after passing an exposure of stratified amygdaloidal trap which would apparently overlie the quartzite, the rocks for about two miles east of the Thessalon appear to consist of green fine-grained chloritic and epidotic slate, alternating with masses that have the aspect of trap, composed of blackish hornblende and greenish-white and reddish feldspar, with a sparing quantity of mica. The slates and trap-like beds alternate in thicknesses varying from two inches to thirty feet, but the thickness of the whole has not been determined, though it probably exceeds 2000 feet.

Rocks of the Thessalon.

Chloritic and epidotic slate.

The masses to the eastward, which overlie the slates, have been examined in some detail, and the sequence and volume of the whole series, including the quartzites and chloritic slates above mentioned, with bands of limestone, chert, and jasper conglomerate, would appear to be as follows in ascending order:—

	Feet.
1. Grey quartzite, thin bedded in some parts; the thickness is very doubtful,..	500
2. Greenish, red-weathering chloritic and epidotic slates, interstratified with trap-like beds; of this mass also the thickness is very doubtful,.........	2000
3. White quartzite, the color sometimes passing into grey; the rock is principally fine grained, but the granular texture is often lost, and great masses of it become vitreous quartzite. The rock on the other hand often becomes coarse grained and assumes the character of a conglomerate from the	

Feet.

presence of pebbles, consisting chiefly of white quartz, varying from the size of duck-shot to that of musket-balls. The beds, which are generally massive, are frequently separated by layers of fine grained greenish-grey silicious slate, and considerable masses of greenstone are frequently intercalated in different parts of the whole thickness,.................... 1000

4. Slate conglomerate, composed of pebbles of gneiss and syenite held in an argillo-arenaceous cement of a grey or more frequently of a greenish color, the latter arising apparently from the presence of chlorite. The pebbles, which are of reddish and grey colors, vary greatly in size, being sometimes no larger than swan-shot, and at others boulders rather than pebbles, measuring upwards of a foot in diameter; the proportions of these also vary much; they sometimes constitute nearly the whole mass of the rock, leaving but few interstices for the matrix, and sometimes on the contrary, they are so sparingly disseminated through considerable masses of the matrix as to leave spaces of several feet between neighboring pebbles, which may be still several inches in diameter; with the pebbles of gneiss and syenite are occasionally associated some of different colored jaspers and others of quartz. The matrix appears to pass on the one hand into a grey quartzite by an increased proportion of the arenaceous grains, and on the other into a thin bedded, dark greenish, fine grained slate, which is sometimes very chloritic. A third form assumed by the matrix is one in which it is scarcely distinguishable from fine grained greenstone. In the slate the stratification is often marked by slight differences of color, in the direction of which it is occasionally cleavable; the bands in other instances are firmly soldered together, but in both cases joints usually prevail, dividing the rock into rhomboidal forms which are sometimes very perfect. Very heavy masses of greenstone are generally interstratified in the rock, which do not seem confined to any one stratigraphical place,....................................... 1280

Limestone. 5. Limestone, usually of a compact texture, but sometimes partially granular; the colors are green, drab, and dark grey, the latter two prevailing. Some beds are occasionally met with of a dull white, with a waxy lustre in fresh fractures; these weather to a yellowish-brown on the exterior, and appear to be dolomitic. The whole band is in general thin bedded, and a diversity of character in the layers, probably arising from the presence of more or less silicious matter, causes the surface of weathered blocks to present a set of bold but minute ribs of various thicknesses, which when the beds are much affected, as they often are by diminutive undulations, contortions, and dislocations, exhibit on a small scale a beautiful representation of almost all the accidents that occur in stratification, affording very excellent ready-made geological models, ... 300

6. Slate conglomerate of the same general character as that beneath the limestone, but the pebbles not so large; it is interstratified with beds of reddish and grey quartzite and layers of fine grained greenish-black and light olive-green silicious slate, some of which yield hones of a very fine description; considerable masses of greenstone are interstratified in various parts of the deposit,.. 3000

7. Red quartzite, interstratified with masses of greenstone; the quartzite is in general granular and of moderately fine texture, but it occasionally becomes a fine conglomerate. The color is sometimes only a light tinge of red and at others a decided red, seemingly derived from minute and thickly disseminated spots or from a diffused tinge of an orange-red, probably due to the presence of iron; but the spots are sometimes of a larger size,

	Feet.
and so arranged as to give to the rock a speckled aspect. The rock is in general thick bedded; some of the beds shew oblique elementary layers, or what is commonly called false bedding, and the surfaces of other beds display well defined ripple-marks; masses of greenstone are interstratified in the deposit, some of them of great thickness, ...	2300
8. Red jasper conglomerates. The rock is sometimes a moderately fine grained white quartzite, often with a vitreous aspect, but it very commonly becomes coarse grained and assumes the character of a conglomerate, the pebbles of which vary from the size of duck-shot to that of grape and canister; these pebbles are almost entirely either of opaque white vitreous quartz or various colored jaspers; some of them are lydian stone, some hornstone, and other varieties, and many of them are banded, shewing their derivation from a more ancient stratified rock. The pebbles are often displayed at the top or bottom or in the middle of fine grained beds; they are sometimes arranged in thick bands, and blood-red jaspers often predominating in a nearly pure white base produce a brilliant, unique, and beautiful rock. Considerable masses of greenstone are intercalated in different parts of the group, ...	2150
9. White quartzite, very frequently of a vitreous aspect; in considerable thicknesses of the rock the bedding appears sometimes to be so completely obliterated, and the whole mass presents so great a uniformity of appearance, that it becomes quite impossible to ascertain the dip or strike, or to distinguish joints from beds, but in other parts massive beds are separated by thin silicious layers resembling chert, and greenstones occur intercalated between different masses of the deposit, ...	2970
10. Yellowish chert in thin and very regular beds, interstratified with layers of green, buff, and grey silicious limestone, and green and pale drab compact silicious slate, with a stratum of red and yellowish fine grained sandstone at the bottom, ...	400
11. White quartzite, frequently of vitreous aspect, and occasionally mottled with lead-grey patches, ...	1500
12. Yellowish chert and impure limestone, similar in its general aspect to the previous chert band, ...	200
13. White quartzite imperfectly examined, ...	400
	18000

Jasper conglomerate.

Chert and limestone.

Stratified greenstone.

The igneous rocks which, as overflows, it will be convenient to consider constituent parts of the stratified series, may be classed as a whole under the denomination of greenstone or diorite. The masses are sometimes very great, and in such cases the rock usually consists of a greenish-white feldspar, and dark green or black hornblende. The feldspar however is sometimes tinged with red, and the diorite then appears to pass into a syenite by the addition of a sparing amount of quartz. These two forms of the diorite are almost always highly crystalline, and in general not very fine grained. Sometimes, however, the greenstone displays a fine texture, and in such cases a large amount of it, more particularly in the lower part of the series, frequently holds much disseminated chlorite, giving a very decided green color. Portions of it are found containing so great a proportion of this mineral as to yield with facility to the knife, affording to the aborigines an excellent material for the manufacture of their *calumets* or tobacco-pipes. In addition to the chlorite, epidote is a prevailing mineral in this description of rock, associated with which an amygdaloid, already alluded to, is in one place seen, some of the cellules of which contain quartz, others calcspar and bitter spar, and some few specular iron. The amygdaloidal trap is very distinctly arranged in layers, which, though they do not exceed two or three in number, give, with beds of porphyritic greenstone containing large crystals of feldspar, occurring near the amygdaloid, a stratified aspect to the whole of the mass of trap associated with them. No such decided appearances of stratification have been met with in the more crystalline greenstones. They usually however display parallel planes of division in several directions, and it frequently happens that some of these parallel planes are only moderately inclined; but there have not been observed on the surfaces or in the character of the rock any distinct evidences of stratification or of successive deposit, and no columnar structure at right angles to any set of planes such as sometimes so clearly marks an overflow. It is therefore in most instances only by a reference to its immediate relation to the sedimentary rocks on each side that the general attitude of any band of the greenstone can be made out.

Amygdaloid.

Intrusive greenstone.

Independent of the overflows, igneous rocks are connected with the formation in intrusive masses. These intrusive masses consist of greenstone and granite. The intrusive greenstones do not seem to differ much in mineral character from those composing the overflows: they constitute dykes which run in so many directions that it is difficult to determine the prevailing ones. These dykes vary in breadth from a few inches to several hundred feet; they cut all the stratified rocks of the series, igneous as well as sedimentary, splitting into branches which often join one another and enclose great fragments and masses of strata. The intrusive granite, in so far as observed, is in general of a decided red color, arising from the presence of a largely preponderating quantity of red feldspar, which is mingled with translucent white quartz: mica is not very abundant, and hornblende sometimes accompanies or replaces it. From large masses of the rock however both these minerals are often wholly absent, but epidote in general forms a constituent, sometimes in great abundance. The intrusive granite occupies a considerable area on the coast of Lake Huron, south of Lake Pakowagaming. It there breaks through and disturbs the gneiss of the Laurentian series, and forms a nucleus from which emanates a complexity of dykes, proceeding to considerable distances. As dykes of a similar character are met with intersecting the rocks of the Huronian series, the nucleus in question is supposed to be of the Huronian age, as well as the greenstone dykes which are intersected by it.

Granite.

The relations of these different intrusive rocks display a succession of events in the history of the Huronian series. There is of course a set of dykes cutting the sedimentary rocks, and giving issue to the greenstone overflows: it is difficult, however, to identify these, but another set of greenstone dykes is seen cutting both the sedimentary and the igneous strata. The intrusive granite, sending forth dykes, intersects the preceding ones, and then another set of greenstone dykes cuts the intrusive granite in its turn. Evidences of disturbance and dislocation accompany all these successive intrusions, those connected with the granite being the most violent. But there is another set of disturbances of still more recent date, and it is to these that are due the metalliferous veins which give to the country its value as a mineral region. Dykes of different ages.

These metalliferous veins intersect all the rocks that have been mentioned. They are probably themselves intersected by veins or cross courses, breaking their regular continuity: but there is evidence that slips or displacements of the country on opposite sides of the veins occurred at the time when the fissures which gave rise to these were formed. Numerous instances occur where granite and greenstone-dykes cut by the metalliferous veins are thrown considerably out of their course, and several examples of this have been observed at the Bruce mines. Metalliferous lodes.

The metal which these veins hold in the greatest quantity is copper, in the forms of vitreous, variegated, and pyritous sulphurets. Iron pyrites is sometimes associated with them, but in general not in large quantities. Copper ore has in one instance been found accompanied by rutile, and in another (at the Wallace mine) associated with an arsenical sulphuret of iron and nickel, containing a trace of cobalt. The gangue or vein stone of the copper ores is in general white quartz; and there is very often present, but not in very great quantity, a white compact yellow-weathering dolomite, which in druses assumes the form of pearl spar; carbonate of lime also appears occasionally in the form of dog-tooth spar. Copper and nickel.

The veins vary in breadth from a few inches to thirty feet; but when of this last great breadth, or even much less, they usually contain a considerable amount of brecciated wall rock mixed up with the gangue. Many of them range from one to three and four feet, and their slope or underlie varies from about fifty to ninety degrees. From such as may be considered master lodes, innumerable branches of various sizes start, some of which visibly diminish before proceeding far, and finally disappear, while others maintain moderate widths with much regularity for considerable distances, and many run to a junction with parallel lodes. On Lake Huron the cracks and dislocations occupied by the main lodes appear to be near to and parallel with the axes of anticlinal and synclinal folds in the stratification, and no doubt were produced when the forces causing the undulations were in operation. Hence these lodes, often for considerable distances, run with the strike of the formation. They are thus in a rude way parallel to one another, and run in directions between west and north-west, more nearly approaching the latter.

Distribution of copper.

The quantity of copper contained in these lodes is very variable, ranging from mere specks of ore in some to large workable amounts in others. In regard to the productiveness of the lodes, it appears probable that it will be different in the different rocks which these may intersect. The underlie of the lodes being in general greater than the dip of the strata, they must pass from one rock to another downwards, and, as the lodes preserve somewhat regular courses, they will also pass from one to another horizontally, from the effects produced in the geographical distribution by denudation, where the strata, folding on anticlinal and synclinal axes, present local transverse depressions or elevations. As far as observations have extended, it appears that the copper is most abundant in the greenstone, least so in the sandstone or quartzite, and more plentiful in the slate when this is free from pebbles than when it becomes a conglomerate. In the quartzite rock the white quartz veins often appear nearly destitute of ore, presenting but a few specks of the yellow sulphuret of copper at intervals, and, when a vein holding much ore in the greenstone can be traced to the quartzite, it seems gradually to lose its richness, and finally presents little else than vein-stone, its breadth remaining undiminished. How the productiveness of the metalliferous veins may be affected when they meet with any considerable body of the intrusive granite has not been ascertained, since none of them have been observed cutting the granite nuclei, and, though they have been found intersecting the granite dykes, these are too narrow to produce any perceptible change in the quantity or nature of the ore.

In the Huronian country there is scarcely any considerable area wholly destitute of cupriferous veins. Instances of these are known to occur at the most southern part of the lower lakes of the Maskinongi, a tributary of the Sturgeon River, at the Wallace mine near the mouth of the White Fish River, where a crop trial has been made on a vein holding both copper and nickel, at the mouth of the Spanish River, and in several parts of the Mississagui. Crop trials have been made of lodes on Root River and Garden River, and various places on and near Echo Lake, but the most important lodes which have been tested are those of the Keating and Cuthbertson locations at the Wellington and Bruce mines. From these latter locations large quantities of ore have been obtained and exported. The lodes here are near the axis of an anticlinal in the strata, and run with the strike towards the north-west.

The Huronian rocks are not known to extend farther to the eastward than the line between Lake Temiscamang and Shebahahnahning, which has already been given in describing the boundary of the Laurentian series.

How far the Huronian series may spread continuously westward from the north part of that line has not yet been ascertained. On Lake Huron the rocks of this series occupy the coast from Shebahahnahning to the mouth of the Mississagui River: and in the valley of the Spanish River they appear to have a breadth northward from Lacloche of about ten miles. The rock which there limits them on the north is probably a part of the Laurentian gneiss, though it has been found difficult to distinguish the gneiss in that part from an intrusive granite. Distribution of Huronian rocks.

The distribution of the series between the Mississagui and St. Mary Rivers is represented on the accompanying map, which is illustrated by a vertical section on a line running northward from St. Joseph Island, through Thessalon Lake, to a distance of about fifteen miles from the shore of Lake Huron. From these it will be perceived that in the area in question the various masses which have been described as constituting the series are arranged in the form of a trough, extending transversely from the lower part of Echo River above Echo Lake to some point beneath the unconformable fossiliferous rocks to the south-west. The longitudinal axis extends along the valley of the Thessalon from a rapid between five and six miles above its mouth to the south-west side of Thessalon Lake, and proceeds thence towards St. Mary River, between Little and Great St. George Lakes. The main trough is divided into three subordinate and nearly parallel troughs by two anticlinal forms. The axis of one of them passes a little south of Echo Lake, but the form appears gradually to die away towards the south-east. The axis of the other anticlinal passes through the Bruce mines, and proceeding westerly gradually bears rather more westward than the axis of the main synclinal, the course of which is about N. 30° W. Map and section. Thessalon trough.

It will be perceived that the strata on the opposite sides of the axis in their eastward strike converge, but that the equivalent members of the series, instead of meeting on the axis, are carried past one another in such a manner that the base of the chert and limestone band (10) on the northward side comes against the middle of the upper slate conglomerate (6) on the southward side, while the base of the same limestone band (10) on the southward side is brought against the upper part of the white quartzite (11) on the northward. This part of the white quartzite (11) is not far from 1500 feet over the base of the limestone band (10), and there must consequently be a downthrow equal to this on the north side of the axis at that part. But between the base of the chert and limestone band (10) and the middle of the upper slate conglomerate (6) there is a thickness of rock equal to upwards of 9000 feet, so that the downthrow must gradually increase to that extent in going nine miles to the eastward. Great dislocation.

From the position where this great fault leaves the Thessalon, about six miles above the mouth of the river, it appears to lose a portion of its southing in its progress eastward, and to come upon the most southern part of Lake Wabiquekobingsing, where the lower limestone band (5) on the north side is brought against what is considered to be Laurentian gneiss. The course of the dislocation thence again turns more south, and farther on it reaches the south-eastern part of Lake Pakowagaming, having gneiss on the south, and the lower slate conglomerate (4) on the north side all the way between the lakes. Its farther progress has not yet been determined.

If the same law applies to the fault to the westward of Lake Thessalon as to the eastward, the downthrow on the northward side of it, after passing a zero point, should change into an upthrow farther on. Near Root River, in a position where we might expect the great fault, we find the limestone band (5) with the slate conglomerates (4 and 6) on the south, and the gneiss of Gros Cap on the north, in such a relation as would answer these conditions; but the dislocation in the intermediate parts being comparatively small, its effect has not yet been completely traced out.

On the line of section the dips of the strata vary in inclination from eighteen to forty-five degrees; but more to the eastward they gradually diminish, and to the east and north of Lake Wahbiquekobing and Lake Pakowagaming the attitude of the strata approaches the horizontal, the slope being seldom over six degrees, and often not over two. The lower slate conglomerate and its associated masses of greenstone are in consequence spread over a very considerable area in that part, and pass beyond the Mississagui. On the opposite sides of this river, however, for some distance up, the dips, though small, are in opposite directions, and prove the existence of a flat anticlinal arch, the axis of which is coincident with the river for eighteen miles, from a point about six miles up from the mouth of the river to an elbow below the junction of the Little White River. Beyond this its course continues to the north-westward.

Mississagui anticlinal.

This anticlinal form limits the Thessalon trough on the north-east side, and the parts examined beyond it are chiefly confined to the banks of the Mississagui. For fourteen or fifteen miles above the mouth of the Little White River, the rocks appear to belong to the lower slate conglomerate and the greenstones associated with it; and beyond this as far as the river has been surveyed, the rock is either gneiss or syenite, with the exception of two miles of slate conglomerate, which occur on the east bank about four miles above the position where the upward course of the stream changes from north-westward to eastward of north. On the Little White River, about five miles up from the mouth, the lower band of limestone (5) makes its appearance. It has been traced about two miles south, and it here most probably constitutes a part of the western outcrop of a trough which underlies an area to the eastward, around which it has yet to be traced.

From the Thessalon westward the southern limit of the Huronian rocks embraces the coast and all the islands immediately near, including the Palladeau group; it takes in, however, only the northern extremity of the largest island, not very far south of the group; and from it crosses to St. Joseph Island, where it includes the promontory which is south of the Island of Campment d'Ours, as well as a portion of the north side of the northwestern extremity of St. Joseph Island. It includes a narrow strip on Sugar Island, at the exit of Great Lake George, and, from a point about half-way up the eastern side of this lake, leaves a margin bearing higher rocks on the east and north sides of the lake, as well as upon the north side of St. Mary River and Little Lake George. This margin appears to project a short distance beyond the average width up the valley of Echo River and that of Garden River; and above Little Lake George it cuts off the Huronian rocks and comes against the Laurentian gneiss, which runs out into the promontory of Gros Cap.

Huronian series on Lake Superior.

On Lake Superior, Huronian slate conglomerates and jasper conglomerates occupy a position between Goulais River and Batchehwahnung Bay, intersected near the latter place by a great east and west syenitic dyke. Farther north, rocks of the series are spread over what appears to be a triangular area, extending along the shore from eight to nine miles on each side of Michipicoten River, at the mouth, and about the same distance up the stream. A little farther west it presents a very narrow strip running about twelve miles along the coast, and another one of eight miles about five miles south from Otter Head.

Thunder Bay.

Another locality in which these rocks have been observed in Canada is Thunder Bay, where they occupy the coast for a distance of ten miles immediately below the mouth of the Kaministiquia River on the north side, leaning in a narrow strip against the gneiss of the lower series. It is not improbable that they may present a narrow belt in the valley of the Kaministiquia. They occupy the coast for about seven miles on each side of the New Pic River, while an interval from this to a point two miles beyond the Old Pic River, including the coast of Peninsula Bay and Harbor and Pic Island, is composed of trap. Beyond this the chloritic slates occupy about fifteen miles of the coast, extending to the neighborhood of the deep cove which receives the Pike River. It appears probable that the slates thus flanking the trap on either hand may be the sides of a trough converging to a point inland, the distance of which from the coast has not been ascertained. The Slate Islands are nearly on the strike of the northwestern side of the trough, and they may probably derive their name from being composed of slate rock;—but the islands have yet to be examined.

Kaministiquia River.

The upper part of the Kaministiquia River, between its sources and Dog Lake, for the greater part of the distance passes through a vast swamp, which is bounded on each side by low granitic ridges, probably belonging to the Laurentian gneiss. The country around Dog Lake is of a mountainous character, thickly covered with forests, chiefly of evergreens, and among them are red and white pine. White and yellow birch are abundant, some of them of large dimensions; and it is chiefly from the neighborhood of Dog Lake that the Hudson's Bay Company at Fort William are supplied by the Indians with birch bark for the manufacture of their canoes.

The water of this lake, of which the surface is probably about 1100 feet above the level of the sea, escapes through a deep narrow gorge, and is precipitated over a succession of heavy falls, amounting altogether to probably upwards of 200 feet, and occasioning the Great Dog Portage, extending a mile and a half across a narrow neck of elevated land. Between the Great Dog Portage and the Grand Falls the river flows over a series of steps, each of them causing falls or strong rapids, with long stretches of still water in the intervals, and six of them occasioning both to upward and downward voyageurs, portages which vary in distance from a few yards to more than a mile. The total fall in the distance is probably 200 feet.

Contact of Laurentian and Huronian rocks.

In the upward navigation of the river the first development of the Laurentian series occurs at the second portage, about half a mile above the Grand Falls. At the lower end of the portage, where the series makes its appearance, the rock resembles a massive syenite, in some parts red and in others whitish, but is probably a hornblendic gneiss in which the lamellar arrangement of the constituent minerals is obscure, as the rock gradually passes into such a gneiss. Resting on it conformably there occurs a series of dark greenish-blue or greenish-black slates, the one rock passing almost imperceptibly into the other. The section occupies upwards of a quarter of a mile on the river bank, and at the upper end of it, as well as at the head of the portage, the dip is N. 54° E. Parallel joints are observed to cut the rocks, the directions of the two main sets being S. 41° E. and S. 13° E. Numerous strong veins of white quartz intersect the slates, sometimes occupying the joints, and the whole formation, both in the strata and in the veins, is highly charged with iron pyrites.

At each rapid part of the river above the Grand Falls there is a greater or less development of these rocks, most frequently presenting the more distinctly stratified part of the gneiss. The best exposure of the slates is at the Three Discharges, about four miles above the Grand Falls, where the rocks are observed to pass from the gneiss to the slate. The slates have a horizontal breadth at right angles to the stratification of upwards of thirty-seven chains, with a dip N. 42° W. $< 68°$ without any apparent irregularities. This would give a vertical thickness of about 2300 feet. Towards the bottom, near the junction with the gneiss, the slates are of a bluish and occasionally of a brownish color. They are intersected by numerous parallel joints, which divide the mass into rhomboidal forms of singular regularity. The middle and upper portions of the section are usually of a pistachio-green resembling the green of epidote, and frequently in part present a jaspery character. They are hard and compact, usually with a conchoidal but sometimes with a splintery fracture. The divisional planes are frequently covered with mica, and in such cases the rock may almost be termed a mica slate. The whole of the beds are charged with iron pyrites, and numerous veins of white quartz intersect them. Imbedded in the slates are sometimes observed masses of various irregular shapes, very rudely spherical, and along the basset edges of the strata numerous pot-holes are worn, some of which are not less than four yards in diameter.

Above this section and in continuation of it, the same rocks are still exposed upon the banks, but in a more disturbed condition. Their color is mostly pistachio-green, with occasional red shades running through it, and iron pyrites is met with in almost every part of them. As far as Dog Lake, the rocks, wherever they were seen, resembled in character those which have been above described. About two miles above the Three Discharges some very large boulders of a conglomerate character are met with, containing blood-red jasper pebbles, and balls of iron pyrites in a dark brownish or blackish matrix, having much of the trappean aspect belonging to some of the varieties of the slate conglomerate. Though nowhere seen in place in this neighborhood, it appears probable that this slate conglomerate may be a member or an immediate sequent of the slates above described. The boulders rest upon these slates, and their form and size indicate that they have not been far removed from the parent rock.

Azoic rocks of the North and West.

In several parts of this continent crystalline stratified rocks are met with, probably of Laurentian or Huronian age. Dr. Bigsby, in 1824, described an extensive tract of gneissoid rocks in Rainy Lake and Lake Lacroix, north of Lake Superior, having a general direction from N.W. to N. by W., and dipping eastwardly. This gneiss was associated with micaceous schists containing staurotide, beds of hornblende, chloritic slates with octahedral iron, greenstone slates and syenite. Porphyritic granite with beryl also occurs in the region. These gneissoid strata form part of the great range of Laurentian rocks which have been traced from Canada to the Arctic sea. They have been farther described by Dr. Dale Owen in the region west of Lake Superior, where they are found upon the Mississippi, Chippewa, and St. Croix Rivers. Mica slates with staurotide are here associated with quartzite, gneiss, hornblendic and syenitic rocks, greenstones and granites, and are overlaid by sandstones of the Potsdam group. Still farther west, in Kanzas and Nebraska, according to Hayden, the Black Hills and the Laramie range consist of reddish porphyritic granite, surrounded by nearly vertical strata of gneiss, micaceous, talcose, and hornblendic schists, with quartzites and clay slates. Upon these, at the base of the Black Hills, repose fossiliferous beds of the Potsdam group.

Missouri. Again, in Missouri, we have ancient crystalline rocks, consisting, according to Mr. Swallow, of ranges of porphyry with syenite, silicious and argillaceous slates, and what appear to be altered conglomerates. With these are associated great masses of specular and magnetic iron ores, sometimes schistose, constituting the famous Iron Mountain and the Pilot Knob. Arkansas. In Arkansas also occur crystalline strata, consisting, according to Engelman, of talcose, hornblendic, and silicious slates, often highly inclined, and associated with beds of dark blue limestone, and at Magnet Cove with iron ores and many fine crystallized minerals, among which are epidote, garnet, mica, brookite (arkansite), schorlomite, and elæolite. These rocks, according to Engelman, probably extend into Texas.

Farther investigation will be necessary to determine how far these ancient strata belong to the Laurentian system, and how far they are of the age of the Huronian series. Both of these groups contain iron ore; for while the great ore beds in Canada, and on Lake Champlain, are Laurentian, those of Marquette in northern Michigan, like that of the Wallace mine in Canada, appear to be included in the Huronian series.

Newfoundland. In Newfoundland, Mr. Jukes has described wide areas of crystalline azoic rocks. These are probably for the most part the equivalents of those of south-eastern Canada, which will be shown in a subsequent portion of this work to be altered palæozoic strata. At Indian Head and at York Harbor on the western coast, however, he observed dark-colored rocks made up of labradorite and hypersthene, and of albite and hypersthene, which resemble the anorthosites of the Laurentian system. We have already stated that the Seven Islands are composed of anorthisite; and it may here be noticed, that, according to Bayfield, the same rock, with a base of labradorite, forms the coast for several miles, towards Mingan.

CHAPTER V.

UPPER COPPER-BEARING ROCKS OF LAKE SUPERIOR.

Rocks newer than the Huronian series; divided into two groups.—Lower group on the Kaministiquia.—Beds of trap.—Upper group; its sandstones, limestones, and amygdaloids, with native copper.—Wrinkled surface of trappean beds.—Intrusive rocks; intersection of dykes.—Metalliferous veins of the two groups.—Copper and silver.—Distribution of the Lower group; of the Upper group.—Battle Islands.—Isle Royal.—Michipicoten Island.—Mamainse.—Sandstones of Sault Ste. Marie and Sugar Island; of Campment d'Ours; its subjacent Huronian rocks and overlying limestones.—Lacloche sandstones.—Age of this series of rocks; probably Lower Silurian.

The Huronian formation on Lake Superior is unconformably overlaid by a second series of copper-bearing rocks, which may be conveniently divided into two groups. Of these the lower consists of bluish slates or shales, interstratified with sandstones and beds of columnar trap, and the upper, of a succession of sandstones, limestones, indurated marls and conglomerates, also interstratified with trap, which is often amygdaloidal.

Lower Group.

The base of this formation, where seen in Thunder Bay in contact with the subjacent green slates or slate conglomerates, presents conglomerate beds, probably of no great thickness, composed chiefly of quartz pebbles, with a few of red jasper and some of greenish chloritic slate, in a greenish arenaceous matrix, consisting of the same materials in a finer condition. These are followed by a set of very regular even layers of chert, sometimes approaching a chalcedony, varying in color from nearly white, through different shades of grey to black, and in thickness from less than half an inch to six inches and even a foot. These are separated from one another by thin layers of dark grey dolomite, weathering rusty-red, and present a striking ribbon-like appearance. Occasionally thicker beds of dolomite occur, sometimes highly crystalline, separating aggregated bands of the ribbon-like strata; and these dolomitic beds, as well as the chert bands, are sometimes interstratified with argillaceous layers.

Thunder Bay: bluish slates.

Chert beds.

Carbonaceous matter.

In the vicinity of disturbed parts the chert sometimes passes into chalcedony and agate, and small cracks are filled with what appears to be anthracite. Some of the chert bands appear to be made up of a multitude of minute, irregular, closely aggregated sub-globular bodies, floating as it were in the silicious matrix. Anthracite seems to be present in the centre of some of these, leading to the supposition that the color of the black chert, even where these shapes are not detected, may be owing to the presence of carbon. In some parts of these oolitic chert layers, small blood-red jaspery spots occasionally become interstratified with the black; and in pebbles scattered along the shores of Thunder Bay, probably derived from such beds, the red spots become so numerous as to produce a finely mottled or spotted jasper, in which the spots are crowded together, but do not run into one another. In some instances these oolitic layers exhibit small rounded grains of argillite in a matrix of crystalline quartz.

Sandstones.

Higher in the formation, argillaceous slates become interstratified with argillaceous sandstones in such an altered condition that it is often difficult at first sight to say whether the latter may not be trap layers. The sandstones are sometimes slightly micaceous, and they are rather lighter in color than the slates or shales; and while the slates sometimes exhibit the structure called *cone in cone*, the harder bands display spherical concretions varying from a few inches to two and even six feet in diameter. In some parts of the vertical thickness calcareous layers are occasionally interstratified among the slates, but few of them are pure enough to be entitled to the appellation of limestone. Iron pyrites occurs disseminated in the deposit, and frequently characterises the cherty portion of it, where it is sometimes present in nodules, and in thin, interrupted layers.

Kaministiquia.

On the Kaministiquia the lowest part of this formation observed occurs near the Grand Falls. Its immediate junction with the rock on which it reposes is concealed from view, but appears to be indicated by the position of a small lake or pond occurring just below the second portage, and of the marshy ravines which run from it in the direction of the strike on each side. The argillaceous slates visibly reach to within a short distance of the pond, (probably brought into place against the Laurentian gneiss by a dislocation,) and keep the river for a quarter of a mile to the Grand Falls, where the strata are seen to slope to the south-east at a very small angle. It is probable that the river flows on the formation all the way from this point to its mouth.

Shales and limestones.

The general color of the rock is here black, weathering to a rusty-brown. Some of the beds being soft and shaly, are easily decomposed by atmospheric influences, while the mass is for the most part a hard argillaceous slate. The whole formation appears to be more or less calcareous, and among the lower members thin beds of magnesian limestone occur, sometimes alternating with thin beds of black chert, and sometimes holding irregularly disseminated black chert nodules. Connected with the chert beds, a black mineral resembling anthracite is frequently seen filling up small cracks, and small jaspery veins are often connected with the rock. Spheroidal concretions of singular uniformity, and sometimes of large size, are disseminated through all that part of the formation over which the river passes, and they are more conspicuously displayed among the more shaly portions of the rock. A little above the lowest rapids there is a great accumulation of these concretions, which have been known to the fur-traders for many years under the title of the Devil's Pots. Some of these are six feet in diameter, with a thickness of two feet, and they are found of all sizes down to that of a pigeon's egg. They are usually more convex on the top than on the bottom, bearing a strong resemblance to the stones used in the game of curling. The lines of lamination are distinctly visible in these concretions; and in some instances, when not removed from the parent bed, the lines could be traced from the concretion to the partially enclosing rock. They are always highly charged with iron pyrites, and their weight, when they are even moderate in size, is in consequence great.

The rock is strongly marked by a jointed structure of a very symmetrical character, dividing the thinly laminated slates into rhomboidal forms of great regularity. At the Grand Falls the direction of the principal joints is S. E. and W. S. W. The height of the Grand Falls from smooth water below to smooth water above is about 119 feet. The rock is wholly of these slates; but the thickness here displayed is only a small part of the total volume of the formation, and belongs to the lower part.

Beds of columnar trap.

In Thunder Bay and on the coast above it, trap bands, conformable with the stratification, are interstratified in several parts of the formation; but they occur in greatest thickness towards the bottom, not far above the chert beds, and at the summit overlying the whole of the mass. This trap has a distinct crystalline texture, and has been in no instance observed to be of an amygdaloidal character. It appears to be composed of black hornblende and greenish-white feldspar of a corneous aspect, which frequently occurs in large crystals, giving the rock a porphyritic character. Magnetic oxyd of iron in minute grains is generally a constituent part of the rock, and seems occasionally to compose several hundredths of it, while quartz in small quantity is often present. The only imbedded accidental minerals met with in it are crystalline prehnite accompanied by calcareous spar, occurring in the beds overlying the chert, and iron pyrites, which is seldom wholly absent from any considerable mass of the rock.

In all cases the trap presents a very striking sub-columnar structure at right angles to the plane of the stratification, and the crowning overflow gives a peculiar aspect to the whole region occupied by the formation to which it belongs. The overflow is from 200 to 300 feet thick, and the whole of the associated rocks, to the base of the formation, may possess a volume of between 1500 and 2000 feet. Where the formation comes on the lake it usually presents bold cliffs, sometimes attaining the height of 1000 and even 1300 feet, in which the upper part, occupied by the trap, exhibits a vertical columnar face, from the base of which the slates, mingled with fallen fragments of trap, form a talus sloping down to the water's edge at an angle of about forty-five degrees.

UPPER GROUP.

White sandstones. Reposing on the formation which has just been described, the first rock met with in Thunder Bay, where the best development of the lower part of the succeeding group occurs, is a white sandstone. The strata are in general of a fine grit, and appear to be composed almost entirely of minute grains of quartz in some parts, and in others small rounded grains of a calcareous character are sparingly intermingled with them. Some beds are coarser than others, and in these rounded pebbles of quartz and occasionally of jasper are seen, seldom exceeding the size of buck-shot. Of these white grits there may be a thickness of about 200 feet.

Conglomerates. They are followed by sandstones, consisting of red and white layers interstratified with one another, and associated with conglomerate beds composed chiefly of pebbles and boulders of coarse red jasper, held in white, reddish, or greenish sand as a matrix. As we ascend in this part of the deposit, the beds appear to hold rather more calcareous matter than those below, and some of the conglomerates enclose patches of limestone with fragments of chert. It is difficult to estimate the thickness of these beds from the difficulty of truly determining the rate of dip, but it appears that at a very moderate computation they cannot be less than 500 feet.

Limestones and marls. These beds are succeeded by limestones of a reddish-white color, and very compact texture (some of which would yield very good material for burning into quick-lime), interstratified with calcareo-argillaceous shales and reddish-white sandstones, the whole giving probably not under eighty feet, with an additional fifty feet of reddish indurated marl at the top.

Succeeding these calcareous strata, after an interval of uncertain breadth, not improbably filled with an additional quantity of the indurated marl, red and white sandstones occur, with conglomerate layers. The red sandstones are often very argillaceous; they are usually variegated with green spots, and ripple-marks and crack-casts are displayed on the surfaces of many beds. The sandstones and conglomerates become interstratified with trap layers, and an enormous amount of trappean overflow crowns the formation.

There appears to be some variation in the thickness of this overflow in different parts of its distribution, as well as some diversity in the arrangement in regard to the interstratification of conglomerate layers. But sections examined in places widely asunder would not make the total volume fall far short of from 6000 to 10000 feet. The trap is in general of an amygdaloidal character, less so at the bottom than higher up, while at the top, in addition to the amygdaloid, there are met with intrusive masses of a more solid and more highly crystalline character. These appear in general to consist of greenstone, sometimes passing into well marked columnar basalt, and they are associated with other masses of a vitreous aspect, exhibiting the forms of pitchstone and pitchstone porphyry.

Stratified and intrusive traps.

The stratification of the amygdaloidal layers is usually well marked, and they do not in general appear to be individually so thick as the more solid and crystalline beds. The rock, independent of the minerals filling the cavities, has an earthy aspect in fresh fractures, but is probably a greenstone. The minerals filling the cavities usually consist of calcspar, quartz in various forms, agate being abundant, together with prehnite, epidote, native copper, specular iron, and various zeolites: those observed are red and white heulandite, stilbite, mesolite, laumontite, and analcime. A chlorite-like mineral often occurs lining the walls of the cells. The epidote and mesolite are met with associated with quartz and frequently with specular iron, in the cells of the amygdaloid of Mamainse, the epidote being occasionally superimposed on the mesolite, and in one instance perfect but minute dodecahedrons of cinnamon-stone garnet were observed resting amidst crystals of the epidote. The cavities are of various sizes and shapes: some containing agate, are six or eight inches in diameter, and others, of very irregular branching forms, are filled with masses of native copper, sometimes weighing so much as eight or ten pounds. Portions of native copper varying from the weight just given to grains no heavier than snipe-shot, and abundantly disseminated through thicknesses of one or more feet, occasionally keep the same stratigraphical place for considerable distances, and constitute workable copper beds. Instances are occasionally met with where the cavities, generally filled with calcspar, present the shape of irregular vertical tubes of about a quarter of an inch in diameter, running up into a bed for several inches, sometimes as many as twelve. Near the base of the bed the tubes often approach to within half an inch of one another; but higher up two of them often join in one, and this may unite with another which comes up singly from the bottom, or is perhaps the result of the combination of other two or more, and so on. The combined tubes appear to be a little larger than the original separate ones. None of the tubes were seen to divaricate upwards.

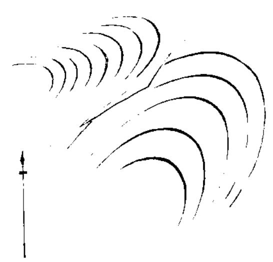
Amygdaloids, zeolites, native copper, &c.

On the surface of some of the beds partially concentric wrinkles, resulting from the flow of the volcanic matter when in a viscid condition, are strongly marked. In one instance (5), on the east side of St. Ignace Island, the courses indicated are N. 65° E. and N. 45° E., in two forms

Wrinkles on beds of trap.

which inosculate on the same surface; and on another and lower surface near the same place the direction of a third form is S. 65° E. From the several directions, the parallelism of the separate beds, and the character of the wrinkles, it appears probable that the general surface on which the volcanic flow occurred was not far removed from horizontality. Another instance was met with on the east side of the lake, where the direction of

5.—WRINKLES ON A BED OF TRAP, ST. IGNACE ISLAND. SCALE ABOUT $\frac{1}{20}$.



the flow indicated by the lines is about east, which is exactly contrary to the dip of the highly inclined surface presenting it.

Though the last two described rocks, and indeed the whole series of stratified deposits down to the gneiss, are all along the coast traversed by a vast collection of dykes, yet in no instance have any of the overlying or interstratified igneous masses been shown to have a direct connection with these. There is often however a great similarity in the characters of the dykes and some parts of the stratified traps, but these resemblances are not always confined to the dykes and beds that are near to one another; and in some cases, while the dyke is found cutting one series of beds, the stratified trap most resembling it is met with at a distance in another series.

Columnar dykes.

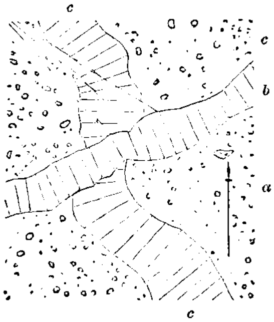
The dykes may be ranged under the heads of greenstone, porphyry, and syenite; but those of a porphyritic and syenitic character bear but an insignificant proportion to the greenstone dykes, to which, in part at least, the others are closely allied. The trap of the greenstone dykes is in general more or less fine grained, often approaching to compact, and its usual constituents are black hornblende and greenish-white feldspar, with in most cases a greater or smaller quantity of magnetic oxyd of iron and a small amount of iron pyrites irregularly disseminated. One of the porphyries contains large crystals of feldspar disseminated through a base of greenstone, the crystals often being spotted with small specks of hornblende. Another of the porphyritic traps partakes of the character of a syenite. In this a dark grey mixture of hornblende and feldspar, with magnetic oxyd of iron and iron pyrites, similar to the greenstone already mentioned, incloses a multitude of irregular patches composed of red feldspar and of quartz, generally hyaline, and rarely of an opaque white resembling chalcedony. The quartz is also occasionally disseminated throughout the matrix without the red feldspar. More rarely red feldspar occurs without the quartz, and still more rarely small quantities of calcareous spar are met with. The whole mass of the dyke however sometimes passes into a uniform small grained mixture of red feldspar and green hornblende with very little quartz, and ceases to have either a porphyritic or syenitic aspect. A third variety of porphyritic trap, constituting some of the dykes, consists of a very fine grained mixture of red feldspar and quartz, holding distinct and not very large crystals of the same minerals; the quartz crystals being colorless transparent hexagonal prisms, terminated by a pyramid at each extremity, and rather uniformly disseminated through the mass. No dyke of an amygdaloidal character has been observed.

The greenstone dykes, whether porphyritic or not, possess, without a single observed exception, a well marked transverse columnar structure, which is in general so truly at right angles to the plane of the dykes, that their underlie can be correctly determined by it. This structure belongs equally to them, whether their dimensions are great or small; but the size of the columns increases with the breadth of the dyke, which sometimes attains 200 feet. The number of these dykes is very great: thirteen of them, of good size, have been counted in the width of two miles, and their parallelism for great distances is as remarkable as their number.

The directions of the greenstone dykes, as well as those of the other

6.—INTERSECTION OF GREENSTONE DYKES, ST. IGNACE ISLAND. SCALE ABOUT $\frac{1}{70}$.

6



a, a, a, Amygdaloidal trap. *b, b,* Dyke running with the stratification.
c, c, Dyke transverse to the stratification.

descriptions which have been mentioned, are in general two, one with the stratification and the other transverse, changing with any important change in the general strike; and they appear to maintain what might be considered a continuation of these courses into the older sedimentary rocks, with a less precise relation to their strike where stratified. The point of intersection of the two sets of dykes has been seldom seen. In one instance, however, (6,) on the island of St. Ignace, a dyke of eighteen inches, coincident with the stratification, cuts another of nearly the same breadth running transversely. Both of these possess a columnar structure, which has not been observed in the dykes of syenitic trap.

The dykes in general appear to be more durable than the rocks cut by them, from which results a peculiarity in the geographical features of the country. The destructive action of the water upon the coast is partially arrested in its progress upon meeting with the dykes, and those which run with the strike are in consequence often found to shield the shore for considerable distances. They sometimes run out into long prongs or promontories, with deep recesses behind them, or present a succession of long narrow islands, which act as breakwaters in defending the neighboring mainland; and it frequently happens that a narrow breach having been effected in a dyke, it will be found to be the entrance to a spacious cove worn out on each side in the softer rock behind it. In almost all these instances commodious harbors are the result, and it is mainly owing to the presence of these dykes that so many such harbors exist on the Canadian side of Lake Superior.

Metalliferous lodes.

In addition to the dykes, a great many mineral veins intersect these rocks. A very large number of these contain a greater or smaller amount of various metalliferous ores: and the indications which they present are such as to render it certain that many parts of the country characterised by them, will, sooner or later, rise into importance as a mining region. The metals whose ores are met with are copper, lead, zinc, and silver, with more rarely nickel, cobalt, arsenic, uranium, and molybdenum.

As in the case of the dykes, the mineral veins belong to two systems,—one coincident with the range of the rock masses, and the other transverse to it. They are therefore parallel to the dykes. The cracks which the veins occupy appear however to be of an age subsequent to that of the dykes. and they sometimes run alongside of them, having the dyke for one wall and the rock of the country for the other, while at other times they are wholly independent of the dykes. As far as the investigations of the Survey have gone, the transverse veins appear to cut those coincident with the range of the rock, where the strike runs about south-west and north-east, and from that to about west and east; but on the east side of Lake Superior, where the strata dip to the west or a little south of it, a sufficient number of facts has not been ascertained to establish a rule with regard to the intersection of the mineral veins. The displacements connected with the transverse or northward and southward veins appear to be greater in amount than those related to the eastward and westward veins; but it is not so certain that the dislocations connected with the dykes follow the same rule. Some very important disturbances have been observed in connection with those veins which are coincident with the strike of the stratification.

Vein-stones of the upper group.

In respect to the mineral contents of the veins, some differences exist in the different parts of the series. In the upper group, which is so much associated with amygdaloidal trap, the mineral veins vary in breadth from a few inches to four or five feet. They are in general composed of calcareous spar and quartz, holding in greater or smaller quantities entangled fragments of the wall-rocks, and dark green saponite is seldom absent. Laumontite is very often abundantly present with these minerals, and sometimes exceeds them in quantity. Associated with the veinstones, fluor spar occurs occasionally. Heavy spar is not unfrequently met with; and in some districts the latter occasionally forms the chief earthy mineral in transverse or north and south veins. Prehnite, thomsonite, analcime, and apophyllite are frequently present, chiefly in east and west veins; and wollastonite, orthoclase, and datholite are to be enumerated among the minerals that occur. Some of the veins, both with the strike and transverse to it, are almost entirely composed of chalcedony and agate, where the rock of the country is allied to pitchstone or to pitchstone porphyry; but these are seldom found to hold metalliferous minerals.

Copper and silver.

When metals are present in the mineral veins, they occur chiefly in the form of sulphurets, with the exception of the silver, which appears to be usually in the native state, even when mixed up with the ores of other metals, unless in the case of galena, where it is probably present as a sulphuret. The copper also is frequently met with in a native state. It usually however occurs in the forms of vitreous copper, variegated copper, and copper pyrites; but it is found also as a carbonate resulting from the decomposition of the other ores where acted on by the weather at the outcrop of a lode. The gangue in those lodes which carry vitreous copper has usually a predominating quantity of calcareous spar or laumontite, and sometimes of heavy spar, while in those possessing pyritous and variegated copper ores it appears to be of a more quartzose character. Native copper is usually accompanied by prehnite, and often by epidote. The silver is found associated with vitreous copper, native copper, and galena, the last of which, with blende and iron pyrites, occurs in company with the sulphurets of copper, and is sometimes met with in the calcareous spar by itself.

The courses of the metalliferous veins of this upper group appear to be different in different parts of the lake, although they preserve uniformity over considerable areas. On the north shore they run with the system of veins coincident with the range of the rock-masses, partaking of an east and west bearing. On Michipicoten Island they belong to the transverse system, and run north and south; while at the east end of the lake, besides the principal lodes running eastward and westward transverse to the stratification, there are others running northward and southward with the strike.

Veins of the lower group.

In the lower group of this series the most conspicuous system of veins consists of those transverse to the stratification. They vary in breadth from a few inches up to twenty feet and more, and are in general composed of calcareous spar, heavy spar, and amethystine quartz. Apophyllite is occasionally associated with heavy spar in some of the veins, and dark green saponite occurs more or less in almost all. Several of them are characterised by small quantities of vitreous, variegated, and pyritous copper, iron pyrites, blende, galena, silver glance, and native silver; and on Prince's location, to the west of Fort William, one of the lodes, in addition to all these metalliferous products, including a promising quantity of the copper ore, holds cobalt and arsenic, with a little gold. The veins coincident with the stratification and cut by these transverse veins, are in general rather thin. They often run side by side with the dykes, and seem for the most part to consist of a breccia of the wall rocks, held together by carbonate of lime and quartz, while saponite is frequently present. Green and purple fluor spar are found in some of them, and prehnite associated with thomsonite occurs in others. The only metalliferous minerals observed accompanying them are iron and copper pyrites; but it is doubtful whether the quantity of the latter is sufficient to give promise of profit in working them. One vein, coincident with the strike of the formation, which occurs on the north-west side of Thunder Bay, appears however to be an exception. It is of great breadth, perhaps not under sixty feet, and in its general characters resembles the transverse veins; its earthy minerals being calcareous spar, amethystine quartz, and heavy spar, while at the same time it carries small quantities of iron and copper pyrites, galena, and blende.

On Lake Superior, mineral veins, analogous to those which have been described as belonging to this series of deposits, were found penetrating the older rocks; but the examination of these veins has scarcely been sufficient to authorise any attempt to describe them. The veinstones appear to consist chiefly of quartz and calcspar, with laumontite occasionally; and the metalliferous minerals, when any are found, are variegated copper, copper pyrites, galena, blende, and molybdenite; but with the exception of a district at the mouth of the Black River, nearly opposite the Slate Islands, the lodes do not seem to be of such frequent occurrence as in the higher rocks, nor are those which have been observed of so important a character.

The lower group composes the whole country, both islands and mainland, between Pigeon River and Fort William; and the valley of the Kaministiquia River, in the eastern part of its course, may be considered as the boundary of its outcrop in this district. Eastward, on the main front of the lake, it constitutes Pie Island and the promontory of Thunder Cape, reaching to a point about six miles to the eastward of its extremity, where a transverse dislocation lets down the succeeding group at least 1300 feet, bringing it suddenly in to occupy the coast in the strike of the other. The lower group however constitutes the whole of the bed of Thunder Bay, on the north side of which the conglomerate layer at its base is seen to rest in a nearly horizontal position upon the highly tilted chloritic slates of the Huronian series beneath; and in one spot it there evenly covers over, without any disturbance, a step in these chloritic slates produced by an ancient transverse fault. Distribution of the lower group.

On the same side, at the eastern extremity of the bay, the chert beds belonging to the lower group occupy two miles of the coast. But the whole volume of the group in this part appears to be gradually thinning down; for while between Thunder Cape (in which alone a vertical thickness of 1300 feet is displayed) and the final outcrop of the base on the north-western side of the bay there is a breadth of more than twelve miles, one of no more than probably three miles would span the distance in the bight of the bay between the Laurentian gneiss and the south-eastern cliffs, displaying the lower white sandstones of the upper group, while the dip does not increase in a ratio sufficient to preserve the volume which occurs to the west. In corroboration of this, where a spur of gneiss comes upon Black Bay, in the vicinity of Granite Islet, the bluish argillaceous slates are altogether wanting, and the sandstones of the upper group are seen to come in contact with the Laurentian rocks. And though the sandstones and the gneiss to the eastward have been more than once detected in contact, the slates have not again been observed in any place, with the exception of one, where they form part of some of the islands in the Grand Detroit exit from Neepigon Bay, to the north of the large centre island of the Battle group, being those islands eastward of Simpson's Island. The thickness of the slates there was not very important, and they probably do not reach much farther in that direction.

Commencing at the Thunder Cape downthrow which has been mentioned, the white sandstones at the base of the upper group constitute an escarpment on the south-east side of Thunder Bay, and are displayed in vertical cliffs rising to 200 feet above the water: they occupy about seven miles on the same side, towards the north-eastern extremity of the bay. The limestones and the indurated marls appear at a point about a mile and a half eastward of the downthrow, on the south side of a tongue of land separating Thunder Bay from Black Bay. Running parallel with the Distribution of the upper group.

sandstones, and dipping south-easterly at an angle of about three degrees, they probably occupy the upper side of the latter bay. Here, however, there is but little exposure of rock, a fringe of marshy land shielding much of the coast.

Beds of red sandstone of a conglomerate character, associated with layers of variegated red shale, are seen reposing on the gneiss of Granite Islet. The conglomerate is composed of the ruins of the underlying rock, and fills up the inequalities and worn fissures of the rock supporting it, displaying a southern dip at an angle of about ten degrees. The variegated shale is calcareous, and it is not improbable that a considerable part of Black Bay may be worn out of the indurated marls.

The higher and more trappean part of the formation commences at Point Porphyry; and on Edward Island and other islands northward, grits and conglomerates are found interstratified with trap layers. The same interstratification is met with in the rocks bordering the south-east side of Black Bay, while those fronting the lake on the south-east side of the peninsula are composed almost entirely of various descriptions of conformably overlying trap. This arrangement of the stratification, occupying a belt of from seven to ten miles in breadth, (which on the lake front is carved out into a multitude of deep coves, and includes a great collection of small rocky islands,) runs in a north-easterly direction across Neepigon Strait, from the mainland to St. Ignace Island. Gradually changing its direction about the middle of this island to due east, it continues on through Simpson's Island, and farther to the eastern extremity of the Battle Islands.

Battle Islands.

A high precipitous escarpment of red sandstone, with white bands and conglomerate layers, all interstratified with occasional beds of variegated red shales, and having a pretty constant dip of eight or nine degrees to the southward, keeps its place on the north side of each succeeding island standing in the line, which curves a little to the south of eastward towards the eastern extremity. A section from the gneiss through the large centre island of the Battle group would shew in place both the blue shales and the succeeding sandstones, apparently diminished in their proportions. In the cliffs on the north side of the last island of the group the limestones are displayed, associated with white sandstones and a conglomerate layer beneath, resting on trap of a porphyritic character, and overlaid by more porous volcanic products, the succession of the sedimentary part in ascending order being as follows:—

Conglomerate and red sandstones,	30	feet.
Red and white shales and sandstones,	70	"
Reddish or flesh-red limestones in beds of from two to twelve inches,.	30	"
White sandstones,	70	"
	200	

The isthmus which separates Black Bay from Neepigon Bay appears to be entirely composed of sand and clay. But it seems not improbable, from the direction which the spur of gneiss, already twice mentioned, assumes in running out to Granite Islet in the first named bay, that an undulation in the stratification connected with it in the superior rocks may cross beneath the sand and clay, and carry its course between St. Ignace Island and the two islands to the north, of which the western one is called the Grange. No northern dip has been anywhere observed, but this may be concealed by the loose material of the isthmus and the waters of the bay: and should such an undulation exist, or a dislocation represent it, it is probable that the strata of the two islands would be a repetition of those of St. Ignace. An escarpment of southward-dipping red sandstone exists on the north side of them, and runs for the sandstone and the overlying trap on the mainland both to the east and the west; while two miles farther north, sedimentary strata, still dipping south at an angle of about five degrees, underlie the perpendicular cliffs of columnar trap at the mouth of the Neepigon River. These strata are very calcareous, and probably belong to the limestones of the formation. The white sandstones which are found at the base of the formation in Thunder Bay have not been here observed to crop out. A considerable space however, probably upwards of a mile, between the basset edge of the calcareous strata and the gneiss, is occupied by a deposit of sand between sixty and seventy feet thick in some places; but to the eastward the red sandstones of Grange Island are seen reposing on the gneiss, without the intervention even of the calcareous beds.

Where these beds and the sandstones associated with them are seen at the outlet of the Neepigon, the overlying trap does not appear to be in a perfectly conformable attitude. It seems to be more horizontal than the sedimentary portion of the cliff. The slope of the beds, as stated, is about five degrees; and as they approach the base of the trap they appear to become obliterated, some of them proceeding farther than others into the igneous mass, but in such a manner that it is difficult to say where any bed finally stops.

It seems not at all improbable that Isle Royal belongs in part to the igneous portion of the upper group. Siscouette Bay occurs about mid-length of the island, on the south side. The bight of this bay is at the foot of a range of trap hills, whose course runs nearly north-east and south-west. The area in front of them between Siscouette Bay and the south-western extremity of the island is composed of red sandstone with conglomerate layers. With a breadth of nearly three miles, they rest upon the trap, and dip about south-east at an angle of ten degrees; while the remainder of the island in its whole length appears to consist of trap, much of which is of an amygdaloidal character. The average breadth of this trap is about Isle Royal.

six miles. The dip of the band appears to be greater than that of St. Ignace, and it is probably stated within the mark at fifteen degrees, the bearing being to the south-eastward. The general strike is well marked by the form of the island; and the number of deep inlets which are worn down in the softer beds at the lower or north-eastern extremity, the most south-easterly of which is not under ten miles long, shews the great parallelism of the different layers. The general position of the island and the dip and strike would bring the whole mass to the front of St. Ignace Island, as if it constituted an addition to the volume of the formation; but it is perhaps a more probable conjecture that there is a trough between the two positions, the northern slope of which is concealed by the waters of the lake, and that Isle Royal constitutes only a repetition of the Neepigon peninsula and archipelago.

Proceeding eastward, the mass of trap which has already been mentioned as flanked on both sides by the chloritic slates in the north-eastern corner of the lake, in the vicinity of Anse à la Bouteille and the Old Pic River, may belong to the formation; but of this there is some doubt. In a straight line across from one side to the other on the coast, it occupies a space of about fourteen miles. No rocks of a sedimentary character have been observed to be associated with it; but its stratification is very distinctly marked, with a dip south-westerly of about twelve degrees. Its character differs in different places; but no portion of it was observed to be amygdaloidal, except one bed, which exhibited a transverse columnar structure. The rock in general appears to approach in character the more solid and crystalline trap which overlies the amygdaloid towards the lake front of the Neepigon and St. Ignace band.

On the upper or western side, the mass is brought into position by an outburst through the chloritic slates, which are well displayed on the main shore at a point nearly due north of the western extremity of Pic Island. The trap there abuts against the chloritic slates. On approaching them, its feldspar, constituting the predominant mineral, assumes a red color with occasional opalescence, and strongly contrasts with the brilliant black hornblende disseminated through it, while among its accidental minerals the rock contains a few zircons. In the first hundred yards near the junction, the slates appear to be shivered and broken into a very coarse breccia, of which the interstices are filled with trap of this character, while in the second hundred yards they are cut up by a number of irregularly parallel, though somewhat ramified dykes of the same, having a general northerly direction, which is that of the dingle marking the course of the junction of the two rocks. At a distance from the junction the trap is still coarse grained; but the general color of the feldspar is a dull green, with black hornblende, and magnetic oxyd of iron. The columnar bed has occasional large patches of a red color, holding red feldspar, white quartz, and black hornblende; but the general color of the matrix in which these are imbedded, is a chocolate-brown, resulting from the feldspar which constitutes the chief part of the mass, in which small cells are filled with calcspar and red and white zeolites, while well defined slender acicular crystals of black hornblende are abundantly disseminated through it. The rock above and below is composed of brownish feldspar and black hornblende, but it is not so compact as the other. It is large grained, and the general mass of the country constituting the Old Pic Point and Island appears to be composed of it. Fluor spar occurs as a disseminated mineral in some of the beds. Judging from fragments on the shore, there are some beds composed of white feldspar, with occasional groups of orange-red grains of elæolite, the whole studded with brilliant black crystals of hornblende, forming a very beautiful rock. The general mass of these igneous rocks weathers to a red, and from a distance may readily be mistaken for the gneiss which underlies the chloritic slates. The hills which they form however are not quite so rugged as those resulting from the older rock.

Much to the south and a little to the east of this is Michipicoten Island, another mass of trap belonging to the upper group. The strata of which it is composed have a general dip to the east of south, and the inclination appears seldom to fall short of thirty degrees. The lower strata towards the north side of the island, particularly as indicated at the upper end, appear to be composed chiefly of amygdaloidal trap, with occasional beds of trap conglomerates, red sandstones, and shales: while towards the south these are overlaid by a considerable amount of compact earthy or sub-resinous red trap, assuming sometimes an obscure and sometimes a distinct porphyritic character, by the display of ill defined crystals of red feldspar or well marked crystals of transparent colorless quartz.

Michipicoten Island

Along nearly the whole of the south side of the island the trap assumes a more resinous aspect, and, its color becoming black, it presents the characters of pitchstone and pitchstone porphyry. Some of the beds associated with these are of an amygdaloidal character, and exhibit large agate veins, which run chiefly in the direction of the strike, but frequently also transverse to it.

About three fourths of a mile out in front of the harbor, which is halfway down the south side, a few narrow islands occur, presenting beds of a peculiar character, amounting to between sixty and seventy feet, dipping southward at an angle of twenty degrees. They are of a general red color, spotted and patched with yellowish-white, and whereever a crack exists the rock is blanched to a small distance on each side of it. The surfaces are uneven, and peculiarly marked with festooned and finely wrinkled forms, composed of very thin close-fitting laminæ with a ligneous aspect, having a thickness sometimes exceeding one or two inches. The rock scarcely resembles a trap, nor does it bear the character of indurated shale; but it may perhaps be an indurated mixture of volcanic mud and ashes, in which the wrinkles result from a partial flow. The total volume of the formation developed in Michipicoten Island, at the most moderate dip observed, would not fall short of 12,000 feet.

On the east side of Lake Superior, white and red sandstones are seen at several points, as also beds of amygdaloidal trap, with coarse interstratified greenstones. The sandstones, except when in the vicinity of disturbances from dislocations, appear to be much less tilted than the trap and coarse conglomerates. Both have a dip westward; but the facts ascertained are not yet quite sufficient to determine in what precise relation the two rocks stand in regard to one another. About two miles north of Cape Choyye a coarse grained bed, supporting some thickness of sandstone colored red, with white bands, and dipping a little to the south of west at an angle of about ten degrees, abuts against a precipitous cliff of the older rocks, as if let down by a north-east and south-west fault.

Cape Choyye.

Cape Gargantua.

About nine miles to the south of this, the peninsula of Cape Gargantua, and some of the small islands immediately near, display amygdaloidal trap disposed in beds dipping to the south of west at an angle of about forty degrees, and resting unconformably on the gneiss. Farther on, Leach, Lizard, and Montreal Islands, as stated by Bayfield, are composed of sandstone, but the attitude of the strata has not yet been ascertained; it seems probable however that the flatness of their geographical surface may be occasioned by the absence of any great slope in their constituent strata.

Pointe aux Mines.

To the south of Montreal Island, sandstones and amygdaloidal trap occupy the lower side of the cove above Pointe aux Mines. The sandstones, where first seen, are nearly in contact with the gneiss, against which they appear to abut, as if brought in by a dislocation. Their dip, at an angle varying from ten to twenty degrees, gradually changes from a direction N. 45° W., to N. 15° W. The trap, coming apparently from below, after an interval of about one hundred yards, in which it is difficult to ascertain its true attitude from its being worn down level with the surface of the water, exhibits a decided dip S. 80° W. $< 30° — 40°$, maintained for such a distance across the measures as to yield a thickness of 3000 feet. This trap is interrupted at Pointe aux Mines by a south-easterly dislocation which brings up the Laurentian gneiss, of which the extremity of the point is composed. From this point the line of demarcation between the gneiss and the overlying unconformable rocks, as has already been indicated, appear to run across in a south-easterly direction to Batchehwahnung Bay, leaving the promontory of Mamainse between it and the lake.

This promontory is composed of amygdaloidal trap and coarse interstratified conglomerates, whose pebbles and boulders consist chiefly of the ruins of the subjacent slate, gneiss, and associated rocks. The general dip of the strata which occupy this area is maintained with considerable constancy in a direction rather south of west, at an angle of twenty or twenty-five degrees, and the breadth across the measures is sufficient to give a thickness probably of not far from 10,000 feet, of which about 1500 feet consist of conglomerate layers, one of them being 400 feet. On the south side of the promontory, approaching Anse aux Crêpes, irregularities prevail, and sandstones in a disturbed condition approach the trap, but keep to the lake side of it. Mamainse.

Between this point and Sault Ste. Marie, stratified amygdaloidal trap has been observed in three places. The first is in the most eastern part of Batchehwahnung Bay, where it reposes on the gneiss with a dip S. 80° W. < 42°. The second is in a cove between two and three miles to the east of the southern boundary of the same bay. The worn condition of the rock renders the dip obscure, but it appears to be N. 60° W. < 22°. A hilly surface rises behind it belonging to the Huronian series. The third position is at the extremity of Gros Cap, where there is but a small quantity of the amygdaloidal, and where trap of a porphyritic character appears to be associated with it. The dip is W. < 45°. Coast to Sault Ste. Marie.

The sandstones in the same distance constitute the promontory between Anse aux Crêpes and Batchehwahnung Bay. They probably underlie also the large island of this bay, and, with the exception of the interval occupied by the trap in the cove at the southern entrance of the bay, compose the coast from a point three miles to the east of the cove round to Goulais Bay, underlying the whole of Goulais Promontory and Maple Island. A narrow strip of the rock is found also leaning against the gneiss on the south side of Goulais Bay, extending seven miles along the coast towards Gros Cap, and dipping gently to the north-westward not quite in the direction of Isle du Parisien, which is also composed of the rock, with a dip of two or three degrees in the direction of White-fish Point.

In every instance the geographical surface of the sandstones on the east side of the lake is low and flat; and their geographical position in relation to the stratified trap would seem to indicate that they overlie the latter, but whether conformably is not yet satisfactorily ascertained. Their presence, as stated by Bayfield, in Caribou Island, seven leagues south of Michipicoten Island, and more than twice as many east of Montreal Island, makes it probable that their spread may be considerable under the waters of the lake, while sandstones occupy a great extent on the south shore. The geologists of Michigan represent them to exist at intervals from the vicinity of Point Iroquois to Grand Island, in which latter spot they are capped by fossiliferous limestone. On this coast at the mouth of the Dead River, north of Marquette, there is a mass of very ferruginous dolomite, of which the stratification is not very distinct; but it is overlaid by the sandstone which fills up inequalities in the surface of the dolomite, and dips at a moderate angle to the south-west. The dolomite is cut by what appears to be a vertical dyke, which, instead of intersecting the sandstone, abuts against the bottom of it.

Sandstones of St. Mary.

The same red sandstone, interstratified with greenish and whitish layers, is observed in various parts of St. Mary River, between Sault Ste. Marie and Sugar Island. To the south-eastward of the lower end of Sugar Island the boundary of the sandstone is covered by drifted boulders or by over-growing moss and forest trees; yet there is evidence in the character of the loose material that the formation extends to the eastern side of Sugar Island, and that, striking into the island of St. Joseph near the north-western extremity, its basset edge runs nearly east, and comes out again on the north coast of the island, about two miles south of the island of Campement d'Ours. On Campement d'Ours there is an outlying patch of the rock resting in a nearly horizontal attitude on Huronian quartzites. It has a thickness of about eighty feet, and consists of whitish and brownish slightly calcareous sandstone, with a two-feet bed of a pinkish color towards the top; and both here and on the island of St. Joseph the sandstone is overlaid by limestone well marked by fossils.

Campement d'Ours.

Lacloche.

The sandstone is again seen at the east end of the North Channel on the island of Lacloche, as well as on the point of the long promontory that comes down towards the island from the mainland. The rock in this neighborhood is from twenty-five to thirty feet thick, and consists at the base of about ten feet of red and green shales, interstratified with thin bands of green-spotted red sandstone, and followed by about sixteen feet of drab and greenish-white slightly calcareous sandstone, in beds of from four to six inches, separated towards the bottom by thin layers of red and green shale. To these succeed between one and two feet of red calcareous sandstone, holding a few of the fossils which characterize the magnesian limestones immediately above, and thus constituting a passage between the two deposits. A narrow strip of the sandstone runs east along the south side of a ridge of Huronian quartzite through the island of Lacloche; it then spreads over a portion of the north-east corner of that island, extending thence across the peninsula of the mainland opposite, where it rests upon the edges of the tilted slates of the Huronian series, and there constitutes the most eastern exposure of the rock observed on the lake.

Age of the series.

The precise age of the upper copper-bearing rocks of Lake Superior is a question attended with some difficulty. Mr. Whitney appears disposed to regard the whole series from the summit of the sandstones of Sault Ste. Marie to the base of the Kaministiquia slates as one group equivalent to the Potsdam formation; but the suspicion of a want of conformity between the Sault Ste. Marie sandstones and the trappean rocks beneath, would induce us to separate the two. The difficulty in coming to a conclusion arises from the want of fossils; none of a satisfactory kind, it is believed, having been obtained, either on the north or the south side of the lake, from beds whose relation to the well ascertained interstratified igneous beds is undoubted.

There does not appear any reason to doubt that the red sandstones of Lacloche and of Sault Ste. Marie are the same, and that the latter, extending with a low dip to the foot of Gros Cap Mountain, strike over to Point Iroquois. The nearly flat sandstones met with between this promontory and Grand Island, with the fossiliferous limestones overlying them in the latter locality, appear to present conditions corresponding with those at Campement d'Ours and Lacloche; and the presence of similar sandstones in the various low islands and peninsulas on the Canadian side, to the east and the north, would seem to make it probable that the rock has a still farther extension in those directions. At the same time, the contrast between the general moderate dips of these sandstones and the higher inclination of the igneous strata at Gargantua, Mamainse, and Gros Cap, combined with the fact that the sandstones always keep to the lake side of these, while none of the many dykes which cut the trappean strata, it is believed, are known to intersect the sandstones (at any rate on the Canadian side of the lake), seem to support the suspicion that the sandstones may overlie unconformably those rocks which, associated with the trap, constitute the copper-bearing series.

From the western extremity of Lake Superior, the trappean strata appear to strike eastward with considerable regularity for 300 miles, until they pass Michipicoten Island and reach the eastern coast. Here the strike suddenly changes to a bearing at right angles to its previous course, with an upward slope to the eastward sufficiently rapid to bring 10,000 feet of strata to the surface at Mamainse, in no very great distance across the measures. This sudden change of strike, and its accompanying phenomena, have much the aspect of a great dislocation, or it may be a great undulation. Its effects are apparent for nearly a hundred miles along the east coast of the lake, and at the extremity of Gros Cap are visible to within a few miles of the overlying red sandstone.

If the overlying red sandstone were of the same age as the trappean formation and conformable with it, it ought naturally to be affected by the disturbance; and the very moderation of its dip should carry it a great way to the south, on the east side of the displacement. There appears however to be no irregularity whatever in the direction of the summit of the sandstone, which is represented as proceeding in a straight line to the westward, across St. Joseph and Neebish Islands, and thence into the northern peninsula of Michigan, maintaining the regularity of its course in this part until it is a long way beyond the line of the Lake Superior disturbance.

The Potsdam sandstone, among its very few fossils, possesses two allied species of *Lingula* (*L. prima* and *L. antiqua* of Hall, or *L. acuminata* of Conrad), the peculiarity of which is the sharpness and prominence of their beaks. The only fossil evidence tending to prove the Sault Ste. Marie red sandstone to be of the Potsdam age, which has hitherto been adduced, is the discovery, in some part of its distribution, of a single specimen of a *Lingula*, pronounced by Mr. Hall to be undistinguishable from *L. antiqua*. In Canada however *L. acuminata* occurs in the beds of passage between the Potsdam and the Calciferous; and another species (*L. Belli* of Billings), which occurs in the Chazy formation, is scarcely distinguishable from *L. antiqua*. It would scarcely be safe to rely on the evidence of a single specimen of such a fossil when it comes in opposition to the upward affinities of the Ste. Marie sandstone, as shown in the passage which has been mentioned between this and the fossiliferous magnesian limestone of Lacloche. In one of the white beds of the sandstone near Marquette there has been met with part of a cast of a *Pleurotomaria* somewhat like *P. Laurentina*, a species belonging to the Calciferous, but it resembles also *P. aperta* of the Birdseye and Black River formation.

As will appear farther on, the fossils of the Lacloche limestone are considered to belong to nothing lower than the base of the Birdseye and Black River formation; and a careful examination of the whole series of fossils obtained by the officers of the Survey from Lacloche to Neebish does not appear to establish any lower fossiliferous horizon in that part. The affinities of the red sandstone of Sault Ste. Marie would thus appear to bring it into the position of the Chazy rather than the Potsdam formation; and if this were established, the copper-bearing portion of the Lake Superior rocks might reasonably be considered to belong to the Calciferous and the Potsdam formations.

CHAPTER VI.

THE POTSDAM GROUP.

POTSDAM SANDSTONE OF NEW YORK AND CANADA.—CONGLOMERATES.—LIMESTONES.—FERRUGINOUS LAYERS.—DISTRIBUTION OF THE SANDSTONE; ITS ABSENCE AT THE ALLUMETTES; ITS EXTENT IN CANADA.—ORGANIC REMAINS; FUCOIDS; SCOLITHUS; LINGULA; ORTHOCERAS; PROTICHNITES; CLIMACTICHNITES.—RIPPLE AND WIND MARKS.—LITTORAL ORIGIN OF THE POTSDAM SANDSTONE.

The name of Potsdam sandstone was given by the New York geologists to a formation which is well developed at Potsdam in northern New York, and is in that region regarded as forming the base of the palaeozoic series of rocks. It is the extension of this sandstone in Canada which we propose to describe in the present chapter. Investigations still in progress, however, show that this sandstone is a member of a series of strata for which we retain the name of the Potsdam group. As stated in the preceding chapter, it is not improbable that the lower slates of the copper-bearing rocks of Lake Superior may belong to this group,—whose history will be further given in a succeeding portion of this volume.

The Potsdam formation is traceable from St. Lawrence county, New York, into Canada, where it has its greatest development in the county of Beauharnois. Here, however, the base of the formation lies in Franklin and Clinton counties, in the state of New York; its nearest approach to the province line being north of Four Corners, where the distance of the base from the Canadian boundary is represented to be about four miles.

The formation fills up the inequalities of the underlying Laurentian series; and in New York the lowest part is described as a coarse conglomerate, deriving its material from the subjacent gneiss, and containing rounded masses of quartz, some of which are eight inches in diameter, held in a fine grained matrix of silicious sand. At Potsdam the rock appears to be a fine grained, yellowish-brown, very even bedded sandstone, affected by a multitude of parallel vertical joints. Professor Emmons states that a hundred square feet of surface may be raised and afterwards split into rails six inches wide and ten feet long, or it may be broken into pieces of the size of a brick, with even edges of fracture. At Malone the rock is a very pale reddish fine grained sandstone, yielding excellent material for building, and large slabs for flagging and coping.

Hemmingford; conglomerate with shale.

Hemmingford Mountain in Canada, close upon the boundary of the province, though it does not reach the base of the formation, displays a thickness of 540 feet of this rock. In a deep ravine on the south side about 180 feet of a coarse grained sandstone are visible, in some parts constituting a conglomerate, with rounded pebbles of white quartz varying in diameter from an eighth to three quarters of an inch, while in most parts of the rock there are thinly disseminated flat pieces of black or green shale one or two inches in diameter by an eighth of an inch thick. The general color of the rock is grey, but greenish and reddish beds occur, and the three colors sometimes follow one another in thin stripes with various alternations. Some parts of the rock crumble in the weather to a yellow or brown sand. One bed of about three inches thick, near the base of the mass, contains a good deal of blackish-brown mica, with a few silvery white scales of the same mineral. Above the strata of the ravine the hill contains about 120 feet of grey sandstone, the lower half of which is rather coarse grained, and below the same strata 240 feet. The dip is northward, and, though at a very small angle, there would still be something to add to the thickness of the formation for that portion which comes to the surface on the south of the province line.

About three miles north of this, on the third range of Hemmingford, exposures of the rock present a grey color, with an occasional streak of brown, and weather to a light grey or greyish-brown. The greater part may be called a conglomerate, with rounded, translucent, white quartz pebbles varying in size from an eighth of an inch to an inch in diameter, and small masses of white or brown feldspar enclosed in a fine grained matrix of quartz and feldspar of much the same color. The beds are from nine inches to two feet thick, and some of them are altogether composed of the fine grained material. In the course of eight or nine miles to the westward of these beds there are several exposures of sandstone. One of

Flagstones.

these displays beds from an inch to a foot thick of pure silicious sandstone, some of which would yield good flagstones of moderate size. The rock is in general fine grained, with occasional pebbles as large as peas. In another of the exposures, the rock is a light grey fine grained sandstone, in beds varying from two inches to two feet, some of which have grains the size of pin heads. Some of the beds are very slightly calcareous, a few of them shew ripple-marks, and many of them fucoids. The rock in many parts weathers to a pale brown or yellow, and a thin coating on some of the surfaces is converted under atmospheric influences into a yellow ochre.

Blueberry Plain.

On Blueberry Plain, on the line between Jamestown and Russeltown, where there is an exposure of seven square miles of the rock, showing however from its approach to horizontality no great thickness, the sandstone is in general light grey in color, many parts becoming opaque white by exposure to the weather. The rock is in general fine grained, but contains occasional white quartz pebbles of half an inch in diameter. Some of the beds, on fracture, are seen to be much stained with brown and yellow spots; but the beds which bleach white are free from these stains, and would answer the purpose of glass-making. Some beds would yield tolerably good flagging-stones from two to four inches thick; but the strata in the greatest part of the exposure are from one to three feet thick, and many of them shew false bedding. Stone for glass-making.

The upper part of the formation is in general a fine grained, white, silicious sandstone, some parts of which are sufficiently pure to yield an excellent material for glass-making. It abounds in durable building stone, and in several places becomes of so free a texture as to furnish a stone capable of resisting great heat without cracking or fusing, and thus to be eminently adapted for furnace-hearths in the manufacture of iron. The formation attains a thickness ranging from about 300 to 700 feet, and at the summit the sandstone becomes by degrees interstratified with beds of magnesian limestone, and presents a passage to the succeeding formation. Furnace-hearths. Interstratified limestones.

It is stated by Professor Emmons, that connected with the summit of the formation there is at Chazy a calcareous breccia formed partly of sandstone and partly of fragments of a dirty grey calcareous rock. This is given by him as one of the characteristics of the formation at its junction with the succeeding one. To the east of Hemmingford Mountain, on the twenty-ninth lot of the second range of Hemmingford, there occur, in an area of which the diameter is less than half a mile, several exposures which appear to be of a somewhat similar character. In one of these, fragments of grey sandstone, some of which are calcareous and others not, accompanied by white quartz pebbles, are imbedded in an arenaceous cement, and some of the included fragments are a sandy limestone holding other fragments of a less calcareous character. Beds of arenaceo-calcareous rock seem to dip under the breccia, and the whole appear to be on the top of a bed of sandstone which is seen within five paces of the mass. Several of such patches occur not very distant from one another; and the intervals, which are always at a somewhat lower level, seem to be occupied by sandstone. Within the area to the westward, a mound of breccia contains angular and rounded masses of grey bituminous limestone, weighing from a few ounces to two and three tons, with others of sandstone; the whole being included in a matrix in some parts of black bituminous shale, and in others of black bituminous limestone; both of which, as well as most of the inclosed calcareous blocks, contain fossils, which appear to be of the Trenton formation. The rock seems to be folded into wedge-shaped masses, so that it is very difficult to arrive at the means of establishing an average dip. The Breccia.

surface here rises into a mound of about thirty feet over the general level of the neighborhood. On the east side of the area including these brecciated masses, there occurs an exposure of about sixty feet wide, in which the greatest confusion prevails, and brecciated limestone is seen abutting against beds of sandstone, sometimes in such a manner that they might be mistaken for a continuation of the same beds. Wherever the breccia occurs, it is usually more or less raised above the general surface around; and throughout the whole area wherever a rock is seen in the intervals among the mounds, it usually consists of sandstone apparently in an undisturbed attitude. In this attitude the sandstone extends nearly seven miles to the eastward, and where it becomes covered by the succeeding rock no breccia is observed. The presence and character of the fossils would appear to indicate that the masses of breccia at Hemmingford are probably connected with some complicated set of dislocations, rather than with any continuous bed spreading over the sandstone.

Distribution. Resting on the gneiss of the Adirondack mountains, the Potsdam formation, in its distribution in New York, sweeps round from Keeseville on the Ausable, a tributary of Lake Champlain, to Alexandria on the St. Lawrence, in Jefferson county. In this distance of nearly 140 miles, the band displays a breadth varying from about five to fifteen miles, with a general northerly dip at a small angle. From this general line, through the effect of a low anticlinal form, it is projected northward into Canada across the county of Beauharnois, and twenty miles farther across Lake St. Louis into the county of the Lake of Two Mountains. On the province line, from the summit on one side of the anticlinal to the summit on the other, the formation occupies about forty miles; but its breadth gradually diminishes northward, and in the neighborhood of Beauharnois village it does not exceed four miles.

Beauharnois.

Fossil tracks. From fifty to seventy feet below the top of the formation, the surfaces of some of the strata are marked by the tracks which have been designated by the name of *Protichnites*. A locality of these is in a field on the land of Mr. Hénault, near Beauharnois. From this the sandstone can be traced along the margin of Lake St. Louis for two and a half miles to the mouth of the Beauharnois canal; and by a careful admeasurement of distances and of the minute changes that occur in the very moderate dips prevailing, it would appear that a surface shewing similar tracks in a field about a quarter of a mile from the margin of the lake and on the north side of the road, is in about the same stratigraphical place with the bed at Hénault's, while the positions of the two localities are equivalent in relation to the outcrop of the overlying Calciferous formation on each side.

Protichnites.

Another locality of the tracks is met with in the vicinity of Pointe du Grand Detroit in Vaudreuil, and a bed of red sandstone occurring not far from it probably occupies a lower stratigraphical position. This locality is about twelve miles from that at the Beauharnois canal, and, like it, is on the west side of the anticlinal axis. Another locality in which the same track-bed is met with is on one of the islands of Ste. Geneviève, between two and three miles east of Ste. Anne, at the upper end of the island of Montreal. This spot is about seven miles from the exposures at Beauharnois village, and like them is on the east side of the axis. The locality at Ste. Geneviève, which is not a mile from Isle Perrot, is marked by *Scolithus*, with which the rock is in some parts completely honey-combed to the depth of three feet, while it is also irregularly interstratified with calcareous bands. Ste. Anne Point may be considered in the strike of the Ste. Geneviève locality, and here we still find the sandstone marked by *Scolithus;* while in Isle Perrot opposite, thin bands of red sandstone occur similar to those of Pointe du Grand Detroit.

At this part the breadth of the sandstone is about ten miles, extending from Ste. Anne to a position in Vaudreuil; but it gradually swells to about twenty miles towards the upper end of the Lake of Two Mountains, where it occupies about equal spaces on the opposite sides of the lake. On the left side of the lake there protrudes through the sandstone about fifty square miles of Laurentian gneiss, constituting Mont Calvaire; and on the other side about a square mile of the same rock occurs, leaning against an intrusive mass of trap, which there pierces the Potsdam formation and composes Rigaud Mountain. Calvaire and Rigaud Mountains.

From Alexandria, on the St. Lawrence in New York, the Potsdam formation reaches the Canadian side of the river, about twelve miles lower down the stream, in the neighborhood of Brockville. From this it is traceable, by a multitude of exposures, running in a meandering course to the vicinity of Perth; the bays and promontories of its geographical distribution being occasioned partly by inequalities in the surface of the Laurentian gneiss supporting it, and partly by very gentle undulations in itself. In this course its most western position is the northern part of Bedford township.

The cliffs below Brockville expose a sequence of from seventy-five to eighty feet thick, consisting of sandstone with interstratified dolomitic beds at the top, and a coarse silicious conglomerate at the base. About two and a half miles above the town an outlying portion of the formation comes in on the river bank, and, occupying it for seven miles up, occasionally shews the silicious conglomerate in unconformable contact with the Laurentian series below. Many of the upper and finer beds of these exposures exhibit fucoids on their surfaces, and the small cylindrical holes of *Scolithus Canadensis*. Fragments of shells also occur in some of the interstratified calcareous layers, but they have invariably been found to be too obscure to be identified. Brockville.

At Charleston Lake there is an extensive development of the formation on the north shore, and outliers occur on many of the numerous islands which stud the lake. On one of these, commonly called Bluff Island, a mile south-west of Charleston village, the following descending section occurs :—

	Ft.	in.
Sandstone, blood-red at the top and chocolate-red at the bottom, with nodules of quartz, weathering brown, on the upper surface,	4	0
Thin bedded white, red, and chocolate-brown sandstone,	4	0
Red and greyish or white sandstone in alternating stripes,	4	3
Dark pinkish-brown sandstone, occasionally striped with blood-red,	5	7
Red and dark brown sandstone,	5	0
Blood-red coarse sandstone with concretionary nodules,	2	0
Dark brown, red, and yellow banded coarse grained sandstone, divided into thin layers,	11	0
Red and yellow sandstone in alternating stripes in thin layers,	7	3
Red and yellow striped and mottled sandstone, of a coarse grain, not well exposed,	11	0
Red coarse sandstone with quartz pebbles scattered through it,	2	6
Dark yellow coarse sandstone striped and mottled with red; the upper part is red, and holds large quartz pebbles scattered through it,	3	6
A conglomerate bed with a matrix of dark brown and yellowish coarse silicious sandstone, sometimes tinged with pink, holding pebbles and boulders, chiefly of quartz, in irregular layers; the largest boulders are one foot in diameter,	8	0
Dark brown coarse sandstone or fine conglomerate, with pebbles chiefly of white quartz, resting on red talco-quartzose rock of the Laurentian series,	2	11
	71	0

The infiltrating iron oxyd, which has stained the red talco-quartzose rock at the base of the section, seems to have imparted its color to the overlying mass: and in some parts of the lake the color of all the lower beds, both sandstones and conglomerates, is deep blood-red, which gradually gives place in the ascending strata to white with red spots and stripes, and then to white alone. On the eleventh lot of the eleventh range of Lansdowne, at the head of one of the northern bays of the lake, there is a section of about forty feet thick, consisting of white sandstone with shaly and slightly calcareous layers at the top, and conglomerate below, which is seen in contact with the Laurentian rocks; but notwithstanding the presence of these, which are brought into place by the uneven surface of the series, the white sandstones are at a higher level in the sequence than the highest beds of the previous section. These white beds are therefore to be taken as additional strata, and the two together would give a total thickness of at least 110 feet. Fucoids, *Scolithus Canadensis* and *Lingula acuminata* are found associated together in abundance in the upper shaly calcareous part; but the last is sometimes rather obscure.

Lansdowne; fossils.

Hematite.

There is likewise a large display of sandstones and conglomerates in the township of Bastard near Beverly, where the red color prevails near to the contact with the older rocks. One exposure occurs on the line dividing the twenty-fourth and twenty-fifth lots in the tenth range of the township, near the town line of Lansdowne, where there is a cliff of sandstone of from twenty to thirty feet high. The rock lies in massive beds, occasionally measuring four feet and upwards in thickness. They are all ferruginous, and, passing upwards from a yellow or light brown into a deep red color, they present small seams and patches of red hematite. On the ninth lot of the twelfth range of Lansdowne also, the same rocks contain patches of hematite, a short distance from their junction with the Laurentian limestone beneath. North from Beverly on the twenty-second lot of the ninth range of Bastard, white sandstone beds, which must be higher in the series than the preceding, contain fucoids, *Scolithus Canadensis*, and in a full state of preservation, *Lingula acuminata*, with some of the valves much less tapering to the beak than others, the one being probably the upper and the other the lower valve of the same species. *Lingula* occurs also in a cliff near Newboro', a short distance from the town line of North and South Crosby. Bastard fossils.

From the neighborhood of Perth, where the sandstone is white, and displays *Protichnites*, the outcrop of the formation proceeds northward, and then, sweeping round to the head of Otty Lake, in Drummond, returns southward in the townships of Elmsley and Montague, where the sandstones are seen encircling a protruding mass of Laurentian gneiss, which rises on the twenty-eighth lot of the sixth range of Montague. The outcrop thence runs northward again to Otty Lake, following it towards the lower end. From this it runs across Ramsay into Pakenham, where it becomes overlapped by the succeeding formation. Westward of the village in this township, however, it appears to surround a shallow synclinal outlying mass of Lower Silurian strata, which extends in a bearing westward of north, from Ramsay nearly across Pakenham.

Between this and the Lac des Chats the formation is apparently overlapped by higher members of the Lower Silurian deposits; and it does not appear at the base of the various outliers of these higher formations which occur from ten to fifty miles to the north-westward, occupying the island of Allumettes, and parts to the east and the south of it. The formation would thus appear not to have been deposited much farther north in this part than the township of Pakenham. It is met with, however, to the eastward, between Lake Chaudière and a spur of Laurentian rock from three to five miles removed from the right bank of the lake, and extending from Lac des Chats to Nepean, a distance of twenty miles. The northern side of this spur forms the surface over which the waters of the Lac des Chats are precipitated into Lake Chaudière; and at the foot of the cascade the Calciferous formation comes up against the gneiss. The two rocks continue in contact for about four or five miles to the southward of east; but then become separated by the gradual emergence of the Potsdam formation, which flanks the Laurentian rock in a narrow band all the way from Tarbolton to Nepean, thence continuing eastward across this township, Absence of sandstone.

and running a short way into Gloucester, where, instead of the dislocation, the Potsdam shews an anticlinal arch.

In Nepean the rock dips northward, and in that direction sinks beneath the Calciferous formation; but the south side of the band, after leaving the gneiss, is brought by a dislocation against the Chazy and Trenton formations, and the continuance of this dislocation on the south side of the Laurentian spur accounts for the absence of the Potsdam in that position.

The rock in Nepean is in most parts a fine grained pure white sandstone fit for glass-making and well adapted for building. It here constitutes the south side of a synclinal form, on the north side of which it rises in Hull

Dislocation.

from beneath higher members of the Lower Silurian series. In Hull the sandstone is observed about five miles north of the Ottawa and about two miles east of the Gatineau, where it is brought into place by a dislocation which branches in Osgood and Gloucester townships from the one previously mentioned, and, running somewhat west of north, crosses the Ottawa at the Little Chaudière Falls, and shews a downthrow on the east side. The sandstone probably occurs on the west as well as the east side of the dislocation, though it has not been observed there.

From this dislocation the rock runs eastward in a narrow band on the north side of the Ottawa, across the townships of Templeton and Buckingham, a distance of about twenty miles; and a small anticlinal fold then carries it to the south side of the river, where it tips a salient point in Clarence on the axis of the anticlinal. Again passing to the north side in Lochaber, near the mouth of the Blanche, it proceeds to within a short distance of the North Petite Nation River. Hills of gneiss prevail on the right bank of this stream, at the mouth; and it would appear that an anticlinal fold or a dislocation runs from the corner of Lochaber to the valley of the South Petite Nation River, carrying the Calciferous to the south side and the Potsdam to the bottom of the Ottawa. An exposure of the Potsdam however occurs on a peninsula on the north side, about seven miles below the mouth of the Petite Nation, where the beds consist of fine grained sandstone, the surface of one of which displays *Protichnites*. A little below this, the river trenches to a small extent upon the Laurentian series, the gneiss of which composes the most salient point of the township of Alfred, on the south side; and the only additional exposure of the Potsdam known on the river is met with on the twentieth lot of the second range of Grenville.

Lachute.

A little beyond this the Calciferous formation, overlapping the Potsdam, comes upon the Laurentian limestone; but the Potsdam emerging again farther on, is displayed at the Rivière du Nord, in an escarpment of between thirty and forty feet of fine grained white sandstone at Lachute, dipping to the southward at an angle of four degrees. The actual contact with the Laurentian series is concealed in a flat sandy valley, varying in breadth from a quarter to half a mile; but a bed with *Protichnites*, which is at the summit of the escarpment, is computed to be about 250 feet over the Laurentian rock, while it is followed by about seventy feet in which sandstone marked by *Scolithus* gradually becomes interstratified with calcareo-magnesian beds, constituting a passage to the formation above.

From this the outcrop turns to E. N. E., and follows the valley of the Rivière du Nord for about twenty miles to the vicinity of St. Jerôme, approaching at Ste. Scholastique (which is about half way) to within about four miles of the sandstones which lean upon Mont Calvaire, at the extremity of the anticlinal spur projected from Beauharnois; the interval being filled up by the Calciferous formation. From St. Jerôme, the course of the Potsdam becomes nearly N.E.; and in this bearing it runs with considerable regularity for about fifty miles, with a varying breadth of from two to four miles, yielding in many places good material for building and for flagging. Toward the eastern end of the distance the thickness of the rock appears to diminish; as about a mile N. W. of Cuthbert's mills on the Chicot there is an exposure of fine grained white sandstone, characterized by *Protichnites*, which is supposed to be near the summit of the formation, and it is yet not far removed in this spot from the Laurentian gneiss. Chicot.

In this vicinity, the Potsdam is suddenly brought against the Trenton formation by a downthrow fault, of which the bearing is about N. 30° E.; and the sandstone is supposed to remain beneath newer members of the Lower Silurian series, along the line of dislocation, for upwards of twenty miles between the Chicot and Rivière du Loup en haut. Leaving this fault it reaches the St. Maurice River at the Grès, where it yields a material of freer grain than ordinary; which has been found at the St. Maurice and Radnor forges to answer admirably for furnace-hearths in the smelting of iron. On the St. Maurice, the gneiss occupies the left margin from the Grès to a spot three quarters of a mile below the river Cachée; but for a part of the distance, near the mouth of the Cachée and above it, it is concealed by clay. The gneiss also occupies the right side to the height of about twenty-five feet in the bank opposite the mouth of the Cachée, but to less than this farther up. Upon it reposes the Potsdam sandstone, which, in an escarpment at the bend of the river in sight of the fall, composes twenty feet of the cliff, while clay conceals what may be in addition to this thickness at the top. The base, which is seen in contact with the gneiss nearly on a level with the stream, is a four-feet bed of conglomerate, composed of white vitreous quartz pebbles, some of them as large as swan's eggs, and a few larger, in a matrix of fine white sand. This fine white sand constitutes the beds above, and it is from them that the furnace-hearths are obtained. On the right bank of the stream, a little below the Cachée, a quarry has been opened in a limestone rock of St. Maurice.

an arenaceous character; and it is probable that between this and the twenty-five feet of gneiss which come to the water's edge, the Potsdam beds may exist, though covered up by debris and vegetation. The total thickness to be given to them would thus not much exceed fifty feet, the dip being S. S. E., with not over one degree of inclination.

Between the St. Maurice and the Batiscan Rivers the rocks immediately lying on the gneiss are covered over with drift, and their precise relations are not known. Beyond this the contour of the Laurentian series, from Ste. Anne de la Pérade to Cape Tourmente, is much more irregular and indented than higher up the valley of the St. Lawrence; and six positions occur where it is projected forward from the general trend, namely at Deschambault, Cap Santé, Pointe aux Trembles, Montmorenci, Sault à la Puce or Chateau Richer, and the Rivière à la Rose. These six positions mark the axes of six folds or anticlinal forms; and the zones of rock which succeed, affected by these folds, exhibit in their turn a rudely corresponding set of projections. Some of the lower zones, however, are partially wanting; and among them is the Potsdam formation, which appears to be absent the whole distance, with the exception of one place at St. Ambroise, where a few beds of the Potsdam sandstone occur, in all about twenty feet thick.

Anticlinals.

St. Ambroise.

Descending the St. Lawrence, no rock has been observed which could be supposed to belong to the Potsdam formation before reaching Murray Bay. A white translucent quartzite here occurs above White Point on the west side of the bay, and at two spots on the east side; one of them within sight of the church just before reaching the Cape, which it is necessary to double in proceeding along the beach to Les Ecorchés, and the other close by Les Ecorchés. In these three localities the rock is rendered cleavable, by the presence of silvery mica, into plates of from half an inch to two or three inches thick, which appear to be conformable with the stratification, and cracks in the quartzite occasionally present green stains due to carbonate of copper. In these different localities, the rock succeeds different descriptions of gneiss: while a uniformity is preserved in the character of the Silurian strata that succeed it, and it might be taken for a mass belonging to this series. It appears doubtful however whether the different exposures may not present distinct beds of quartzite belonging to the subjacent gneiss. The thickness of the deposit at Les Ecorchés is about forty-five feet.*

Lower Silurian strata are known to exist on one of the islands at the entrance of the Bay of Seven Islands; and there being a considerable area of flat country between the coast and the Laurentian rocks, it is possible

* It has been ascertained, by Dr. Dawson of McGill College, Montreal, that these quartzites really belong to the Laurentian series.

there may be an outcrop of the Potsdam formation resting upon them. No examination, however, has yet been made to ascertain the fact. Between the Calciferous formation of the Mingan Islands and the Laurentian gneiss on the main shore there is room for the Potsdam; and loose fragments of both white and red sandstone with the characters of this formation, having been met with on the coast, it appears probable that it is present, but it has not yet been seen in place.

Belle Isle. Red and white sandstones are known to occupy various localities on the north side of the straits of Belle Isle, such as Perroquet Island and Ance aux Blancs Sablons, and there is little doubt that they belong to the Potsdam formation. Such specimens of the rock as have been obtained are rather coarse grained; and some of these shew the existence of conglomerate beds, in which the pebbles are half an inch in diameter, enclosed in a matrix of red and white sand, the colors being arranged in parallel layers, and sometimes exhibiting false bedding. It would however be in vain to attempt a description of the rock in this region until a larger number of facts have been ascertained.

Extent of the formation. The Potsdam sandstone is thus traceable on its north-western outcrop from the straits of Belle Isle to Bedford, a distance exceeding 1000 miles. But there appears to be some doubt whether the deposit extends much farther westward in Canada. Between Pakenham and Brockville the outcrop of the sandstone rests on the east side of the low gneissic ridge which connects the Laurentian rocks of the Adirondack area with the main range in Canada, and causes a break between this outcrop and the next exposure of the sandstone to the westward, which is upon the opposite side of the low ridge; the distance between the two outcrops in Canada being about thirteen miles.

The formation is not largely developed on the west side of the ridge, the greatest thickness of it observed at any one place being certainly not over forty or fifty feet, while west of Knowlton Lake, in Loughborough, it appears gradually to decrease in thickness, and eventually to die out altogether. Storrington The largest spread of it in this part is in Storrington (formerly Pittsburgh) township, where it comes from under a limestone escarpment, and terminates in an irregular outcrop running from Brass's Point on Loughborough Lake, in the ninth lot of the tenth range of Storrington, to the twelfth lot of the eighth range on Vanluvin's Creek, a short way below Daly's mills. The rock is for the most part of red and greenish colors, generally fine grained, having pebbles of opaque white quartz distributed scantily and irregularly through it. In some parts it is of a pale greenish color, with reddish or yellowish layers, and in others it is a nearly pure white fine grained silicious sandstone. Some portions also are a brick-red and very ferruginous, and others a coarse quartz conglomerate.

Near the road leading in a general easterly direction from Vanluvin's mills to Dog Lake landing, in the twelfth lot of the ninth range of Storrington, a cliff of sandstone exhibits the following section in ascending order :—

	Ft.	in.
Grey moderately fine grained sandstone in a solid bed, holding angular pebbles of white quartz, the largest of which is from six to seven inches in length,..	4	0
Dark grey rather coarse grained sandstone, with frequent very red stains, and weathering of a rusty-red color, ...	2	0
Yellowish fine grained sandstone,..	0	6
Dark grey rather coarse grained sandstone, mottled and striped with red and yellow, holding pebbles of opaque white and bluish-grey quartz, usually angular, sparingly disseminated through the bed, ...	2	0
Dark grey yellow weathering very hard silicious sandstone, striped yellow and reddish,..	0	6
Dark grey yellow-weathering sandstone as before, with spots of brick-red,.....	1	9
	10	9

At intervals, the road for about eight chains east from this section exposes flat surfaces of grey sandstone, sometimes rather obscurely ripple-marked, and studded with quartz pebbles. Four chains to the south another cliff arises, shewing strata supposed from their position to be higher beds, which in ascending order are as follows :—

	Ft.	in.
Grey and red coarse grained sandstone in alternate beds, ...	8	9
Red and white coarse grained sandstone, with small pebbles of white quartz distributed over the divisional planes of the bedding, ...	4	0
A confused mass of conglomerate, composed of large pebbles of quartz loosely and irregularly imbedded in a sandy matrix, ...	8	0
Red and grey coarse grained sandstone in a set of thin beds, with small quartz pebbles scattered over the divisional planes,............................	3	0
	23	9

At the place where the conglomerate occurs, the dip, as indicated in the overlying beds, is S. 50° E. $<$ 10°, but that dip is only local. On the north side of the road the rocks are very nearly flat, and no conglomerate resembling the eight-feet bed in the above section is observed at all. At Daly's mills, on the eleventh lot of the eighth range, there is an exposure of about thirty feet of sandstone, the upper beds of which dip about N. 16° W. $<$ 10° — 12° ; and in the same stream, a little higher up, on the twelfth lot of the tenth range, similar beds dip S. 66° E. $<$ 15°; but the strata between are nearly flat, and these comparatively high angles of inclination appear only near their junction with the inferior Laurentian series, resting on which the unconformable Silurian beds seem almost always to be slightly accommodated to the worn surface.

Between the area of Potsdam sandstone to which these sections belong, and another north of it, there appears a position, just west of Vanluvin's mills, where the formation is overlapped by the succeeding rock. The northern area occupies both sides of the stream above the mills, and extends to Loughborough Lake.

At Brass's Point, which belongs to this area, the sandstone is very white and fine grained, and it is frequently penetrated by slender cylindrical holes, for the greater part vertical. These are tinged of a dirty brown or rusty color, and contrast strongly with the white stone. They are supposed to be *Scolithus Canadensis*. Below the white sandstone there is a fine silicious conglomerate, and that is underlaid by grey sandstone, which is occasionally seen resting on the gneiss, the whole thickness displayed not exceeding six feet. At another point, on the south side of Loughborough Lake, in the seventh lot of the ninth range of Storrington, a cliff exposes about twenty feet of the sandstone sloping gently south-west towards the foot of a calcareous escarpment, which rises abruptly on the south side of the bay west from this point. At Knapp's Point opposite, and on a small island near, there are similar strata.

To the west of Knapp's Point it is very probable that the formation is again overlapped by the succeeding rock, as no exposure of the Potsdam is seen for seven miles, though the superior rock can be traced without much difficulty the whole way; and on the north side of the lake, on the thirteenth lot of the third range of Loughborough, it is seen to approach close to the gneiss.

Outliers in Loughborough

In the township of Loughborough the formation occurs occasionally in outlying patches, resting upon gneiss or crystalline limestone. One of these outliers is on the eleventh lot of the ninth range, at the northern end of Eel Lake, where a cliff of about forty or fifty feet high is capped by red or purplish and white silicious sandstone, arranged in layers of from six inches to one foot thick, the whole thickness being about sixteen feet. The lower part of the cliff is concealed by debris from the sandstone beds; but the outlier, which does not appear to exceed a few acres in extent, is surrounded by gneiss. Other small outliers occur near the base of the fossiliferous escarpment, on the fourth and fifth lots in the rear of the seventh or the front of the eighth range of Loughborough, some of which occupy an area of about an acre, and rest immediately on the crystalline limestone.

On the west side of Knowlton Lake, sandstone strata come from beneath an escarpment of fossiliferous limestone, and rest upon crystalline limestone. At the south end of the lake there is an exposed thickness of fourteen feet of red and grey or greenish massive sandstone, in beds of from three to four feet, over which the ground is level for about fifty yards, and then rises rather abruptly on it the talus of the escarpment of the superior fossiliferous formation. One portion of the red bands here is very ferruginous, almost passing into hematitic iron-ore. The unctuous powder resulting from it imparts its color to the soil around, and the surface of the hematitic bed is marked by concretionary ferrugino-arenaceous masses, from one to three inches in diameter, giving it a mammillated character.

Knowlton Lake.

At the north or lower end of Knowlton Lake, on a bold square-shaped bluff, which comes out between the outlet and a long bay on the east side, there is a considerable display of sandstone. The cliff rises at some points to the height of sixty feet. The upper part is red or red and green, in rather thin beds, some under three inches in thickness, and the upper surface is mammillated as before. The lower beds are mostly massive, being from nine to eighteen inches thick, and their colors are red, green, and drab, in some parts alternating in very thin stripes. The lower part of these beds appears to rest on a rather fine silicious conglomerate; but the latter being seen only just at the edge of the water, its relation has not been satisfactorily ascertained, although the impression is that it belongs to the Laurentian series below. The same measures come out at a little distance north of the lake, on the second lot of the tenth range, and are again seen on a small brook on the road between the ninth and tenth ranges near the town line between Loughborough and Portland; immediately west of which the superior fossiliferous limestone rises in an escarpment, without any intervening sandstone. Beyond this no indication of the Potsdam formation has been observed in Canada, unless eight feet of red soft calcareous sandstone at Marmora, resting on the gneiss and succeeded by certain beds of limestone without observed fossils for thirty feet upwards, be supposed to represent it, or unless, as before suggested, a portion of the upper copper-bearing series of Lake Superior be considered of the Potsdam age.

Organic remains.

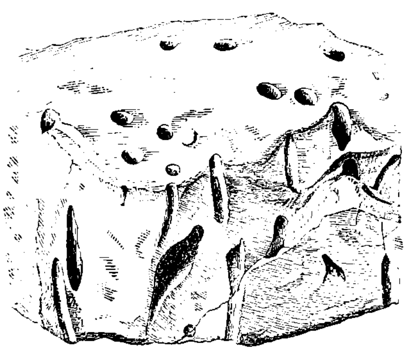
The evidences of organic life in the Potsdam sandstone are but few. In Canada fucoids exist in it in abundance, some of which have been figured by Mr. Hall in the Palæontology of New York. With these there are associated *Scolithus Canadensis*, *Lingula acuminata*, *Ophileta compacta*, a large *Pleurotomaria* allied to *P. Laurentina*, and fragments of two species of *Orthoceras*, all in the upper part of the formation. In addition to these, there occur three different descriptions of tracks, two of which are supposed to have been impressed by molluscous animals, and the third by some crustacean. The more remarkable of the former has been named *Climactichnites*, and the latter *Protichnites*.

Fucoids.

The fucoids abound most in the upper part of the formation, and one prevailing form of these marine plants presents a reticulating arrangement of stems spreading over the surfaces of the beds, the meshes of the net-work being four, five, or six-sided, and sometimes, when largest, measuring fourteen inches in diameter; while the rope-like stems which divide them are an inch wide, standing out half an inch in relief on the sandstone. The mesh-like compartments are sometimes filled with a green shale, and the forms much resemble crack-casts, and might be taken for such, were not similar forms sometimes traceable on splitting open closely fitting surfaces of sandstone when no shale is present between, and were not smooth surfaces of an arenaceo-bituminous limestone in the succeeding formation met with, presenting thin black bituminous pellicles arranged in similar reticulating figures, both large and small. It is not improbable, however, that in some cases these forms may really be casts of cracks.

7.—SUPPOSED ANNELIDE BURROWS. NATURAL SIZE.

7



Scolithus Canadensis (Billings).

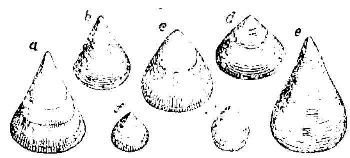
The upper part of the formation is abundantly marked over considerable surfaces by *Scolithus Canadensis*, which, when the rock is weathered, is seen on the surface of the beds in the form of small nearly circular holes, from one twentieth to one fourth of an inch in diameter. These sometimes penetrate vertically to the depth of several inches; but in general, on breaking up the rock, they are found to be more or less curved in different directions, and often irregularly contorted and intermingled with each other. They are not unfrequently somewhat prismatic, the transverse section exhibiting three, four, or five sides. The casts of the interior of these cavities in freshly broken or unweathered masses of the rock usually appear as solid cylindrical or angular rods, composed apparently of grains of sand cemented by a slightly calcareous matter, more or less tinged with peroxyd of iron. The origin of these holes is not quite certain: some suppose them to be the remains of fucoids, others of corals, while many are of opinion that they were the habitations of small burrowing marine or shore-frequenting animals. Whatever may have been their origin, they Scolithus.

characterize the upper part of the formation extensively. The original specimens, upon which the genus was established, differ from those above described in being straight and more decidedly cylindrical, and are therefore probably a distinct species,—but at present very little is known concerning the affinities of these fossils.

Lingula; Orthoceras.

In Lansdowne and Bastard, in what we consider to be the beds of passage between the Potsdam and the succeeding formation, *Scolithus* and fucoids exist in abundance, and are there found associated with *Lingula acuminata*. At Beverley in the township of Bastard and in the township of South Crosby small orthoceratites and *Ophileta compacta* occur, though

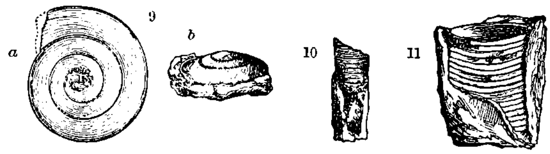
8.—BRACHIOPODA.



Lingula acuminata (Conrad). Specimens showing the variations in form and size; *a, b, c* and *e* are ventral valves; *d* is a dorsal valve; *f, g*, are young shells.

rarely, in beds which hold this same species of *Lingula* in vast profusion. At Beauharnois, on the south side of Lake St. Louis, about twenty miles above Montreal, *Ophileta compacta* occurs near the beds with *Protichnites*.

9-11.—GASTEROPODA AND CEPHALOPODA.



9.—*Ophileta compacta* (Salter). *a*, view of the lower ? or flat side. *b*, cast of the upper or concave side.
10.—Fragment of an *Orthoceras* from Beverley.
11.—Fragment of an *Orthoceras* from South Crosby.

This name has been given to the foot-prints of an animal which Professor Owen has pronounced to be some species of crustacean.

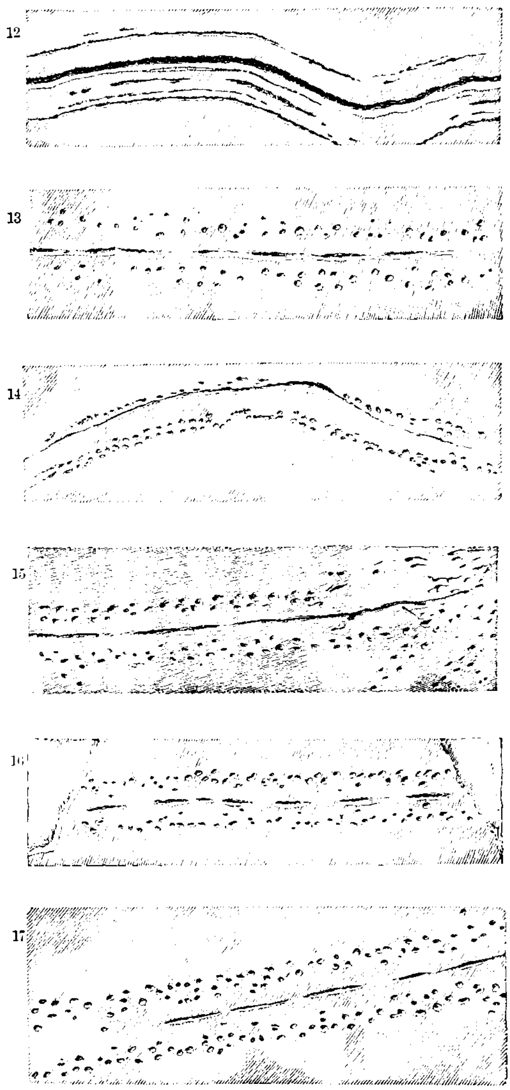
Protichnites.

The first track discovered was met with near the mill on the St. Louis River at Beauharnois; and the late Mr. Abraham, editor of the *Montreal Gazette*, was the first to draw attention to it, by a notice in his journal, in which he compared it to the track of a tortoise. A plaster cast of the track having been inspected by Professor Owen, the first examination by this celebrated comparative anatomist rather tended to confirm this opinion. But the original stone having been subsequently submitted to him, as well as two additional original surfaces and casts of a great number of other impressions of the same order, several of these giving much clearer evidence than the first specimen, Professor Owen was led to conclude that the footsteps could not have been imprinted by any quadruped, and that analogies were most in favor of their having been produced by some species of crustacean, but of a family wholly distinct from anything presented by the crustacean forms of later geological periods or of the present day.

The track, when the specimens are most perfect, generally presents a median groove more or less flat and of different proportionate widths in different specimens, with a number of footprints on each side in corresponding pairs. Certain sets or numbers of these pairs have homologous repetitions throughout the whole length of the track, as if they were the result of successive applications of the same impressing instruments, and the numbers of corresponding pairs in the homologues of different tracks are sometimes different, constituting something which may be considered analogous to difference of species. The homologues in different tracks appear to have sometimes seven and sometimes eight answering pairs of pits, and it is difficult to say whether the pits are to be taken as impressed by the extremities of so many legs, thus giving the animal fourteen legs in one case and sixteen in the other, or whether some of the impressing points are to be grouped in twos or threes, making some of the legs bifid or trifid, and thus diminishing their number, as Professor Owen is inclined to suppose. The impressions are generally of such a nature as to negative the supposition that the impressing instruments were of a soft or padded nature, and the depth and trenchant sharpness of the markings in the bottom of some would seem to show the effect of hard horny points.

The groove in most of the tracks is so uniformly in the middle between the footprints as to have favored the supposition that it might have been produced by an immovable breast-plate or plastron; but in one remarkable instance, at a bend in a track, the groove gradually leaves the middle, and, while it seems impressed with more force than usual, approaches and partly obliterates the footprints on the convex side, as if the pressing part had been a tail, which when the body turned to one side, interfered with the footprints in the rear on the other. A feature common to all the grooves is that each repetition of the series of footprints is accompanied with a deepening and shallowing of the groove, giving it the appearance of a chain of shallow troughs, which, when the impression is light, are separated from one another by intervals of an ungrooved surface. The groove is often but faintly indicated, and occasionally is not perceptible. It frequently happens, when this occurs, that the footprints are stronger and deeper than when the groove is more conspicuously impressed.

12-17.—TRACKS FROM BEAUHARNOIS. SCALE $\frac{1}{10}$.



12.—*Protichnites lineatus* (Owen).
13.—*P. alternans* (Owen).
14.—*P. multinotatus* (Owen).
15.—*Protichnites septemnotatus* (Owen).
16.—*P. octonotatus* (Owen).
17.—*P. octonotatus* (Owen).

In some of the tracks, while the groove is straight, the exterior limits of the footprints offer a congeries of segments of a circle convex on the outside; but those on opposite sides of the groove alternate, the segment on the one side starting from the middle of a segment on the other, and giving to the whole series of footprints in the track a serpentining course, as if the animal had waddled in its gait. In one of the tracks there are three narrow grooves instead of footprints on each side of the main one, as if the limbs of the animal had been dragged along while the body was afloat.

Prof. Owen's names. In conformity with these various differences in the tracks, Professor Owen has given separate provisional names to several of them, not for the purpose of indicating a positive specific difference in the animals which impressed them, but for the convenience of reference. The generic term is *Protichnites*, and the specific names are *P. septemnotatus*, *P. octonotatus*, *P. multinotatus*, *P. alternans*, and *P. lineatus*.

The surfaces on which the tracks of these animals are impressed are sometimes smooth, and sometimes beautifully ripple-marked. On the latter the tracks have often beaten down the ripple-marks, and the sand of the ridge has been dragged into the furrow, in such a way as to show the direction in which the animal was progressing. In all the tracks, with the exception of *P. lineatus*, there is a diverging arrangement of the successive answering pairs of footprints in each homologous set of impressions, and the relation of this divergence to the direction of progress in the tracks on the ripple-marked surfaces, gives the means of establishing the direction of movement in every other case.

The most abundant locality of these tracks is on the field of Mr. Hénault, about half a mile westward from that near the mill. There are four exposed areas in the space of four chains. Before any specimens were removed, the first area shewed ten tracks running in different directions, and sometimes crossing one another; they varied in width from four inches and a quarter to five inches and a half, and their total length was 108 feet. The second displayed eleven tracks, from five to six inches wide, measuring about 108 feet. The third shewed five tracks of from four to six inches wide, and were altogether sixty-one feet long; the fourth, five tracks from three quarters of an inch to five and a half inches wide, and giving an aggregate length of eighteen feet. Another area in the next field had ten tracks of from four to six and a half inches wide, with a total length of fifty-six feet.

Section at Beauharnois. The following is a section of the beds as they succeed one another in descending order in the vicinity, the whole of them being fine grained:—

	Ft.	in.
White sandstone, hard and compactly granular, with indications of closely soldered elementary layers,	6	0
White sandstone, with small ferruginous spots and indistinct traces of *Scolithus Canadensis* at the top; the joints in the top are stained with peroxyd of iron,	2	0

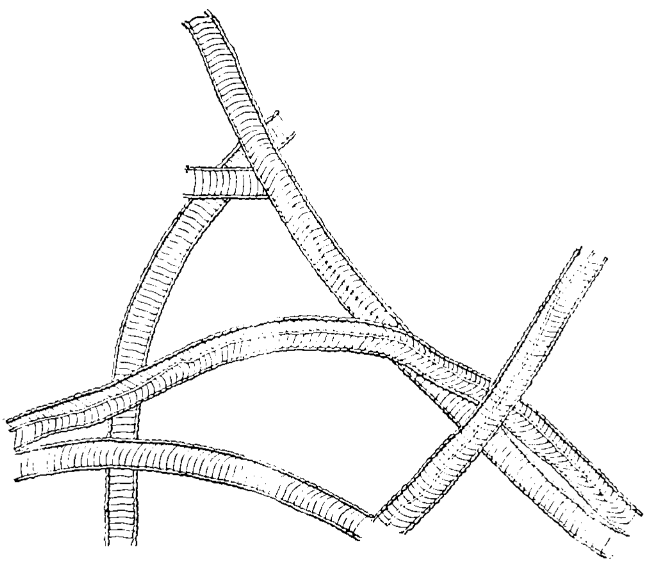
		Ft.	*in.*
White sandstone, even-bedded and splitting into rectangular blocks, fit for building purposes,		1	6
White sandstone with very regular cleavage and bedding, fit for building and glass-making; there are ripple-marks and reticulating fucoids on the top,		1	3
White sandstone with a smooth surface,	0·7 inches.		
White sandstone with ripple-mark and tracks,	0·5 "		
White sandstone with ripple-mark,	0·1 "		
White sandstone with wind-mark,	0·1 "		
White sandstone with a smooth surface and tracks,	0·2 "		
		0	$1\frac{6}{10}$
White sandstone; this bed is made up of beautifully regular parallel layers of from two to four inches, closely fitting together, but distinctly marked by very slight differences of color; the joints are remarkably regular, and the bed would yield excellent material for glass-making and building, and perhaps for flagging,		3	0
White sandstone with broad ripple-mark on the top, measuring from eight to ten inches between the ridges,		4	0
Light grey limestone in patches, passing into sandstone, and displaying abundance of *Scolithus Canadensis*,		0	4
White sandstone,		5	4
White sandstone slightly calcareous, with a thin more silicious bed at the top, covered over with iron stains, and marked by *Scolithus*,		4	11
White sandstone marked on top by *Scolithus*,		1	1
White sandstone slightly calcareous, with ripple-mark and *Scolithus*,		1	6
White sandstone less calcareous, with *Scolithus*,		0	6
White calcareous sandstone; the calcareous matter is more abundant in portions, and the rock wears unequally,		2	0
White sandstone slightly calcareous, with *Scolithus* prevailing in a few inches at the top,		2	2
White sandstone slightly calcareous, with a *Scolithus* bed at the top,		2	1
White sandstone slightly calcareous, *Scolithus* at the top,		0	6
White sandstone with a *Scolithus* bed at the top, holding calcareous patches,		2	6
White sandstone with calcareous indications, and a *Scolithus* bed at the top,		2	6
Measures concealed,		10	0
Greyish calcareous sandstone, with two bands of limestone pebbles towards the middle; the top and bottom surfaces of the bed are marked with large reticulating forms; some of the meshes are fourteen inches in diameter, and the stems from one and a half to two inches wide: the forms of the meshes are sometimes four, sometimes five, and sometimes six-sided; the part included within the mesh is filled with clay or rather a crumbling dark green shale, giving a brownish streak; when the shale is removed the stem-like portions stand out in relief to the height of half an inch. Geodes or nodules of reddish calc spar occur in the bed, sparingly disseminated,		2	0
		55	3

Ripple and wind marks.

The ripple-marks which occur on surfaces so close to one another in succession among the track-beds, run in different directions, as if they had been caused, not by a current in deep water running in one general direction, but by a tide ebbing and flowing, and obeying the influence of varying local accidental causes. On one surface is observed the natural edge or termination of the ripple-ridges, with a track coming up to it and then ceasing, as if the wave had reached no farther and one part of the surface had been dry, while the water, operating on another close by, had obliterated the track in producing the ripple-mark. The subjacent surface is again marked by ripples, and the succeeding one by wind, as is shown by a multitude of slender straight parallel ridges, so well known to all who have observed the effect of a strong wind on loose sand or snow. This surface had been previously marked by ripples, and the erosion, by the wind, of the ripple-ridges appears to have more or less reduced each of them to a series of small separate mounds, ranged in the line of the ridge. Behind all these mounds there are stains of peroxyd of iron; and it appears probable that the peroxyd may have been derived from ferruginous grains, from which the lighter sand had been winnowed by the wind. We may thus have a comparative measure of the strength of the wind, which was sufficient to propel silicious sand, but insufficient to carry along grains of iron ore.

About a mile from Perth, in a quarry on the sixth lot of the third range Climactichnites of Perth.

18.—TRACK FROM PERTH. SCALE $\frac{1}{30}$.



18.—*Climactichnites Wilsoni* (Logan).

of Drummond, belonging to Mr. Glen, Dr. James Wilson of Perth has discovered, in association with *Protichnites*, the trail of what is supposed to have been some species of mollusk. A description of the track, which has received the name of *Climactichnites*, has been given in *The Canadian Naturalist and Geologist*, vol. V. p. 279. It consists of a series of parallel ridges, resembling ripple-marks, about an inch and three quarters apart. These are arranged transversely between two narrow, continuous, parallel, beaded sinuous ridges, about six inches apart, giving to the whole impression a form very like a ladder of ropes. The transverse ridges are occasionally straight, but in general more or less curved, and there runs along the track a ridge intermediate between the two side ridges, which, although not so conspicuous as these, is seldom altogether wanting, but appears to be most obscure when the transverse ridges are straight. The intermediate ridge does not keep constantly parallel with the side ridges, but occasionally runs in sinuous sweeps from within an inch and a half of one side to within the same distance from the other; and the most salient part of the transverse ridges, when these are curved, appears generally, but not always, coincident with its position.

The Potsdam, a shore deposit.

That portion of the Potsdam group which has here been described appears to have been deposited in shallow water along the margin of the Lower Silurian sea, and the wind-mark on one of the surfaces connected with the track-beds at Beauharnois proves incontestably that these beds were uncovered at the ebb of tide. In the eight localities in which these tracks have been met with, extending on the strike of the formation for about 400 miles, the beds on which they are impressed are always of the same lithological character, and seem to stand in the same relation to the summit of the formation, where this can be ascertained. We have thus good reason to believe that all these beds were at nearly the same geographical level at the same time. Three of the localities occur along the foot of the Laurentide hills, from which the beds stretch out at a very low angle into the Silurian plain in front. The hills, at no very great distance from the outcrop of the Potsdam formation, rise to heights varying from 500 to nearly 4000 feet; and while the sand at their base lay between the ebb and flood of tide, the flank of the Laurentide mountains must have formed the coast of the Lower Silurian sea. As has already been stated, these hills extend from Labrador to the Arctic Ocean, and we can thus trace out this ancient limit of the ocean for 3500 miles.

The thoroughly rounded form of the grains of sand composing a large portion of the deposit, and the fact that all the material other than quartz has been bruised up and washed out from so much of it, would seem to make it probable that the formation accumulated slowly, and that the Potsdam coast remained unchanged for a great length of time. The fact, however, that the formation is in some places overlapped by the succeeding deposit, would seem to show that a subsidence had commenced toward the end of the epoch; and the passage, by interstratification, with the succeeding rock, which is so distinct in many places, appears to indicate that the subsidence was slow and gradual. Its duration, and the area affected by it, must be proved by the accumulation and distribution of the succeeding formations. If it be assumed that the track-beds were deposited at about the mean level of the sea, we have a bench-mark by which to know how nearly they have been restored to their original position after their subsidence and re-elevation, and what inequalities of level were produced over the area including them, during the period of their movements. The present heights over the summer level of Lake St. Peter,* of the various track-bed localities which have been mentioned, are approximately as follows :—

Beauharnois, east side of anticlinal,.........	80	feet.
Beauharnois, west side of anticlinal,........	80	"
Vaudreuil, ...	83	"
Ste. Geneviève Island, near Ste. Anne,.....	75	"
Chicot, ...	160	"
Lachute, ...	145	"
Petite Nation,............................	130	"
Perth, ...	430	"

* Lake St. Peter is the highest part of the St. Lawrence affected by the action of the tide. At the flood of spring tides its surface rises about six inches, not however from any back flow in the lake, but from a diminution in the rate of its current through the accumulation of the water farther down. The summer level of the lake is a small but uncertain number of feet above high water at Quebec, and it has not been ascertained how much the latter is above the mean level of the sea. The heights of the great lakes of the St. Lawrence, and of most of the points in the interior, given in the first chapter, are calculated from the summer level of Lake St. Peter as a datum; but they are spoken of as above the level of the sea, because, while the difference is not great, such a datum is more readily understood.

CHAPTER VII.

THE CALCIFEROUS FORMATION.

THE CALCIFEROUS SANDROCK; A MAGNESIAN LIMESTONE; PART OF A GREAT GROUP.—GEODES; CONCRETIONARY LAYERS.—CLAYSTONE.—DISTRIBUTION OF THE FORMATION; ITS ABSENCE IN SOME PARTS OF CANADA.—MINGAN ISLANDS.—FOSSILS; GASTEROPODS; ORTHOCERATITES.—TRILOBITES.

The name of Calciferous sandrock was given by the New York geologists to the formation which immediately succeeds the Potsdam sandstone. Calcareous sandstone beds mark the passage between the two; but the characteristic portion of the formation, at least in Canada, is a granular magnesian limestone or dolomite, which, from its rough weathered surfaces and its slight effervescence with acids, may have suggested the name of the Calciferous sandrock. We purpose in the present chapter to describe the extension in Canada of the formation which is thus designated in New York. In the valley of the Upper Mississippi, where this formation is greatly developed, it is known as the Lower magnesian limestone. Investigations now in progress tend to show that this calciferous sandrock forms part of a great series of strata, which in Eastern Canada are known as the Quebec group, and that it is there represented by the limestones at Point Lévis. As mentioned in a previous chapter, it is supposed that a portion of the upper copper-bearing rocks of Lake Superior is of the same age.

The typical Calciferous sandrock, which succeeds to the Potsdam in New York and the adjacent parts of Canada, consists in the lower part of a dark bluish-grey, crystalline, strongly coherent dolomite or magnesian limestone, weathering yellowish-brown, and very often holding small geodes, generally filled with calcareous spar, but sometimes containing quartz crystals, sulphate of barytes, sulphate of strontian, and sulphate of lime or gypsum. The fossils have in most cases disappeared, leaving only their moulds in the rock. The upper part of the formation is in some places a bluish-grey calcareous argillite, weathering yellow or brown, and often having a bituminous odor. The total thickness of the formation is supposed to be about 300 feet.

A short distance above Maitland, in the township of Augusta, the following ascending section* was measured, shewing the beds of passage :— Section at Maitland.

	Ft.	in.
White quartzose sandstone, with thin interstratified calcareous bands,	5	0
Brownish-grey calcareous sandstone,	2	0
Measures concealed,	10	0
White sandstone with soft brown-stained vertical streaks, probably *Scolithus Canadensis*,	5	0
White sandstone, calcareous in the upper part,	4	0
Pale grey limestone, with great quantities of fucoids on the upper surfaces of the beds,	3	0
Measures concealed,	6	0
Pale grey or drab colored sandstone in thin beds,	3	0
Bluish-grey silicious limestone,	0	6
Measures concealed,	6	0
Dark grey calcareous sandstone,	2	6
Grey quartzose sandstone, weathering brown,	2	0
Dark bluish-grey limestone,	3	0
Dark brownish-grey cherty limestone, in irregular layers,	2	6
Dark bluish-grey limestone with geodes of calcspar; there are exposed on the surfaces fucoids and many convoluted shells,	5	0
	59	6

Gentle undulations in the strata occur descending the river from this, carrying the same measures to the vicinity of Battle Windmill, a little below Prescott. The dip of the measures is here nearly east, at an angle of two or three degrees, and the following section is met with in continuation of the previous one :— Section near Prescott.

	Ft.	in.
Grey limestone,	3	6
Dark bluish-grey limestone, with occasional large concretionary balls,	2	0
Brownish-grey rather coarse textured limestone, with obscure convoluted shells,	4	6
Dark bluish-grey limestone, of a crystalline texture, sometimes tinged with red, and separated into beds by thin layers of a very dark blue shale,	1	2
Dark bluish-grey limestone, with geodes of calcspar,	0	6
Brownish calcareo-arenaceous shale,	0	3
Dark bluish-grey limestone,	0	8
Pale grey compact limestone, with geodes of calcspar; a thin division of greenish-brown shale lies between it and the previous bed,	0	10
Pale grey compact yellow-weathering limestone, rapidly disintegrating on the surface,	0	8
Drab colored calcareous sandstone, probably magnesian, with a large quantity of calcspar in geodes,	1	5

* The beds described as limestones in the sections here given, are in most, if not in all cases, dolomite; and it is not improbable that some of those designated as calcareous sandstones may be of a similar nature, although at the time the sections were examined they were supposed to be, as previously described by Prof. Emmons in New York, mixtures of silicious sand with limestone. Many of the dolomites of this series, however, have a large admixture of sand.

	Ft.	in.
Grey limestone, with many geodes of calcspar, and cracks lined with the same mineral,	0	7
Grey limestone,	0	5
Pale grey limestone, weathering of a decided yellow, and rapidly disintegrating on exposed surfaces; the bed is filled with concretionary masses, the concentric layers of which are frequently interleaved with white calcspar,	1	2
	17	8

Section at Rigaud.

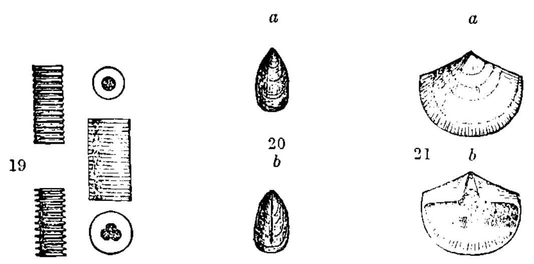
At the bridge on the Rivière à la Graisse, at Rigaud on the Ottawa, there is an exposure of the upper part of the Potsdam formation and the beds of passage. The dip is S. $< 4°$, and the following is an ascending section of the beds of passage:—

	Ft.	in.
Light grey sandstone, dotted with many dark grey translucent grains. The surface weathers into small pits,	2	0
Dark grey calcareous sandstone,	2	0
Dark grey sandstone,	1	3
Grey calcareous sandstone,	1	6
Whitish sandstone, with two *Scolithus* beds at the top,	3	6
Grey hard close-grained calcareous sandstone, with geodes of calcspar,	2	8
Grey hard vitreous sandstone,	0	9
Grey fine and close grained sandstone,	0	6
Grey close grained limestone, probably magnesian, with geodes of calcspar,	1	6
Greyish and whitish sandstone, with bands of magnesian limestone weathering reddish,	1	0
Greyish and whitish sandstone, with bands of limestone weathering yellow,	1	7
Grey brownish-weathering magnesian limestone with geodes of calcspar,	3	2
Grey brownish-weathering magnesian limestone, with small geodes of calcspar,	0	8
Grey close grained yellow-weathering magnesian limestone, with large geodes of calcspar,	2	0
Whitish sandstone, grey and calcareous in parts,	2	6
Grey sandstone slightly calcareous, with about one inch of coarse grained sandstone on the top, weathering like a *Scolithus* bed,	0	6
Grey sandstone with much calcareous matter at the top,	0	10
Grey close grained calcareous sandstone; the surface weathering into grooves and small pits,	1	6
Reddish-grey magnesian limestone, with a conchoidal fracture. It weathers into fine grooves like ripple-mark, as if fucoids were running through it,	2	0
Grey close grained calcareous sandstone, with some bands more silicious than others. It holds geodes of calcspar; the surface weathers into grooves and small pits. Between the layers there are coatings of hard sandstone. The beds hold *Helicotoma* and *Murchisonia*, rather obscure,	2	3
Reddish-grey magnesian limestone, with a few geodes holding calcspar,	2	0
Reddish-grey magnesian limestone,	5	0
	40	8

Claystone.

On this part of the Ottawa the middle portion of the formation is concealed; but the summit is met with on the bank of the river above Carillon, where about a hundred feet of arenaceous limestone and of a bituminous calcareous clay-stone terminate in a singular and extensively spread concretionary layer, like that noticed in the section below Prescott. In some large exposures of it on the Grenville canal, about half a mile below

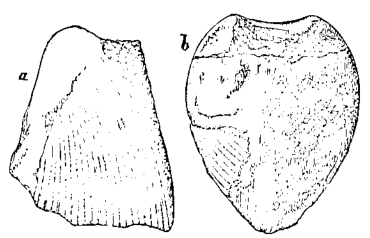
19-21.—CRINOIDEÆ AND BRACHIOPODA.



19.—Crinoidal columns from the Calciferous formation.
20.—*Lingula Mantelli* (Billings); *a*, ventral valve; *b*, dorsal valve.
21.—*Orthisina grandæva* (Billings); *a*, ventral valve; *b*, ventral valve shewing area and foramen.

Grenville village, surfaces of half an acre shew the concretions, consisting of concentric layers seemingly cut horizontally in half and packed closely together, some of them being two and three feet in diameter.

22.—LAMELLIBRANCHIATA.



22.—*Conocardium Blumenbachii* (Billings); *a*, side view; *b*, posterior view.

Distribution of the formation.

The flat anticlinal mass of Potsdam projected northward from Beauharnois into the county of the Lake of Two Mountains, divides the Canadian portion of the Calciferous formation into two parts, which join over a shallow saddle-shaped depression in the neighborhood of Ste. Scholastique.

In the geological map of New York, the eastern portion of this formation is represented as appearing near Keeseville, no very great distance above the base of the Potsdam, where both are overlapped by the succeeding member of the Lower Silurian series. The Calciferous there emerges with a wedge-like point, and runs in a band of about two miles wide, to the province line; but here the dip probably diminishes considerably, as the formation in Canada spreads out on the east side of the Beauharnois anticlinal to a breadth of six miles, and in some places more. With this breadth, a little to the west of the Richelieu River it folds over an anticlinal, the axis of which runs northward under Chambly. On the west side of this the formation sweeps round the extremity of a synclinal in its progress to Lake St. Louis, east of Hénault's track-bed.

Lake St. Louis. Proceeding eastward from the track-beds on the east side of the Beauharnois anticlinal, white Potsdam sandstone, marked by *Scolithus*, and nearly horizontal in attitude, can be traced along the shore of Lake St. Louis for about a mile; there is then an interval of about a mile without any exposure, beyond which the Calciferous makes its appearance. Thin interstratified bands, more arenaceous than others, are still characterized by *Scolithus*, and more massive dolomitic ones by *Ophileta compacta* and *Maclurea matutina*. The strata are nearly flat, and, seen at intervals, continue so for about six miles to the bridge over the Chateauguay River; in the first two miles, these same two species of gasteropods are met with in several exposures, while the lithological character of the rock varies but little the whole way.

Montreal Island. Northward from this the formation passes across the upper end of the island of Montreal, where the lower beds are characterized by *Leperditia Anna* and *Murchisonia Anna*. It then crosses the upper end of Isle Bizard, and the summit of the formation, turning more eastward, comes in upon the north-west side of the upper part of Isle Jésus, leaving, through the effect of gentle undulations, a broad expanse of the rock between the island and the Rivière du Nord, marked near the village of St. Eustache by *Lingula Mantelli*. North-eastward of this the breadth rapidly diminishes, and north of St. Lin is reduced to about two miles. Varying from this to four miles, it follows the Potsdam band until it meets with the Chicot downthrow, beyond which to the north-eastward it is not yet certainly known for several hundred miles.

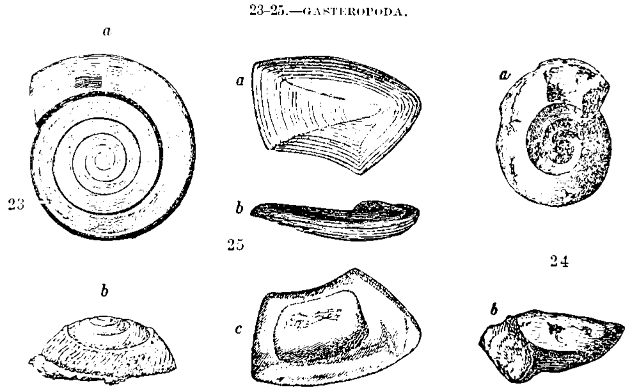
On the west side of the Beauharnois anticlinal, the Calciferous, following the Potsdam in its sinuosities, completely surrounds the triangular Silurian trough lying between the Ottawa and the St. Lawrence. Passing westward from the track-bed on the west side of the anticlinal, the lower formation can be traced with little interruption obliquely across the measures for a distance of three miles up the St. Lawrence, where it becomes interstratified with calcareous and magnesian layers; but at St. Timothy, three miles farther up, sandstone beds holding *Scolithus* are still met with, and *Bathyurus conicus* with *Pleurotomaria calcifera* occurs in the calcareous ones. For three or four miles farther up the river the strata are concealed by drift until reaching Grande Isle, where quarries expose good limestone beds resting horizontally on others of an arenaceous character.

The fossils of these limestone beds appear to belong to the Chazy formation, of which the strata of the island may perhaps constitute an outlier. The summit of the Calciferous must thus be on the mainland close by.

From this neighborhood the outcrop of the formation on the south side of the triangular trough runs chiefly on the south side of the St. Lawrence, where it has a breadth, varying, in consequence of the smallness of the dip, from ten to fifteen miles; the greatest width being about opposite to Williamsburgh, where it is wholly in New York. Notwithstanding the width of the deposit, however, the only fossil species met with in Canada in this part, in addition to those of St. Timothy, are *Holopea ovalis* and *Murchisonia arenarea*, occurring in the township of Godmanchester. The

South side of the St. Lawrence.

23-25.—GASTEROPODA.



23.—*Ophileta compacta* (Salter): *a*, view of the flat under side; *b*, cast of the concave upper side.
24.—*Maclurea matutina* (Hall); *a*, view of under side; *b*, view of aperture.
25.—Operculum of a species of *Maclurea*, perhaps *M. matutina*; *a*, *b*, *c*, exterior, side, and interior views.

great amount of drift covering the country prevents the summit of the rock being seen on the Canadian side higher up the river: it is supposed to be somewhere near Matilda, but the base of it has already been indicated in the section at Battle Windmill.

From the neighborhood of Ste. Scholastique, where the inferior part of the formation bends over the shallow saddle-shaped depression on the Beauharnois anticlinal, the northern base runs to Lachute and the southern to Rigaud, in which places they have already been indicated. The summit of the formation, at right angles across the measures from Lachute, occurs near the front of Chatham on the east side of the township. The distance across is six miles, and the inclination of the strata about seventy-five feet in a mile, which would give a thickness of 450 feet.

Chatham.

The band in its progress westward from this, along its outcrop on the north side of the triangular trough, diminishes considerably in its breadth towards Grenville, where, as has already been stated, it appears to overlap the Potsdam for a short distance. Beyond this it seems to maintain a pretty uniform breadth, following the Potsdam zone until it meets with the Hull fault; but in its progress it is often concealed wholly or in part by the river, and passes to the south side of it only in Alfred, Plantagenet, and Clarence.

Grenville.

Rigaud.

At Rigaud, the summit, at right angles from the base, is concealed by drift, but is probably about two miles east of the line between the eastern and western divisions of the province. From Rigaud, the base of the formation appears to pass close round the west end of Rigaud Mountain, and then to turn south-east towards Beauharnois; while the summit from the vicinity of Rigaud on the one hand and Grande Isle on the other, is projected twenty miles west of the mountain, through the influence of a sharp anticlinal form, folding over the axis of which the rock presents a low ridge running across Lochiel and two miles into Kenyon. The dip on the north side of the anticlinal is sharper than that on the south; and on the crown of the arch two narrow exposures of Potsdam, each about a mile long, protrude through the superior formation. They are about seven miles apart, and the more easterly one is about six miles from Rigaud Mountain.

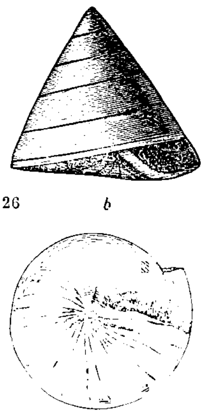
Dislocation.

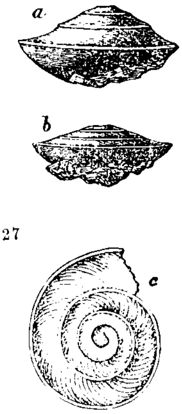
This fold thus divides the triangular trough into two subordinate synclinals, and in its progress westward traverses the townships of Osgoode, Gloucester, Nepean, March, Huntley, and Fitzroy, and comes upon the Lac des Chats near the mouth of the Madawaska; but in these townships the strata on the axis of the fold have become torn asunder, and the fold is represented by the dislocation which has already been alluded to as bringing the Chazy and the superior rocks against the Potsdam in Nepean. The fault which branches from this in Osgoode and Gloucester, and crosses the north subordinate trough into Hull, brings up the Calciferous in Gloucester to abut against the Utica formation; and from this position on the south side of the trough, and a corresponding upthrow displacement on the north, the two outcrops come to a point, joining at the base in Bristol, and at the summit in the south part of Torbolton on the margin of Lake Chaudière. The south outcrop is much the broader of the two; it flanks the Potsdam to within about four or five miles of Fitzroy Harbor, but there, as has already been stated, overlaps it, and comes against the gneiss, forming the Chats cascade.

On the west side of the Laurentian spur, the Calciferous, like the Potsdam, is concealed by superior deposits along the line of the main dislocation, until reaching the division between the townships of Huntley and Fitzroy. Here the Calciferous emerges with a wedge-shaped point from beneath the Chazy and is carried by a synclinal form into MacNab, and back through

Pakenham, Ramsay, and Beckwith. This trough, like the great one, is divided into two subordinate synclinal forms by an anticlinal; on the axis

26, 27.—GASTEROPODA.

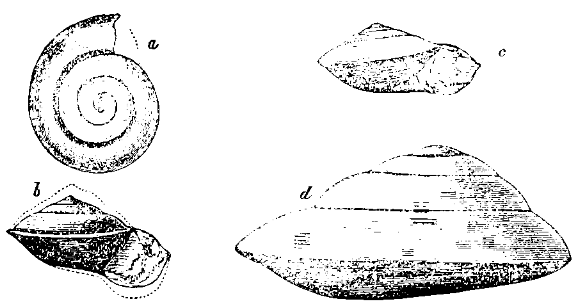




26.—*Pleurotomaria Ramsayi* (Billings); *a*, side view; *b*, view of base.
27.—*Pleurotomaria calcifera* (Billings); *a*, common form; *b*, variety with depressed spire; *c*, view of spire.

of which, running parallel with the axis of the main fold, the Calciferous is carried nearly to the west corner of Huntley, where it is pierced by an Huntley.

28.—GASTEROPODA.



28.—*Pleurotomaria Laurentina* (Billings); *a*, view of spire of small specimen; *b*, side view of the same; the dotted line shows the elevation of the spire in other specimens; *c*, *d*, side views of other specimens.

elliptical exposure of Potsdam, surrounding a protruding point of gneiss. In Pakenham, within a ring of Potsdam, it constitutes the higher part of Pakenham.

the shallow outlying Silurian trough already mentioned; and farther north on the Lac des Chats it forms the rim of another outlying Silurian portion, without any Potsdam coming from below it. Beneath the Allumettes outlier and the adjacent ones, it appears, like the Potsdam, to be wanting.

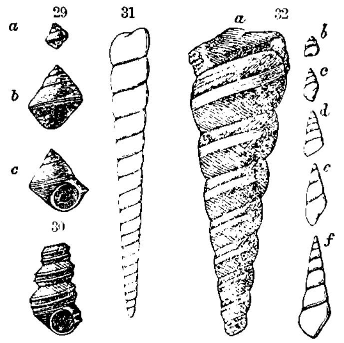
Beckwith and Osgood to the St. Lawrence.

Between Beckwith and Prescott, the base of the formation has been given in tracing the summit of the Potsdam, but the summit of the Calciferous between Gloucester and Matilda is by no means so certain. Between the St. Lawrence and a line from Beckwith to Osgoode, there may be upwards of 2000 square miles of the formation in an almost unbroken sheet; but the covering of drift in this region is so general that comparatively few opportunities of observation occur, and this is particularly the case in that part where the junction of the Calciferous and the Chazy may be expected. To the west of the Potsdam in Gloucester, the Calciferous appears to be brought against the Hudson River formation, both in Gloucester and Osgoode, by the branch fault which runs into Hull. To the south-west of this, the exposures of the rock that have been met with nearest to the supposed summit are at Spencer's mills on the Petite Nation, and at Grant's mills lower down, in the first lot of the seventh range of Edwardsburgh. In Oxford, the rock is exposed in the twenty-sixth lot of the tenth range, and in the thirteenth lot of the eighth range, not far from a denuded mass of quartzite belonging to the Potsdam formation or to the Laurentian beneath. It occurs also near Kemptville, on the twenty-fourth and thirtieth lots of the third and fourth ranges, and in South Gower on the tenth lot of the ninth range. In Young, it is exposed on the eleventh lot of the eighth and ninth ranges at Loyada Lake in the rear of the township, and also in Kitley near the village of Kitley Corner. On the Rideau canal it is seen at Smith's Falls, in a cliff of thirty feet, and at Kilmarnock, Mirickville, and Nicholson's Rapids. The beds of the Calciferous formation have been extensively used in the construction of some of the locks of the Rideau canal, and these in general afford good examples of the stone. The stone has been used for building purposes at Brockville and Prescott, and in the neighborhood of Brockville and at Mirickville; some of which yields good lime of a dark color, producing a mortar of considerable strength.

None of this formation has been observed among the Thousand Islands, and there is no certain fossil evidence that it occurs on the west side of the low Laurentian ridge here crossing the St. Lawrence, either where the Potsdam is present, or farther to the westward where it is absent. On the west side of the ridge, following the Potsdam where this is present, and resting on the Laurentian series where it is wanting, there are generally met with thirty or forty feet of strata almost destitute of organic remains, and about the same amount with a few fossils insufficient to determine the age of the strata with certainty. The first well characterized beds which succeed these belong to the Birdseye and Black River formation.

It has already been stated that in the eastern part of the province the formation is not recognized with certainty for several hundred miles beyond the position where it comes up against the Chicot fault. It does not appear to succeed the Potsdam at St. Ambroise; and it is not until reaching the Mingan Islands, between 500 and 600 miles to the north-eastward, that we have any of its characteristic fossils. At Bay St. Paul and Murray Bay, however, there is met with a calcareous sandstone Mingan Islands.

29-32.—GASTEROPODA.



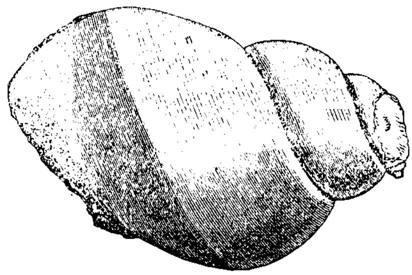
29.—*a*, *b*, *c*, *Pleurotomaria gregaria* (Billings).
30.—*Eunema prisca* (Billings).
31.—*Murchisonia linearis* (Billings).
32.—*a*, *Murchisonia Anna* (Billings); *b*, *c*, *d*, *e*, *f*, small specimens supposed of the same species.

which in the latter place rests on the quartzite that has been mentioned as occurring there. It probably belongs to a higher rock, but the Calciferous formation between that and the Mingan Islands may be covered up by the waters of the St. Lawrence.

At the Mingan Islands and on the neighboring coast, there appears an interesting exhibition of this formation extending from Mingan River to Ste. Geneviève Island, a distance of about forty-five miles. It occupies the inner range of islands and most of the coast, with the exception of a projecting block of land at Clear Water Point, which is composed of the succeeding deposit. The contact of the formation with the lower rock, whether Laurentian or Potsdam, has not been seen; but proceeding from west to east, the summit appears to run outside of Harbor Island, and to strike into the mainland in the corner of the bay above Clear Water Point.

From this it trends to Wood Island, so that the whole of Hunter's Island and of Ste. Geneviève Island belong to this formation.

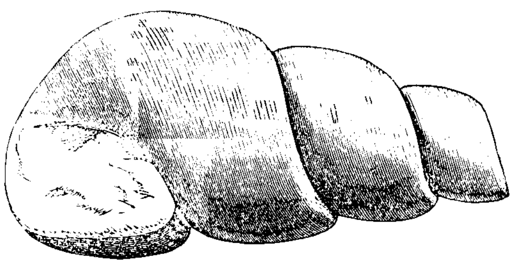
33.—GASTEROPODA.



33.—*Murchisonia arenaria* (Billings).

The rock is here a brownish-yellow and yellowish-grey arenaceous magnesian limestone, holding many geodes and irregular masses of yellowish-white calcspar, and many nodules and patches of yellowish-white chert, which sometimes replaces organic remains. The rock weathers to a dark yellowish-brown, and presents a carious and fretted or honey-combed surface,

34.—GASTEROPODA.

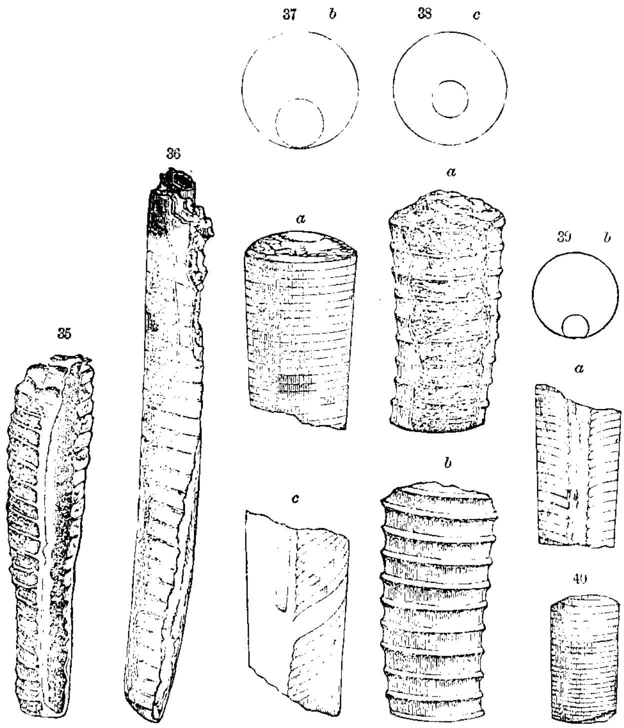


34.—*Subulites calcifera* (Billings).

with a multitude of pits sinking to the depth of sometimes three and four inches; while the salient parts, which are tough and strong, often resemble a confused and tangled collection of twigs; sometimes the surface is worn into rough deep fretted botryoidal shapes. The strata are in general somewhat massive, and dip to the south at a small angle, probably not exceeding a hundred feet in a mile.

In many parts, and particularly in the island of Ste. Geneviève, there are circular areas, varying in diameter from a few paces up to a hundred yards, around which the strata for a short distance dip suddenly and considerably towards the interior, which is confusedly filled with amorphous masses of rock of coarser and softer character than the strata around, and yielding more irregularly and freely to the weather. In some places, where partial sections of these are seen in the cliffs of the island, the areas appear

35–40.—CEPHALOPODA.

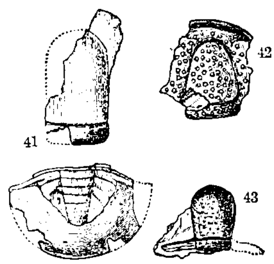


35.—*Orthoceras Becki* (Billings). 36.—Siphuncle of *O.* ———? 37, *a.*—*O. Montrealense* (Billings); *b, c,* sections of the same, showing the siphuncle. 38, *a, b, c.*—*O. Lamarcki* (Billings), with sections. 39, *a, b.* —*O. sordidum* (Billings). 40.—*O. deparcum* (Billings).

to be connected with funnel-like forms, which suggest the idea that they may be the effect of ancient springs, which rose to the surface through the yet unconsolidated sediment, washing away the finer particles, and disturbing and confusing the arrangement of the strata. Remains of ancient springs.

The Mingan development of the Calciferous formation, in a thickness which may reach 250 feet, has added greatly to the number of species characterizing its fauna. On the island of Ste. Geneviève, where chert replaces some of the forms, in addition to *Stenopora fibrosa?* and crinoidal columns resembling some of those of the genus *Glyptocrinus*, there are met with, *Trochonema tricarinata*, *Maclurea matutina*, and the operculum of another species not yet known, *Helicotoma uniangulata*, *Piloceras Canadense*, *Orthoceras multicameratum? O. Becki*, and *Bathyurus Cybele*.

41-43.—CRUSTACEA.



41.—*Bathyurus amplimarginatus* (Billings). 42.—*B. conicus* (Billings). 43.—*B. Cybele* (Billings).

On Hunter's Island, with *Piloceras Canadense* occurs *Holopea turgida*. In a bay near the Pointe des Morts, the rock, which is a tough yellowish-grey arenaceous magnesian limestone, holds many specimens of *Pleurotomaria Laurentina* and *Subulites calcifera*. In the bay above Clear Water Point there occurs a white limestone at the summit of the formation, in which is found *Conocardium Blumenbachii;* and in the same rock on Birch Island, outside of Harbor Island, there are *Pleurotomaria abrupta*, *P. miser*, *Eunema prisca*, and *Murchisonia linearis*.

CHAPTER VIII.

THE CHAZY FORMATION.

LIMESTONE OF GRENVILLE.—SANDSTONES AND SHALES.—PHOSPHATIC NODULES, WITH LINGULÆ.—MONTREAL LIMESTONES.—DISTRIBUTION OF THE FORMATION.—BEDS WITH ENTOMOSTRACA.—OUTLIERS.—MINGAN ISLANDS.

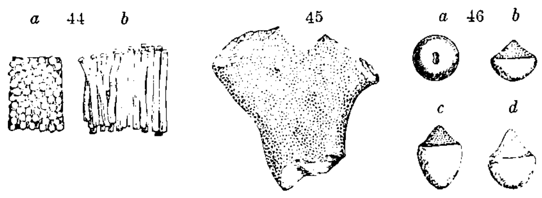
The limestone which overlies the Calciferous formation is designated by the New York geologists as the Chazy limestone, from its occurrence at Chazy, on the west of Lake Champlain. In Canada this limestone becomes associated with sandstones and shales, and is here described as the Chazy formation. Near Grenville, resting upon the band of concretionary limestone, which is there the highest visible member of the Calciferous formation, occurs about ten feet of a calcareous rock, having a bituminous odor, and light or dark grey in color: much of it weathers to a yellowish-brown. A three-feet bed of limestone at the base of this has been quarried in several parts of Chatham and Grenville, for the purpose of burning into quicklime, and occasionally for building stone. The bed is fossiliferous, and contains *Leperditia Canadensis*, *Isochilina Ottawa*, and *Beyrichia Logani*, in great abundance, two or three inches of limestone being in some places almost made up of them. With these are associated *Pleurotomaria pauper*, *Helicotoma umbilicata*, *Murchisonia perangulata*, *Cyrtodonta faba*, *Orthoceras Hisingeri*, and *Bathyurus Angelini*. These are considered the lower beds of the Chazy formation in this part; but at the Chute à Blondeau, about seven miles below Grenville, there is associated with the strata a seven-feet bed of calcareous conglomerate, the pebbles of which are of grey limestone, weathering to a lighter grey on the exterior, while in the calcareous matrix are contained comminuted organic remains. Four feet of dark grey yellow-weathering probably magnesian limestone underlie this, and six inches at the bottom are marked by fragmentary remains of encrinites. Grenville limestone.

These calcareous strata are succeeded by about fifty feet of whitish sandstone, in beds of from two or three to twelve inches, interstratified

Sandstones and shales.

with bands of green shale, holding a vast collection of fucoids, of which a bilobate species is the most conspicuous. Some of the sandstones are porous and moderately fine grained, and yield good fire-stones, while others are coarse, and, in addition to white quartz pebbles, some of them a quarter of an inch in diameter, hold a multitude of black phosphatic nodules, mingled with small fragments of *Lingulæ*. The surface of some of the

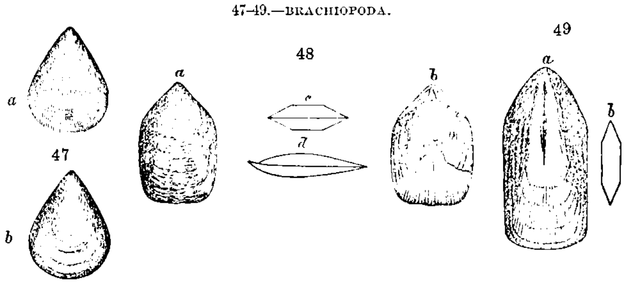
44–46.—ZOOPHYTA.



44.—*Columnaria incerta* (Billings); *a*, end view; *b*, side view.
45.—*Stenopora fibrosa* (Goldfuss).
46.—*Bolboporites Americanus* (Billings); *a*, view of the base showing the small depression; *b*, *c*, *d*, side views.

sandstones display ripple-marks. From Grenville, where the beds have been most exposed by the cutting of the canal, they are found to cross the Ottawa to Hamiltonville in Hawkesbury, and to extend a mile and a half back from the river. Half a mile beyond them a low escarpment appears, the beds in which are composed almost entirely of *Rhynchonella plena*,

47–49.—BRACHIOPODA.



47.—*a*, *b*, *Lingula Belli* (Billings).
48.—*Lingula Huronensis* (Billings); *a*, ventral valve; *b*, dorsal valve; *c*, transverse section; *d*, longitudinal section.
49.—*Lingula Lyelli* (Billings); *a*, ventral valve; *b*, transverse section.

and afford good building stone. Many large loose angular blocks met with before reaching the escarpment, have this species disseminated in a somewhat arenaceous matrix, associated with small black phosphatic nodules and fragments of *Lingulæ*; and it is probable that there may be some thickness of such beds between the sandstones and the more calcareous strata above.

In this neighborhood, the sandstones, although free, yield but an indifferent material for building purposes, though some pretty good slabs from them have been usefully applied as coping in some of the locks of the Grenville canal; but in the neighborhood of Pembroke, about 120 miles farther up the Ottawa, some of the beds, of a foot in thickness, give an excellent freestone, well suited for purposes of construction. At the Allumettes Rapids in this part, the sandstones rest upon the Laurentian gneiss; and in a conglomerate bed at the base of them, dark brown phosphatic nodules occur in abundance, with great numbers of *Lingula Lyelli*, and a few of some species of *Pleurotomaria* or *Holopea*. The shells of the *Lingulæ* are often wholly or in part imbedded in a paste of the phosphate, and, where both valves are together, the interior of the shell is filled with it. The *Pleurotomariæ* are phosphatic casts of the interior of the shells. Some of the nodules are two inches in length by nearly an inch in diameter, and there appears little doubt that they are coprolites. By analysis it has been found that the shells of the genus *Lingula*, both ancient and recent, unlike most other shells, are composed chiefly of phosphate of lime; and it is probable that the phosphatic paste in which the shells are imbedded, is nothing more than comminuted fragments of *Lingulæ*, evidently the food of the animal from which the coprolites were derived. These consist chiefly of phosphate of lime, with small quantities of carbonates, and some organic matter, which by heat evolves ammonia with an odor of burnt horn. They include a portion of sand and fragments of the shells of lingula, often of considerable size. In this sandstone at Aylmer, where the rock is thinly and irregularly bedded, *Asaphus canalis* occurs; a specimen of this species found there, without the head, would, if complete, measure about eight inches in length.

Phosphatic nodules

Lingulæ

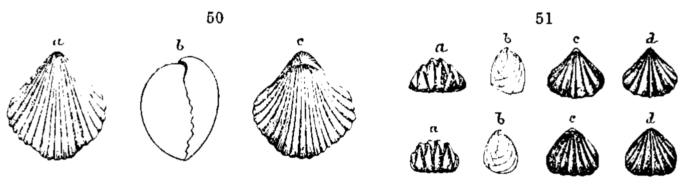
The upper part of the formation is largely developed in the neighborhood of Montreal, and is associated with beds almost filled by *Rhynchonella plena*, which appears to be most abundant at the top. Others are made up of comminuted organic remains, in which fragments of cystideans and crinoids largely prevail, giving to the rock a granular or crystalline character, from the usual peculiar crystallization of these fossils. The most common species among the cystideans are *Malocystites Murchisoni* and *Palæocystites tenuiradiatus*, while among the crinoids the fragments of *Blastoidocrinus carchariædens* are very numerous. Associated with the fragments of these two orders, *Bolboporites Americanus* occurs. It is classed by Salter as a coral, but it presents the same crystalline peculiarity as the crinoids and the cystideans. In the beds holding *Rhynchonella plena*, *Orthis platys* is occasionally abundant; and among the characteristic

Montreal limestones

fossils of the formation in the neighborhood, are *Pleurotomaria calyx* and *Serpulites splendens;* the latter of which, often found more or less spirally twisted, is usually of a deep brilliant black color, and on analysis has been found, like the lingula, to be composed of phosphate of lime.

The beds of this part of the formation are massive, and afford large blocks for building purposes. Those near Montreal have been employed in the construction of the lower locks of the Lachine canal. The usual color of the beds is grey, but they occasionally weather to a light brownish tinge, and some of the layers to a decided yellowish-brown. These are usually found to be of a magnesian character, and some bands and patches are sufficiently so to constitute dolomites. The thickness of this part of

50, 51.—BRACHIOPODA.



50.—*Rhynchonella plena* (Hall); *a*, ventral valve; *b*, side outline; *c*, dorsal valve.
51.—*Rhynchonella orientalis* (Billings); four different views of two specimens.

the deposit is estimated to be about sixty or seventy feet, and the total volume of the formation is supposed not to exceed 150 feet.

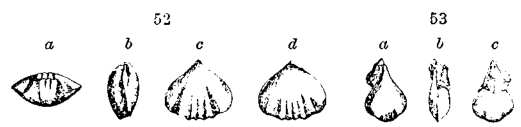
Geographical distribution.

In its geographical distribution, the deposit appears to form a zone around the geological depression between the Ottawa and the St. Lawrence. In Hawkesbury, opposite to Grenville, where its presence has already been alluded to, it has a breadth of about two miles; and its upper part, among other fossils, is marked by *Orthis imperator*. The sandstone of the lower part occupies a small area in the front of the townships of Grenville and Chatham, reaching nearly to Carillon, where the base crosses the Ottawa to Point Fortune. From this, the formation appears to sweep round to the westward into Lochiel, where it folds over the anticlinal axis which has already been alluded to, and where it presents the usual abundance of *Rhynchonella plena*, with some small black nodules of phosphate of lime. Again returning eastward, the base reaches Grande Isle on the south side of the St. Lawrence; while large angular blocks of grey limestone filled with *Rhynchonella plena*, indicate a proximity to the summit of the formation about a mile below Dalhousie mills on the river de l'Isle.

From this, westward, the country is so much covered with drift that no exposures of the rock have been observed until reaching Sheek's Island, opposite Mille Roches, in the higher part of the township of Cornwall.

Here a grey limestone almost entirely composed of *Rhynchonella plena*, with a few examples of *Beyrichia Logani*, rests on a mass of greenish shale abounding in fucoids, and attests the presence of the middle part of the formation. On the twenty-fourth lot of the fourth range of Cornwall, about a mile and a half or two miles north of Mille Roches, a quarry is opened in massive beds of black limestone, with fossils apparently belonging to the succeeding formation. In the sixth lot of the same range of the township, in a quarry of which the stone has been extensively worked for the construction of the canal locks, a similar description of black massive beds occurs; and here also some of the fossils appear to belong to the succeeding formation, so that the summit of the Chazy would probably occur some short distance north of the margin of the St. Lawrence in this vicinity. Cornwall.

52, 53.—BRACHIOPODA.



52.—*a, b, c, d, Camerella varians* (Billings).
53.—*a, b, c, Camerella longirostra* (Billings).

Beyond Cornwall, following the outcrop given to the Calciferous formation round to Osgoode, no exposures of the Chazy have been anywhere observed, and its position must be taken as occupying a belt of country lying between the exposures of the Calciferous on the one hand, and those of the Birdseye and Black River, or of the Trenton formation, on the other. In Osgoode, the deposit must come up against the same fault which brings the Calciferous against the Hudson River formation, and there must thus be a breach in the outcrop of the Chazy. In conformity with this, a limestone is met with at the base of an escarpment on the twenty-second lot of the fifth range of Nepean, which is supposed to represent the summit of the deposit, being in the same escarpment overlaid by beds belonging to the Birdseye and Black River, followed by others of the Trenton formation. The escarpment is here about a mile south of the Potsdam formation, towards which the beds dip at an angle of from one to three degrees; and it is probable that the Chazy comes up against the Potsdam about a couple of miles to the north-eastward, on the south side of the fault. Dislocation.

From this, the formation is traceable into Huntley, and a considerable display of it occurs on the road running across Huntley from March to Ramsay, in the eighth and ninth lots, from the sixth to the twelfth ranges, as well as on the same road across from the twelfth range of Ramsay to Shipman's on the ninth range. In this part, the formation consists of the yellowish-white sandstone in the lower part, with a grey limestone above, Beds with entomostraca.

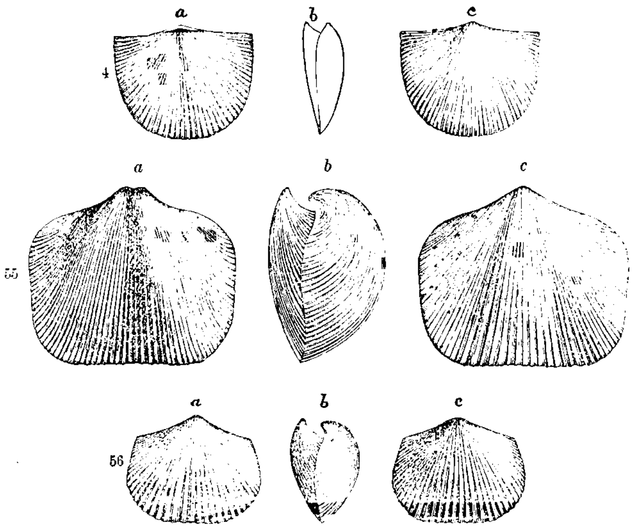
in which there is an interstratified bed of blackish-brown limestone crowded with bivalve entomostraca: not far above which, are several feet of yellowish-grey buff-weathering argillaceous magnesian limestone, applicable for the purposes of hydraulic cement. The species in the blackish-brown limestone are for the most part *Leperditia Canadensis*, many of them of the variety *Louckiana*. Associated with these is *Bathyurus Angelini*, and in the grey beds occurs *Strophomena alternata*. *Rhynchonella plena*, which marks the upper part of the limestone to the eastward, is in this part very rare or altogether absent. On the ninth and tenth ranges of Huntley, the road crosses a peat bog about a mile wide, which is probably underlaid by the Calciferous formation, as the bog is on the axis of the anticlinal in Huntley which has already been mentioned as bringing up a dome of gneiss. The Chazy is found on each side of the bog, and, in folding over this axis, reaches the south corner of Fitzroy. In rounding the southern extremity of the southern synclinal, the formation reaches to some distance on the line between Goulburn and Beckwith. On the south side of this synclinal, the Chazy, being nearly flat or slightly undulating, presents a breadth of between two and three miles for more than half-way across Huntley; but this breadth diminishes to not much more than half a mile on the confines of Pakenham. On the sixth lot of the tenth range of this township, it again turns upon the axis of the synclinal, and *Leperditia Canadensis* in crowded abundance characterizes a brownish-black limestone as before.

Huntley anticlinal.

From this the formation probably has a considerable spread to the north-eastward towards the spur of Laurentian gneiss which runs through Fitzroy. The details of its distribution in this part, however, are not quite certain. At Dickson's mills, the formation is concealed by a dislocation connected with the Huntley anticlinal. The dislocation, throwing the measures down on the north side, brings the Calciferous against the Birdseye and Black River formation; but about half a mile to the north-eastward, the Chazy emerges from beneath this latter. It is here, on the north side of a shallow synclinal, subordinate to that on the north side of the Huntley anticlinal; parallel to the axis of which another anticlinal occurs, about two miles and a half removed from it. The Chazy, in folding over this axis, is carried forward to the second lot on the line between the third and fourth ranges of Fitzroy: but between this and the spur of Laurentian gneiss in Fitzroy, no exposure of the rock has been observed, with the exception of one about three miles to the north-east on the second lot of the ninth range of the township, where it appears to abut against the gneiss on the north side of the more northern synclinal.

The Chazy appears to form two patches on the Calciferous outlier of the Lac des Chats, and westward to constitute the lowest rock of the outlier of the Allumettes Island and of the outliers south of it. The number of these westward outliers is six, three of them being on the Bonnechère, and the formation appears to constitute a rim to each of the six, but in the most northern the rock is concealed beneath the waters of the north channel of the Ottawa. Chazy outliers.

54-56.—BRACHIOPODA.



54.—*Orthis platys* (Billings); *a*, dorsal view; *b*, longitudinal section; *c*, ventral valve.

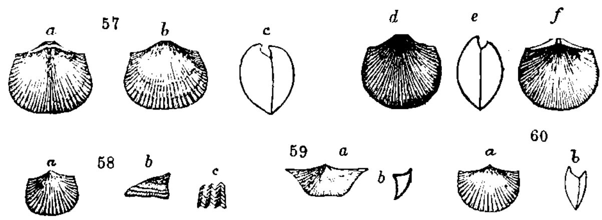
55.—*Orthis imperator* (Billings); *a*, dorsal valve; *b*, side view; *c*, ventral valve.

56.—*Orthis borealis* (Billings); *a*, ventral valve; *b*, side view; *c*, dorsal valve.

On the north side of the dislocation connected with the Rigaud and Fitzroy anticlinal, the Chazy follows the Calciferous formation, and occupies, in its relative place, a large part of the northern trough west of the Hull and Gloucester fault, leaving but two patches of superior rock, one in Hull and the other in Nepean. In Nepean this fault brings the Chazy Nepean.
against the Utica formation, but in Hull it appears to abut against the Hull.
Trenton. The arenaceous part of the Chazy is displayed at Aylmer in Hull, and in the eleventh range of Eardley, on the north side of the Ottawa, as well as in March on the opposite side, overlaid in each place by the limestone holding *Leperditia Canadensis*, and followed there, as well as in Nepean, by the cement bed. In Nepean, *Leperditia* is accompanied by *Rhynchonella plena*, but this does not appear to be in great abundance.

Anticlinals. Between the Hull and Gloucester fault and Grenville, the Chazy formation keeps wholly on the south side of the Ottawa. In its progress it is affected by four nearly parallel anticlinals, the axes of which approach to north-west and south-east. Two of these have already been alluded to as affecting the previously described Silurian deposits, one of them crossing the Ottawa from Buckingham to Clarence, and the other from Lochaber to Plantagenet. The higher of the other two crosses from Templeton to East Gloucester, and the lower from Buckingham to Cumberland. In folding over the former of these two, which are two miles and a half apart,

57-60.—BRACHIOPODA.



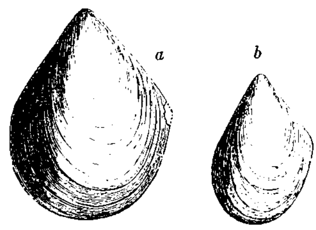
57.—*Orthis pervcta* (Conrad) ; *a, b, c, d, e, f*, different views of two specimens.
58.—*O.* —— *Porcia* (Billings) ; *a*, ventral valve ; *b*, side view ; *c*, portion of surface magnified.
59.—*O.* —— *acuminata* (Billings) ; *a*, ventral valve ; *b*, side view.
60.—*O.* —— *disparalis* (Conrad) ; *a*, ventral valve ; *b*, side view.

the summit of the Chazy is carried two miles from the margin of the river, and over the latter about a mile and a half. On the Buckingham and Clarence axis, which appears to be connected with a dislocation, the distance is not quite certain, but it probably does not fall short of four miles, while on the Lochaber and Plantagenet axis it may be about three miles. In other parts the distance of the summit of the Chazy from the river seldom exceeds a mile, with the exception of Alfred, where its course is probably four miles south of the gneiss, which constitutes the most northern part of the township.

L'Orignal. The arenaceous portion of the formation is traceable at intervals in the whole of the distance from Ottawa city, followed by the bed displaying entomostraca ; and on reaching the South Petite Nation River, beds crowded with *Rhynchonella plena* again make their appearance, though they do not seem to be so massive as they are in Hawkesbury. In the neighborhood of L'Orignal some beds from two to four inches thick, which are worked for tombstones and other purposes, are largely made up of this fossil ; and in the entromostraca beds, in addition to some of the species already named, there occurs *Leperditia amygdalina*, which is the largest species of this family in the formation.

On the east side of the Beauharnois anticlinal the formation under description follows the Calciferous along the margin of Lake Champlain from the neighborhood of Keeseville to the province line, passing in its course the town of Chazy, from which it takes its name. Beyond this, folding over the axis of the Chambly anticlinal and under the corresponding synclinal to the west, the formation attains Lake St. Louis, the summit of it reaching some distance below Caughnawaga. At Caughnawaga, beds crowded with *Rhynchonella plena*, accompanied with *Orthis borealis*, rest immediately upon the arenaceous part of the deposit. They yield massive blocks of building stone, which are marked with small rose- Lake Champlain.

61.—LAMELLIBRANCHIATA.



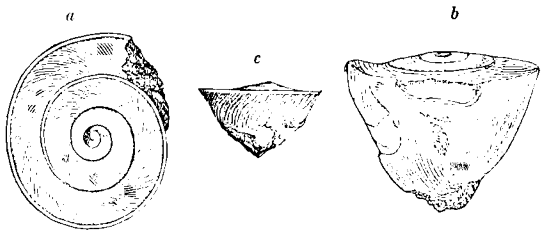
61.—*a*, *b*, *Vanuxemia Montrealensis* (Billings).

red spots, and when cut and polished afford a pretty marble. From this the formation, crossing Lake St. Louis, enters on the island of Montreal above Pointe Claire, and is thence traceable to Ste. Geneviève, where it affords very fine building stone. It then passes to Isle Bizard, which it crosses about mid length, in a belt coming upon the Lake of Two Mountains, at a point where a quarry is worked in it. In this quarry it shews a grey limestone, exhibiting the same rose-red spots as at Caughnawaga, and gives fine massive blocks.

The upper end of Isle Bizard displays the Calciferous formation, and the lower the Trenton, which is seen above and below the seigniorial mill on the Rivière des Prairies. The Trenton is also displayed on the opposite side of this stream for some distance, commencing a little below the extreme point of Isle Jésus. The Calciferous formation occurs a little below the same point, on the opposite side of the island, on the river St. Jean au Jésus, so that the Chazy, unless it is let down and buried by a fault, must enter on the island at the very extremity in a very narrow band. Widening as it proceeds, it sweeps round by St. Martin and the Rivière des Prairies, above and at Lachapelle's bridge, the upper part of the formation crossing the river to the island of Montreal in the vicinity of Isle au Chats. At the south end of the bridge just mentioned there are quarries in the formation, and from these it gains the neighborhood of St. Laurent Montreal Island.

church. It is seen again on the north side of the cross-road between Côte St. Laurent and Côte Ste. Catherine, running close alongside this road to its junction with the Ste. Catherine road, and then turning toward the Mile End road, which the summit crosses about a hundred yards on the city side of the first milestone beyond the toll bar.

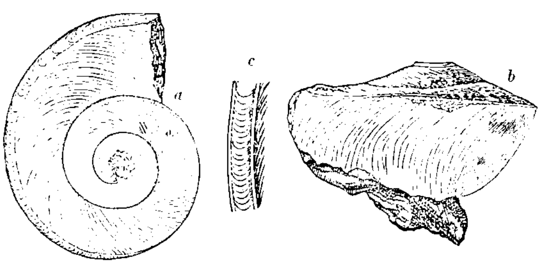
62.—GASTEROPODA.



62.—*Pleurotomaria calyx* (Billings) ; *a*, view of the flat spire ; *b*, side view ; *c*, a smaller specimen of the same.

This is the position in which, as already mentioned, the Chazy limestone is quarried in the vicinity of Montreal. From it, the top of the formation, after reaching northward to the cross-road from Côte St. Michel to Côte de la Visitation, turns westward, and again crosses the Rivière des Prairies a little below the Sault au Recollet. It sweeps round thence, probably about a mile behind Les Ecors and the rocks of St. Vincent de Paul,

63.—GASTEROPODA.

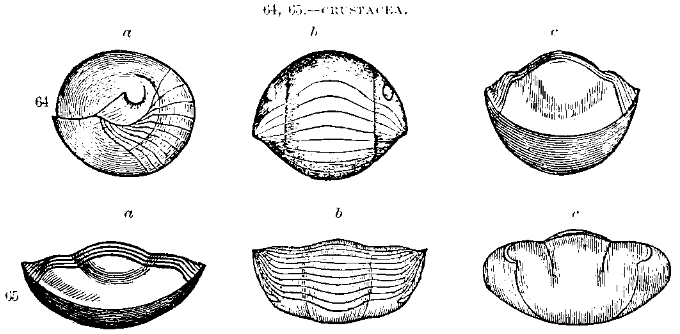


63.—*Pleurotomaria docens* (Billings) ; *a*, view of spire ; *b*, side view ; *c*, portion of band enlarged.

which are of the higher formations, and gains a position a little way west of the village of Terrebonne. Making a sharp turn here, it is traceable to the south-westward to within about a mile of Ste. Rose, keeping some distance from the river St. Jean au Jésus. The whole band probably crosses the stream here to the Rivière aux Chiens, a tributary joining on the north-west, whence it runs to Côte St. Louis, where it has been quarried about three miles north-eastward of Ste. Thérèse.

In its farther progress it reaches the vicinity of St. Lin, north-west of the mills on the Little River, about half a mile above its junction with the Achigan, where entire thick beds of the formation, giving fine building stone, assume the rose-red color mentioned as occurring in spots at Caughnawaga and Isle Bizard. Here *Rhynchonella plena* characterizes the St. Lin; trap.

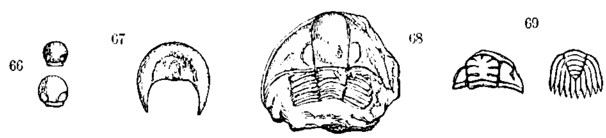
64, 65.—CRUSTACEA.



64.—*a, b, c, Illænus globosus* (Billings); three different views.
65.—*a, b, c, I.* —— *Bayfieldi* (Billings); " " "

rock, and *Stenopora fibrosa* is associated with it in some abundance. Where the Little River cuts the formation, it is paved with trap for about fifty yards. About ten feet of this trap are seen in a cascade which occurs at the spot. It appears to be an intercalated mass, and a calcareous bed of fifteen inches, lying on the top, is converted into a highly crystalline condition. Farther to the north-east the Chazy is traceable to the village of

66-69.—CRUSTACEA.



66.—*Sphærexochus parvus* (Billings).
67.—*Harpes antiquatus* (Billings).
68.—*Bathyurus Angelini* (Billings).
69.—*Amphion Canadensis* (Billings).

Industry, where it occurs under the foundation of the mill, and is marked by *Pleurotomaria staminea*. From this the band appears to become thinner; and it is not at present recognised with certainty to the north-east beyond the Chicot dislocation, until reaching the Mingan Islands, the interval being upwards of 500 miles. Industry.

Mingan Islands.

At the Mingan Islands the Chazy formation bears lithological characters somewhat different from those which have been given above. The lowest part seen of the deposit occurs in the bay above Clear Water Point, and the following is a section of the strata in ascending order:—

	Feet.
Reddish cream colored compact limestone with a conchoidal fracture, weathering pale yellow,	1
Greenish and brownish-black shale,	1
Reddish cream colored limestone as before, in beds of from one and two inches to a foot, interstratified with greenish shale in beds of about the same thickness,	28
Greenish shale with *Rhynchonella orientalis* (which is a variety of *R. plena*) in great abundance,	3
Grey granular limestone with false bedding, holding comminuted fragments of encrinites and other organic remains, including *Bolboporites Americanus*, *Rhynchonella orientalis*, a few of *Camerella longirostrata*, and other species,	13
Grey nodular limestone with *Columnaria parva*, *Stenopora adherens*, *Fenestella incepta*, *Orthis piger*, *Strophomena incrassata*, *Ctenodonta nasuta*, *Nautilus Jason*, *Amphion Canadensis*, *Harpes antiquatus*, *Illænus globosus*,	20
Grey magnesian limestone, with *Murchisonia aspera*, *Maclurea Atlantica*, *Orthoceras multicameratum*, *O. bilineatum*, *O. natator*, *O. Maro*, *O. Antenor*, *O. Minganense*, *O. Shumardi*, *Illænus Bayfieldi*, and other fossils,	12
	78

The following section, in ascending order, occurs on Large Island at its most northern point; it is supposed to belong to the Chazy formation, and, from the fewness of the organic remains in it, probably overlies the previous beds :—

	Ft.	in.
Yellowish-grey limestone, weathering yellow, probably magnesian,	5	8
Green and black shale,	2	0
Yellowish-grey limestone, with *Leperditia amygdalina* at the top,	7	3
Yellowish-grey concretionary limestone, weathering yellowish-brown ; the concretionary masses are from six to eighteen inches in diameter, and the concentric layers of the concretions thin,	4	0
Dull drab colored limestone, weathering slightly yellow, with nodules of chert ; the surfaces of the beds show fucoids,	6	0
Dull drab colored compact limestone, weathering slightly yellow, in beds of from six to twelve inches,	18	0
Drab colored mottled arenaceous limestone, weathering yellowish-brown, in beds of from three to nine inches, with corals,	10	0
Pale yellowish-grey arenaceous limestone, weathering yellowish-brown, in beds of from three to nine inches, well marked with fucoids on the surfaces and with impressions of *Straparollus*,	12	6
Measures concealed,	7	9
Yellowish-white arenaceous limestone, in beds of from one to two feet thick, without observed fossils ; this would make an excellent building stone,	8	0
Green calcareo-arenaceous shale,	1	6
Light greenish-white coarse grained calcareous sandstone, in ill defined beds, with numerous obscure fragmentary fossils, and several small black nodules and patches,	5	0

	Ft.	in.
Measures concealed,	4	0
Green and grey shale,	11	0
Drab colored argillaceous limestone in even beds, some of which would probably yield hydraulic lime ; ripple-mark occurs on some of the surfaces,	7	0
Greenish shale,	1	9
Greenish-drab compact limestone, mottled with yellowish-drab organic remains ; this would make a handsome marble,	10	0
Greenish-drab very compact limestone, resembling lithographic stone in its texture, but unfitted by the presence of small transparent crystals of calcspar ; the beds are from three inches to one foot thick ; this would make a very fine building stone,	5	0
Light drab compact but brittle limestone, in beds of from six to eight inches, with no observed fossils,	45	0
	171	5

It is not certain that this includes the top of the Chazy, as between the section and the lowest organic remains of the succeeding formation there is a thickness of seventy-eight feet, of which the character has not been ascertained. It would however appear probable that the total volume of the formation in this part does not exceed about 300 feet. It appears to include all the islands outside of Harbor Island, from the Perroquets to Clear Water Point, and with this point the islands to the east of it as far as Wood Island. From this range, however, is excepted the southern part of Large Island, which appears to belong to the succeeding formation.

CHAPTER IX.

THE BIRDSEYE AND BLACK RIVER FORMATION, AND THE TRENTON FORMATION.

THE BIRDSEYE, BLACK RIVER, AND TRENTON LIMESTONES; A GREAT GROUP.—SECTION NEAR MONTREAL; MOUNT ROYAL.—DISTRIBUTION EASTWARD IN THE ST. LAWRENCE VALLEY.—MONTMORENCI FALLS.—SAGUENAY; LAKE ST. JOHN.—DISTRIBUTION OF THE GROUP ON THE OTTAWA; OUTLIERS.—ITS DISTRIBUTION IN WESTERN CANADA.—LAKE SIMCOE.—MANITOULIN ISLANDS.—LACLOCHE.—ST. JOSEPH ISLAND.—CAMPEMENT D'OURS.—THE UNDERLYING SANDSTONES.

The great mass of limestone strata which overlies the Chazy formation was by the New York geologists divided into three portions, each of which was supposed to be characterized by peculiar fossils. Lowest in this series they placed the Birdseye limestone, so named from its peculiar aspect, due to the abundance of *Tetradium* which it contains. To this succeeds the so-called Black River limestone, followed in its turn by the division which, from the Trenton Falls, has received the name of the Trenton limestone. In their extension into Canada it has been found that the distinctions between these divisions of this group are less definite than in New York, and the whole series of strata is therefore described together. In the tabular view given in Chapter II. we have represented the Birdseye and Black River limestones as one formation. Its characteristic fossils will be introduced in the following pages before those of the Trenton formation.

Section at Montreal.

In the vicinity of Montreal we have shown that the summit of the Chazy formation consists of a mass of limestone marked by an abundance of *Rhynchonella plena*. This is succeeded, after a short interval, by a set of dark-colored limestones, of which the following is an ascending section:

	Feet.
Measures concealed,	10
Greyish-brown compact bituminous and somewhat brittle limestone, weathering to a lead-grey, in beds of from three to six inches, with a smooth conchoidal fracture; slender tube-like forms run in various directions in the rock, filled with crystals of calcspar, probably replacing the remains of *Tetradium fibratum*,	2
Dark greyish-brown compact bituminous limestone, weathering lead-grey, with a conchoidal fracture, in beds of from three inches to a foot; towards the	

	Feet.
middle of the mass *Tetradium fibratum* occurs in abundance, most of the tubes being filled with calcspar; the beds contain univalve and bivalve shells, difficult to be obtained from the brittleness of the stone,............	5
Brownish-black bituminous nodular limestone intermixed with thin films of shale; some of the nodules contain fossils; among these are *Tetradium fibratum*, *Helicotoma planulata*, and *Leperditia Canadensis*,........................	1
Brownish-black compact bituminous limestone, in two beds, with *Tetradium fibratum*, *Stenopora fibrosa*, *Columnaria incerta?* *Stromatopora compacta*, and *Helicotoma planulata?*...	2
Brownish-black compact bituminous limestone in two massive beds, with *Tetradium fibratum*, *Cyrtodonta Huronensis*, *Helicotoma planulata*, as well as broken crinoidal stems,..	5
Brownish-black compact bituminous limestone in a massive bed, with nodules and patches of black chert and silicified fossils; among the fossils are *Tetradium fibratum*, *Stenopora fibrosa*, *Rhynchonella recurvirostra*, *Murchisonia gracilis*, *M. ventricosa*, *Pleurotomaria lapicida*, *P. aperta*, *P. rotuloides*, *P.* ——, *n. s.*, *Helicotoma planulata*, *Ctenodonta nasuta*, *C. contracta*. On the top of the bed are *Columnaria alveolata*, *Petraia profunda*, *Stenopora fibrosa*, *Ctenodonta nasuta*, *Vanuxemia inconstans*, *Maclurea Logani*, *Trochonema umbilicata*, *Helicotoma planulata*, *Orthoceras Bigsbyi*,.....	3
	28
Black bituminous limestone, not quite so compact nor so brittle as that of the previous beds, nor quite so pure; its fracture is less smooth, and there is a slight tinge of yellow in the grey of its weathered surfaces. It is divided into massive beds of from one to two feet thick, containing *Columnaria alveolata*, *Orthoceras Bigsbyi*, and *O. multitubulatum*,....................	10
	38

Divisions of the group.

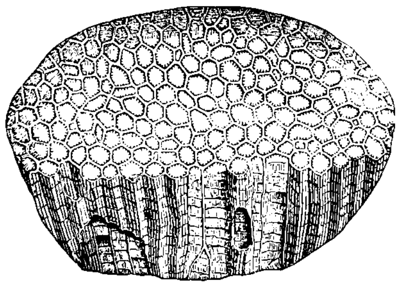
The lower of these two masses represents the Birdseye, and the upper the Black River limestone of New York. In Canada, the line of demarcation between the two appears frequently to become very indistinct, and we have in consequence been under the necessity of grouping them together. In the vicinity of Montreal there is a distinct separation between the Birdseye and Black River formation, and the succeeding Trenton formation; but in some parts of the province, those fossils which are regarded as most strongly distinguishing the Birdseye and Black River, become associated with several that are characteristic of the succeeding division; and we are not prepared for the present, in representing the distribution of the whole series on the map, to distinguish its parts by different colors. It will therefore be convenient in this place to add to the preceding section the details of the Trenton formation, premising that the strata with which it commences are seen in contact with those already given. The section is as follows:—

Black bituminous nodular limestones in beds varying from two to four inches, separated by layers of black bituminous shale of from one to two inches thick. The beds are highly fossiliferous from the very base, and contain among other organic remains *Stenopora fibrosa*, *S. petropolitana*, *Glyptocrinus ramulosus*, *Rhodocrinus pyriformis*, *Pleurocystites elegans*, *Ptilodictya*

	Feet.
acuta, Intricaria reticulata, Graptolithus amplexicaule, Leptæna sericea, Strophomena alternata, Orthis testudinaria, O. lynx, Rhynchonella increbescens, Camerella hemiplicata, Lingula curta, Discina Pelopea, Ceraurus pleurexanthemus, Asaphus platycephalus, Leperditia Canadensis, ...	10
Grey bituminous granular limestone in beds of from three to eighteen inches at the bottom, passing into black nodular bituminous limestone at the top, interstratified with black bituminous shale in irregular layers of from one to three inches. The grey limestone is a mass of comminuted organic remains, which consisting largely of the ruins of crinoids and cystideans, give, from the peculiar crystallization of these fossils, a crystalline character to the rock. Among the fossils are *Stenopora fibrosa*, which is very abundant particularly in the shale, *Ptilodictya acuta, Leptæna sericea, Strophomena alternata, Orthis testudinaria, O. lynx, Camerella hemiplicata* in considerable numbers, *Rhynchonella increbescens, Ambonychia bellistriata, Conularia Trentonensis, Lingula Progne, Orthoceras* ——— ? *Ceraurus pleurexanthemus, Calymene Blumenbachii,* and *Asaphus platycephalus*. The lowest bed is eighteen inches thick, and in a grey granular matrix holds patches and lumps of shale of about an inch in diameter; it is succeeded by thinner beds, which are grey and granular in the middle, but become black and more compact towards the exterior, the black color increasing and the beds becoming more nodular towards the top,...	10
Grey granular bituminous limestone of the same character as before, in massive beds of from ten inches to two feet thick, separated by thin partings of black bituminous shale; at two feet from the top there is interstratified a two-feet band of black nodular limestone in layers of from one to four inches, separated by thin layers of shale. There are extensive quarries in these grey limestones near Montreal, from which is obtained the chief part of the stone at present used in the construction of the best houses of the city. The fossils of these beds are pretty much the same as those of the previous mass,......	10
Black and dark grey bituminous nodular limestone, weathering light grey, in beds varying from two to eight inches in thickness, separated by irregular layers of black and brown bituminous shale of from one to three inches. The nodular character of the limestone arises from the unequal distribution of argillaceous material in the rock, causing it to weather into lumps, and rendering it unfit for building purposes. About the middle of the mass, which is the part most exposed, the following fossils, among others, are met with, *Stenopora fibrosa, S. petropolitana, Ptilodictya acuta, Leptæna sericea, Strophomena alternata, Orthis testudinaria, O. lynx, Camerella hemiplicata, Discina cœlata, Conularia Trentonensis, Ceraurus pleurexanthemus, Calymene Blumenbachii, Asaphus platycephalus, Trinucleus concentricus,*..............	150
Black bituminous compact limestone, containing about ten per cent. of argillaceous matter; it is divided into even beds of from three to ten inches, many of which present a set of regular and parallel joints dividing them into rectangular bars. The argillaceous mixture increases towards the surfaces of the beds, which are separated by layers of dark brown or black bituminous shale, varying in thickness from mere partings to two or three inches. The limestones weather to a light grey, often with a tinge of yellow, and sometimes, when near trap dykes, to white. The surfaces of the beds usually show in relief and often in abundance the remains of cystideans; these are almost wholly of the species *Glyptocystites Logani*, of which weathered masses of the limestone occasionally appear to be almost completely made up. Of the fossils enumerated in the nodular beds nearly every one is met with in these more regular strata, though perhaps not in the same profusion,............	350
	530

It is probable that above the foregoing section there are additional beds, in which the layers of shale gradually increase in thickness, so that the total volume of the formation may be regarded as approaching about 600 feet.

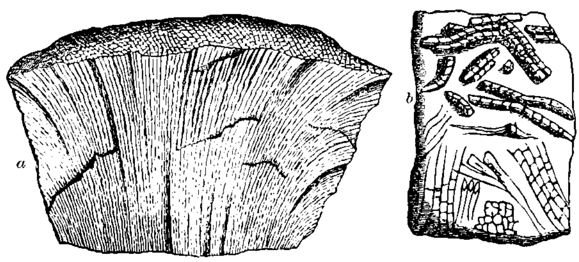
70.—ZOOPHYTA (B. B.)



70.—*Columnaria alveolata* (Goldfuss).

The Birdseye, Black River, and Trenton formations * constitute one of the most persistent and conspicuously marked series of strata of the Lower Silurian period on the continent of North America. In its distribution in Distribution

71.—ZOOPHYTA (B. B.)



71.—*a*, *Tetradium fibratum* (Safford); *b*, the same with the tubes separated and scattered through the rock.

Eastern Canada, it enters the province from New York, where it occupies a position on the west side of Lake Champlain, and it appears to follow the Richelieu River, which discharges the lake, to within a short distance of

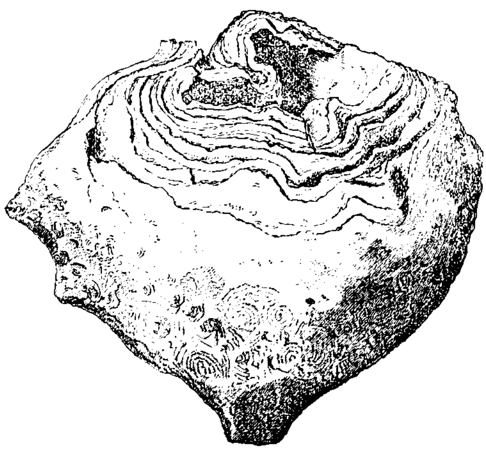
* The figures of the characteristic fossils of the Birdseye and Black River formation will be given in this chapter before those of the Trenton formation, and will be distinguished by the initials B. B., those of the Trenton being marked TR.

St. John. The nearest exposures occur about two miles west of the town, where the rock is quarried and burnt for lime. The strata dip N. N. E. < 4° and appear to belong to the smooth even-bedded limestones of the upper part of the Trenton. They are very fossiliferous, and the surfaces of some of the beds are crowded with various forms in high relief. From these beds and from the interstratified shales, which crumble in the weather, are obtained, among other fossils, very perfect specimens of *Leptæna sericea*, *Strophomena alternata*, and *Orthis testudinaria*, showing the outside and inside of the shells. It is probable that the very summit of the series approaches somewhat nearer St. John, but at the town itself we have the Utica formation.

Chambly anticlinal.

Not far from this locality the strata fold over the axis of the Chambly anticlinal, and then, sweeping round the synclinal form to the west, come upon

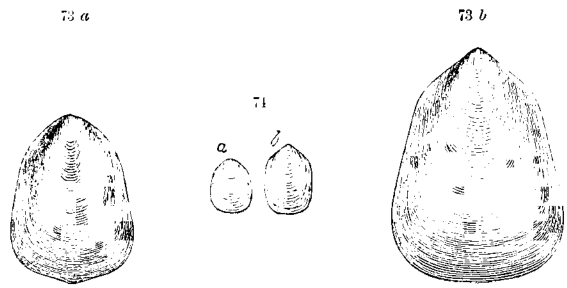
72.—ZOOPHYTA (B. B.)



72.—*Stromatopora rugosa* (Hall). A small and perfect specimen.

the St. Lawrence, the base being a little below the village of Caughnawaga and the summit a little above the Sault St. Louis mill; the breadth across the measures on the bank of the river being about three miles. Crossing to the island of Montreal, the measures spread out considerably, and, while the summit strikes nearly straight across, the base, turning westward, reaches Pointe Claire, about twelve miles higher up. In front of the church at Pointe Claire there is an exposure of grey granular limestone which belongs to the Chazy formation, and about a mile north of it there is situated a quarry of black limestone. The dips near the church and in the quarry both partake of a southerly direction; but as the quarry displays the higher rock, being of the Birdseye and Black River formation, there must be undulations or dislocations in the neighborhood to account for the relative attitude of the two exposures, though from the small inclination of the strata these may not be important. From this quarry was obtained the stone used in the construction of the piers of the north half of Victoria Bridge, while that of the south half was from what is said to be the same formation, at Isle la Motte, in Lake Champlain. On the north side of the Pointe Claire quarry there is a vertical exposure of about thirty feet of massive strata, varying in thickness from one to three feet, the blocks obtained from which for the bridge ranged from four to seven tons. In the lower portion of these strata *Tetradium fibratum* occurs in abundance, associated with *Murchisonia gracilis*, *M. perangulata* and *Leperditia Canadensis*, while at the top are *Columnaria alveolata*, *Strophomena alternata*, *Cyrtodonta Huronensis*, *Orthoceras Bigsbyi*, and *Encrinurus vigilans*.

73, 74.—BRACHIOPODA (B. B.)



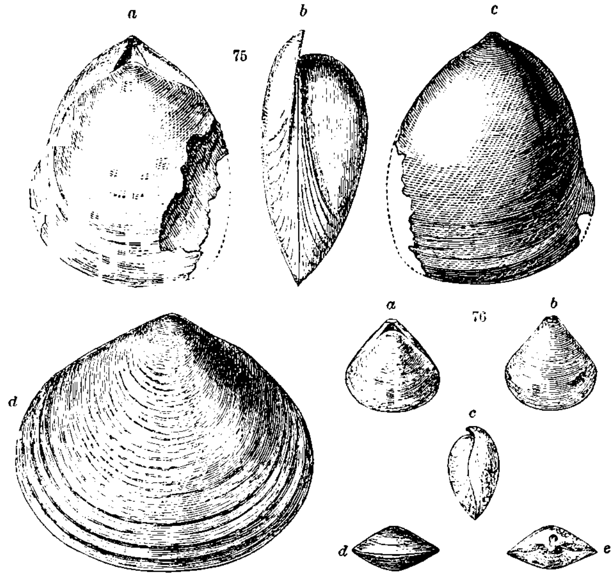
73.—*Lingula Eva* (Billings); *a*, dorsal valve; *b*, ventral valve.
74.—*Lingula Kingstonensis* (Billings); *a*, dorsal valve; *b*, ventral valve.

From Pointe Claire, the base of the series follows the zone of Chazy by Ste. Geneviève, Isle Bizard, Isle Jésus, and Isle aux Chats, to the vicinity of Montreal, and thence by the Côte de la Visitation, Côte St. Michel, Sault au Recollet, the lower part of Isle Jésus, and the river aux Chiens to the vicinity of St. Lin. The summit, pursuing a straighter course from Sault St. Louis, is traceable by many exposures all the way down the eastern front of the island of Montreal, in general removed about a mile from the edge of the water, and always dipping easterly at a very small angle. From this distribution, and from what has been said before, it will be perceived that a flat anticlinal arch, of which the axis runs from the north end of Mount Royal to a point a little westward of Ste. Thérèse, carries the Calciferous formation south-eastward into Isle Jésus, and the Chazy eleven or twelve miles farther on, across this island, and across that

Montreal Island

Anticlinals. of Montreal to within three miles of the St. Lawrence. This anticlinal is traversed nearly at right angles by two others, one in each of the islands. This gives to the upper half of the island of Montreal the form of a shallow trough, in which the series of limestones here described extends in a spur from Côte St. Antoine to the upper end of Isle Jésus, narrowed

75, 76.—BRACHIOPODA (B. B.)



75.—*Obolus Canadensis* (Billings); *a*, dorsal view, showing area of ventral valve; *b*, side view; *c*, ventral view; *d*, dorsal valve of a broad oval variety.

76.—*Eichwaldia subtrigonalis* (Billings); *a*, dorsal view; *b*, ventral; *c*, side; *d*, front; *e*, apex, showing the foramen.

transversely in two places about six miles apart. Towards the northern end of the spur at the White Horse Rapid, on the Rivière des Prairies, about two miles below Isle Bizard, there is a part in the trough deeper than the others, which holds a small isolated patch of the black shales of the succeeding formation.

White Horse Rapids.

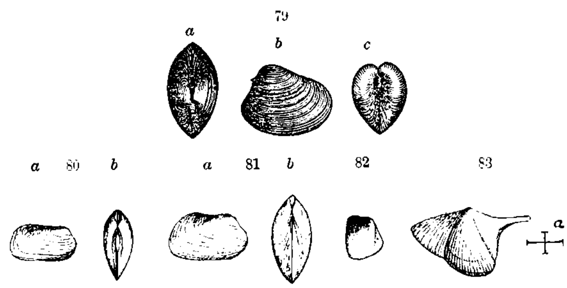
Mount Royal. The main body of Mount Royal is an intruded mass of trap. The stratified rocks that are entangled with it on the east side appear to belong to the upper part of the Trenton, and those on the west to the Birdseye and Black River formation. The grey limestones towards the base of the Trenton are probably overlaid by the igneous rock. A superficial area of about 700 acres, resembling in shape the frustrum of a wedge, is occupied by the trap, the highest part of which is about 750 feet above the St. Lawrence in the harbor of Montreal. From this mass the strata dip on both sides, more rapidly on the east than on the west, the inclination on

77, 78.—BRACHIOPODA (B. B.)

77.—*Camerella Volborthi* (Billings); *a*, *b*, *c*, ventral, side, and dorsal views.
78.—*Camerella Panderi* (Billings); *a*, *b*, ventral and dorsal views.

the former being about ten degrees. On this side, the flank of the hill, to the height of about 360 feet above the river, is occupied by limestone strata, the rise of which near the reservoir terminates in two or three abrupt

79–83.—LAMELLIBRANCHIATA (B. B.)



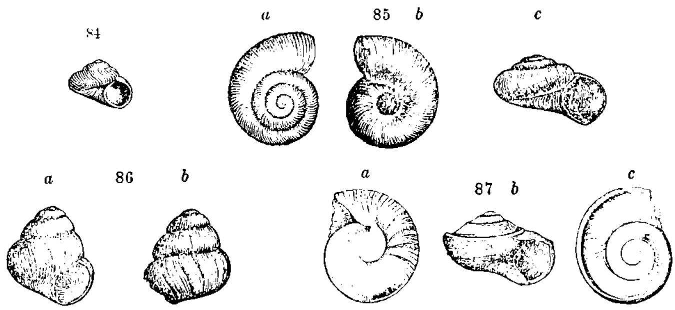
79.—*Ctenodonta abrupta* (Billings); *a*, *b*, *c*, three different views of the same specimen.
80.—*Modiolopsis Maia* (Billings); *a*, view of right valve; *b*, dorsal view.
81.—*M.* ——— *Nais* (Billings); *a*, view of right valve; *b*, dorsal view.
82.—*Cyrtodonta Leucothea* (Billings).
83.—*Conocardium immaturum* (Billings), enlarged; *a*, natural size.

steps, presenting successive narrow terraces. On these the dip, approaching the trap, moderates almost to horizontality, and the attitude of the two rocks is such as to leave it doubtful, without farther evidence, whether the limestone runs under the trap or abuts against it.

Around Mount Royal a great many dykes and interstratified masses of trap are met with, all probably related to the igneous mass of the mountain. The quarries in the limestones of the formations from the Chazy to the Trenton inclusive, in the rear of the city, display a number of the dykes of various thicknesses, up to three and four feet. They appear to run in various directions, one set approaching north, with the strike, and another at right angles, so as to intersect one another as well as the lime- **Trap Dykes.**

stone. In some of the quarries, the limestone having been removed from among them, the dykes are left standing up several feet above the bottom of the quarry, and present in a marked manner the various details of the cracks they once filled. Very few of these cracks appear to be accompanied by important vertical displacements: most of the slips which have been observed do not exceed from a few inches to one or two feet, and this is not sufficient to disjoint in any remarkable degree the outcrops of the strata, notwithstanding the moderation of the dip, which seldom exceeds five degrees in inclination.

84-87.—GASTEROPODA (B.B.)



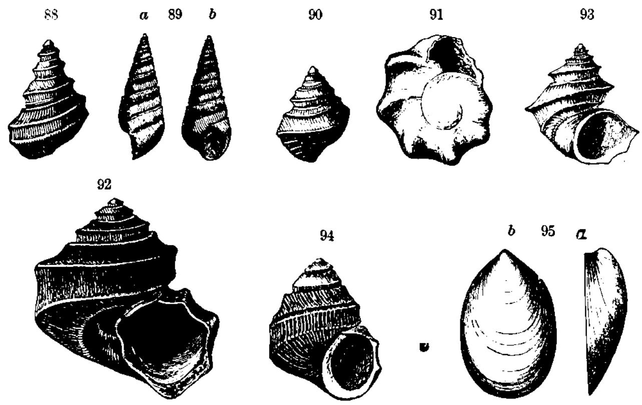
84.—*Straparollus asperostriatus* (Billings).
85.—*Straparollus Circe* (Billings); *a*, view of spire; *b*, umbilicus; *c*, aperture.
86.—*Straparollus Eurydice* (Billings); *a*, view of aperture; *b*, back view.
87.—*Pleurotomaria Eugenia* (Billings); *a*, *b*, *c*, three different views of the same specimen.

Intercalated trap.

An intercalated mass of trap, of some importance, crosses the Papineau road about a mile and a half from the St. Lawrence. It has been followed on the strike of the limestone for about five miles to the northward, but southwardly it is lost beneath the drift sand and clays in less than half a mile. If the band were carried farther forward in this direction, it would come into place about ten acres to the east of the trappean precipice of that side of Mount Royal. The direct breadth of the band in the vicinity of the Papineau road is between 200 and 300 yards. It is divided into two thick layers, and exhibits two distinct escarpments running parallel to one another. It dips with the stratification of the smooth even-bedded black limestones overlying it, at an angle of about five degrees, which would give a thickness of between fifty and eighty feet. That it is an intruded mass, and not an overflow, is made evident by the fact that a foot or two of the overlying limestone is occasionally met with in the condition of a breccia, of which the fragments are held together by the trap as a matrix.

Between Ste. Thérèse and St. Lin, the junction of the Chazy and Birdseye limestones is displayed about a mile north of the church of Ste. Anne des Plaines, and an escarpment, on the summit of which the road to St. Lin runs for about a mile, is composed of the upper of these rocks. The junction of the deposits crosses the road dividing the seigniories of Terrebonne and Lachenaye, probably a short distance south-east of the point where this road is intersected by the one to St. Lin, and it thence sweeps round to the village of St. Lin on the Achigan. The occurrence of the Chazy to the north-west of the mills on the Little River, above its junction with the Achigan, has already been mentioned. Farther down on the Achigan, the Black River division, marked by *Columnaria alveolata*, is seen at the bridge just below Mr. Pangman's mill, leaving room for the Birdseye St. Lin

88-95.—GASTEROPODA (B. B.)



88.—*Eunema strigillata* (Salter).
89.—*a*, *b*, *Eunema cerithioides* (Salter).
90.—*Cyclonema semicarinata* (Salter).
91.—*Holopea Pyrene* (Billings).
92.—*Trochonema umbilicata* (Hall).
93.—*Murchisonia serrulata* (Salter).
94.—*Murchisonia Arachne* (Billings).
95.—*Metoptoma Erato* (Billings); *a*, *b*, side and dorsal views.

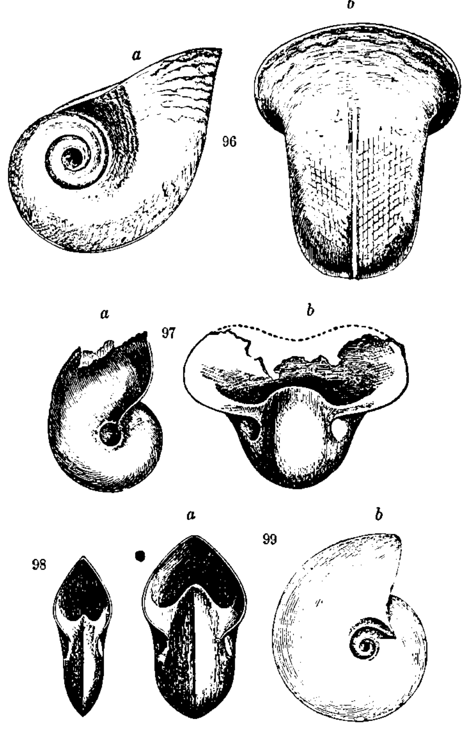
between the two localities; while about three quarters of a mile still farther down, though probably not more than 200 yards directly across the measures, black and grey limestones are met with, representing those near the base of the Trenton at Montreal.

Proceeding from this position across the measures towards the St. Lawrence, there is a breadth of between four and five miles, in which the strata are concealed for a considerable distance to the right and left, on the strike. Beyond it, black limestones, higher in the series, occur on the river St. Esprit, at the bridge on the road from St. Rocque to St. Jacques, and at intervals on the stream, to the vicinity of Mr. Viger's mills, not far from

St. Rocque; black limestones and shales.

where the stream crosses the boundary line between the seigniories of St. Sulpice and L'Assomption. South-westward from this, black limestones, interstratified with a considerable amount of black shales, are exposed on the Achigan at the village of St. Rocque, and for a mile up to the junction of the Ruisseau des Anges. The limestones, which are in beds of three or

96-99.—GASTEROPODA (B. B.)

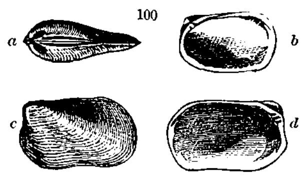


96.—*Bellerophon sulcatinus* (Emmons); *a*, side view; *b*, dorsal view.
97.—*Bellerophon Charon* (Billings); *a*, side view; *b*, front view.
98.—*Bellerophon disculus* (Billings).
99.—*Bellerophon Argo* (Billings); *a*, front view; *b*, side view.

four inches, are characterized by *Leptæna sericea*, *Orthis testudinaria*, *Ceraurus pleurexanthemus*, and *Calymene Blumenbachii*, and the shales, some of the layers of which are three feet thick, by a *Lingula* resembling *L. curta*, and by *Graptolithus pristis*. The latter species is referred by Hall to the Utica slate, and it is probable that the beds may not be far below the base of this formation.

Farther down the Achigan, where it intersects the line between the two seigniories mentioned in the last paragraph, there is an exposure of black limestone of the Trenton formation, and about half a mile from this, to the south-east, black shales of the Utica formation make their appearance.

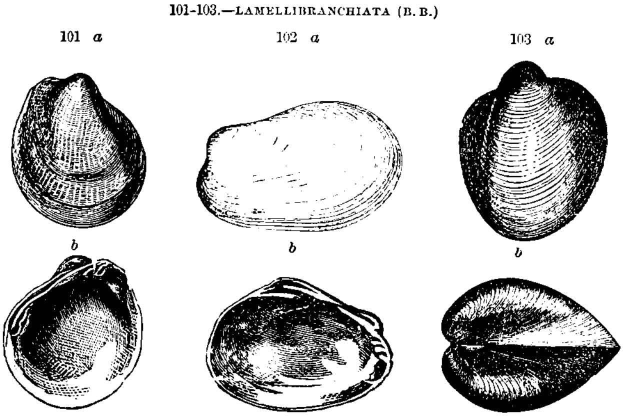
100.—LAMELLIBRANCHIATA (B. B.)



100.—*Matheria tener* (Billings) ; *a*, dorsal view ; *b*, interior of right valve ; *c*, exterior of left valve ; *d*, interior of left valve.

But above these positions, on the stream, and about half a mile to the south- Intruded
west of the boundary line, there is a considerable exposure of trap, the course of which would carry the intruded mass between the limestones and

101-103.—LAMELLIBRANCHIATA (B. B.)



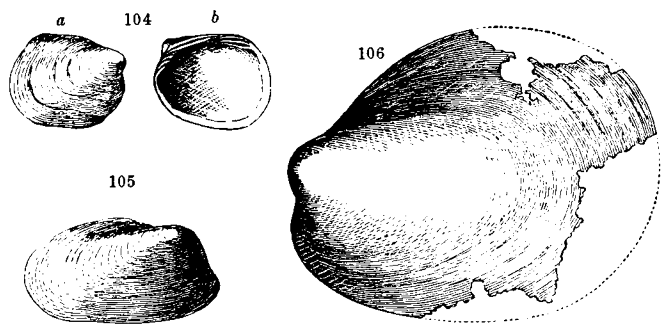
101.—*Cyrtodonta obtusa* (Hall) ; *a*, left valve ; *b*, interior of left valve.
102.—*Cyrtodonta Huronensis* (Billings) ; *a*, left valve ; *b*, interior of left valve.
103.—*Cyrtodonta cordiformis* (Billings) ; *a*, right valve ; *b*, dorsal view.

the shales, and there may possibly be some dislocation connected with it. Trap occurs also about two miles below St. Rocque: it is in nearly horizontal beds, but the sedimentary strata with which the igneous rock is associated are not visible.

Between the Achigan and the outcrop of the Birdseye and Black River formation, in its range from the neighborhood of Terrebonne to St.

Terrebonne. Lin, there is an area of about 200 square miles, which the anticlinal of Isle Jésus throws into a synclinal form, with a breadth of about fifteen miles. The dips along the outcrop show that the trough must be very shallow, and it is probable that there may be several minor undulations subordinate to it. The area however is very much covered up with drift, and there have been no facts ascertained to determine whether

104-106.—LAMELLIBRANCHIATA (B. B.).



104.—*Cyrtodonta rugosa* (Billings) ; *a*, right valve ; *b*, interior of right valve.
105.—*Cyrtodonta subcarinata* (Billings), right valve.
106.—*Cyrtodonta Canadensis* (Billings), left valve.

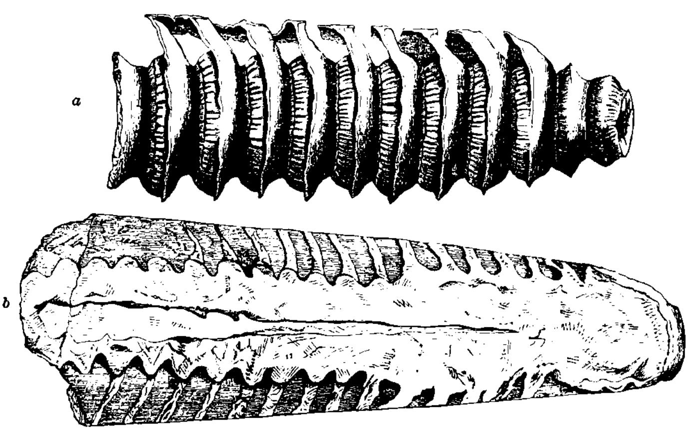
any of the Utica formation occurs in it. The only exposures of rock that have been met with are at Mr. Pangman's mills on the Mascouche, and upwards of a mile to the south-east, on the road from these mills to the village of St. Henry. In both of these localities black limestones of the Trenton formation occur; and as the dip in each, though at a small angle, is towards the south-east, there must be a shallow synclinal crossing the road between St. Henry and Isle Jésus.

Naquareau River. On the Naquareau River there is an exposure across the Birdseye, Black River, and Trenton formations, extending from the Dalles, about a mile and a half above the junction of the Red River, to a point about two and a half miles below it; and there is another of the same measures from three to five miles to the north-east, on the Assumption River, extending from the Industry. village of Industry to a large island in the stream, just ten miles, in a straight line, from the St. Lawrence. The distance across the strata in a direct line is a little over two miles and a half; the dip, which varies from S. S. E. to S. E., does not exceed two or three degrees, and the whole thickness reaches a little over 480 feet. This section, which rests upon thirty feet of Chazy, under the foundation of the mill and upper bridge at the village, consists of nearly fifty feet of Birdseye and Black

River, marked by *Tetradium fibratum* and *Columnaria alveolata*. Above this, some of the lower beds of the Trenton, varying from six inches to a foot in thickness, give good building stones, which have been used on the spot for the construction of the railway bridge over the river. The grey beds are included in a total thickness of ninety feet, above which are 140 feet of dark grey nodular limestone, succeeded by 200 feet of black limestones of smoother and somewhat more brittle character. It is not certain that these beds reach the summit of the Trenton formation.

Between the Naquareau and the Achigan there is a partial exhibition of the same beds, from the Birdseye upward, on the Red River and at the village of St. Paul; but following the strike lower down the valley of the St. Lawrence, the whole mass constitutes a low ridge, distinctly traceable for eight miles in a direction approaching E. N. E., the breadth of which gradually diminishes the whole way, until at this distance it comes to a point, and disappears about a mile and a half south-west from Mr. Olivier's mills on the Bayonne. The Birdseye and Black River strata running on the north-west side of this ridge, are exposed on the river Chaloupe, and so is the upper part of the Trenton beds, but the Chazy are concealed. St. Paul.

107.—CEPHALOPODA (B. B.)



107.—*Orthoceras Bigsbyi* (Stokes); *a*, fragment of the siphuncle separated from the rock; *b*, a longitudinal section shewing the siphuncle and the septa.

Immediately below Olivier's mills there is a section which exposes 420 feet of the Trenton formation, and occupies about a mile on the Bayonne. Just at the mills, some of the dark colored limestones of the lower part of the deposit are seen abutting against the light grey geodiferous beds of the Calciferous formation, affording clear evidence of the same fault Dislocation.

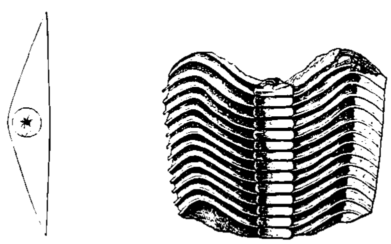
which has already been alluded to as dislocating the Potsdam near Mr. Cuthbert's mills on the Chicot. At these latter mills, which are nearly six miles to the north-east of the Bayonne, and at a spot a mile lower down on the Chicot, dark colored bituminous limestones are again met with. The more south-eastern exposures are of the Trenton formation; those at the mills are lower beds of the same formation, and they reach to within three quarters of a mile of the Laurentian gneiss. The Trenton may abut against the gneiss; but the interval being covered with drift, this has not been positively ascertained.

Côte St. Joachim.

Following the road leading from Cuthbert's mills through Côte St. Jacques and Côte St. Joachim, we meet with three exposures of black bituminous limestone in the latter, the whole of them belonging to the Trenton formation. The first one, with a dip of five degrees to the south-eastward, reaches to within a little over a mile of the general range of the gneiss; and the other

108, 109.—CEPHALOPODA (B. B.)

b 108 a



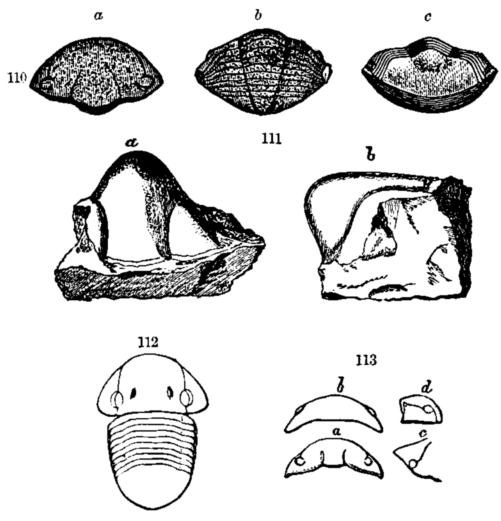
109

108.—*Orthoceras anceps* (Hall); *a*, view of a specimen showing the siphuncle and the septa; *b*, transverse section.
109.—*Cyrtoceras exiguum* (Billings).

two, upon the river Cachée and one of its tributaries, to about half that distance, where they show a scarcely perceptible inclination. That on the Cachée is at Mr. Hamelin's mills, where the thickness displayed is ten feet. In a range with these three Trenton exposures, there is another with a dip of not over three degrees in the fief Carufel, about a mile and a half from the south-western boundary, again about a mile from the gneiss. On the Maskinongé River, the black beds of the Trenton are covered up; but at the foot of the cascade which the stream sends down the flank of the Laurentian rocks, calcareous beds containing a great amount of silicious grains, and resembling some of those of the Chazy at the Dalles on the Naquareau, may belong to this formation, and their dip, which is still to the south-eastward, being raised to an angle of fourteen or fifteen degrees, seems to indicate a proximity to the fault.

In the sixteen miles between the Bayonne and the Maskinongé, it is not easy to decide with certainty where to draw a line representing the summit of the Trenton formation. No traces of the Utica formation have been discovered in the whole distance, nor indeed have exposures of any rock been heard of between those already mentioned and the St. Lawrence. The nearest approach yet known to the upper limit of the Trenton in this area is therefore indicated by the upper beds on the Bayonne, and by an exposure which occurs on the Little River du Loup, two miles beyond the Maskinongé, in the parish of St. Ursule, a mile S. E. of the church. This locality is about four miles, across the measures, from the gneiss.

110–113.—CRUSTACEA (B. B.)



110.—*Illænus Conradi* (Billings), three views of a rolled-up specimen; *a*, the head; *b*, the thorax; *c*, the tail.
111.—*Illænus conifrons* (Billings); *a*, upper surface of head; *b*, side view.
112.—*Illænus Milleri* (Billings).
113.—*Illænus angusticollis* (Billings); *a*, back part of head; *b*, front; *c*, oblique view of one of the cheeks; *d*, side view.

Between the Little River du Loup and the St. Maurice the distance is nineteen or twenty miles, and the breadth from the outcrop of the gneiss to the margin of Lake St. Peter and the St. Lawrence is twelve or thirteen. The area may thus be considered to contain 240 square miles. In the whole of this, only two exposures of the fossiliferous rocks have been met Grand Pré.

with. One of them is on the St. Charles brook, on the property of Mr. Honoré Plauder, in the seigniory of Grand Pré, not far from the division between it and Dumontier, and about a mile and a half removed from the gneiss; the other is at the falls of the Little Yamachiche River, where this is crossed by the road leading from St. Joseph to the Grès. In the latter place, the beds, which have a total thickness of about fifteen feet and contain nodules and patches of chert, are nearly flat, but the geographical position would appear to indicate a gradual turn in the strike, conforming with the trend in the gneiss.

St. Maurice.

The rock which overlies the Potsdam on the St. Maurice is a limestone in which the fossils are too obscure to determine its age. In lithological characters it resembles the Birdseye formation, and whatever portion of the Trenton is on the river must be concealed between the position of this rock and Pointe à la Hache on the left bank of the river, nearly opposite the St. Maurice forges, where there occurs an exposure of the Utica formation.

Between the St. Maurice and the Batiscan there is a distance of about eighteen miles, which for a breadth of from ten to twelve miles presents a nearly level surface covered with drift. The same character belongs to an additional space between the Batiscan and the Charest, with that part of the Ste. Anne de la Pérade which is below the junction of its tributary. The distance between these last limits is about seven miles; and from the St. Maurice, the whole space between the gneiss and the St. Lawrence may comprise an area of about 200 square miles. In the whole of this there have as yet been discovered only two exposures of the fossiliferous formations. These both occur in the Ste. Marguerite range: the first, belonging to the Trenton, in Cap de la Madeleine seigniory, about four miles from the St. Maurice; and the other, on the Rivière au Lard, a tributary of the Champlain, about five miles and a half farther on, in the seigniory of Champlain. In the latter exposure, the brook on which it occurs cuts across the measures in a south-east direction for about a mile, and the strata, presenting a dip with the stream of from two to two and a half degrees, may have a total thickness of about 200 feet. The chief part of this belongs to the Trenton formation; but *Columnaria alveolata*, occurring in abundance at the base, shews it to include portions of the Black River.

Rivière au Lard.

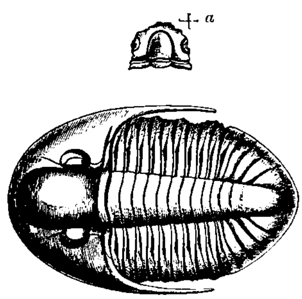
Deschambault anticlinal.

Between the Charest and the line between the seigniories of Deschambault and Portneuf, the exposures of limestone are numerous, and the measures to which they belong are thrown into a synclinal form by the Deschambault anticlinal. The axis of this runs from a spur of gneiss, which is upwards of two miles north of the church of Deschambault, to the church of Grondines. The most easterly exposures seen in the trough are at the Three Rapids on the Ste. Anne, where a black bituminous limestone is met with, within ten acres of the boundary between Deschambault and Portneuf, and within half a mile of the gneiss. The dip is down the river (S. 86° W. $<$ 7°); the beds visible have a transverse measure of 650 yards, giving a thickness of 250 feet. The beds are thin, and at the base much loaded with nodules of chert, and occasionally interstratified with very thin layers of the same Poi mineral, while at the summit occasional crystals of blende occur. The most common fossils are some of those characteristic of the Trenton formation, such as *Stenopora fibrosa*, *S. petropolitana*, *Leptæna sericea*, *Strophomena alternata*, *Orthis testudinaria*, *O. lynx*, *Rhynchonella increbescens*, *Lingula riciniformis*, with an undetermined *Orthoceras*, some of which are replaced by chalcedony and beautifully weathered out. Three miles farther down the river, and over a mile and a half from the gneiss, the same characteristic fossils, in a similar state of silicification, occur at a spot called the Cascades, close upon the division line between Deschambault and Chevrotière. From this for twenty acres to St. Olivier bridge, and for some distance below, the river is confined to a narrow channel, with vertical sides of limestone rock,

114, 115.—CRUSTACEA (B. B.)

115

114



114.—*Bathyurus extans* (Hall).
115.—*Bathyurus Smithi* (Billings), an imperfect head of this species, enlarged; *a*, natural size.

between which the current is sufficiently strong, in some parts, to make them difficult of examination. Among the fossils at and immediately below the bridge are *Stenopora petropolitana*, *Ptilodictya acuta*, *Strophomena alternata*, an undetermined *Orthis*, *Lingula Briseis*, with an undetermined *Cyrtodonta* in great abundance, and *Asaphus platycephalus*. The distance north-westward from the bridge to the gneiss is between two and three miles, and the beds are probably higher in the series than those preceding. Rocks of the Trenton are laid bare in many places farther down the river, the last of which is at a rapid some distance above the mouth of the Charest. The dip of the beds is S. 11° W. $< 1° — 3°$. The strike would run to a point a little way up the Charest; and not far from the spot, beds are seen holding characteristic fossils of the Trenton formation.

Grondines. From these last positions the summit of the Trenton sweeps round by an exposure near the south-western boundary of the fief Dorval, about a mile and a half from the St. Lawrence. It crosses the river-side road to the Grondines, about a mile within the seigniory, and comes upon the water of the St. Lawrence at Pointe à Maçon, a little above the ruins of the old church and windmill at the Grondines village.

From Pointe à Maçon to the Chevrotière, a distance of about four miles, the coast consists of a naked and often vertical cliff of the same limestone in slightly inclined strata, piled up in some places to the height of a hundred feet over the water, and the road on the summit runs on a bare ledge almost the whole way. It is towards the upper end of this cliff that the upper part of the Trenton folds over the Deschambault anticlinal. Chevrotière. From the mouth of the Chevrotière a road runs back in a nearly straight line across the concessions to St. Olivier bridge on the Ste. Anne; a parallel road runs some distance from the mouth of Belle Isle brook; and on both these roads, and in various parts of the seigniory of Chevrotière, the Trenton formation is largely exposed. Extensive quarries are worked in it on the first mentioned road in the fourth concession, where massive granular beds of a light yellowish-grey give a very excellent building stone, which somewhat resembles that from the grey beds of the Trenton at Montreal; but the Chevrotière, or as it is commonly called the Deschambault stone, is more evenly colored, yellower, more granular, and softer than that of Montreal. If in the same stratigraphical place as the Montreal grey beds, these of Chevrotière, being towards the middle of the general trough, must be brought to the surface by an undulation. Associated with the fossils most commonly marking the Trenton, these beds contain *Capulus Trentonensis*, not remarked elsewhere in this formation.

Following the upper part of the formation from the mouth of the Chevrotière, the rock crosses the Belle Isle brook and the adjacent road more than a mile from the coast, and is seen in a quarry, where it shews massive beds of a dark grey color with thin patches of black shale. Small cracks and crevices in the beds are filled with a black mineral, supposed to be altered bitumen, which, resembling coal in its color and its inflammable properties, has occasionally been mistaken for this species of fuel. The quarry is about a mile from the St. Lawrence, and, rising in a step in the land, close in front of the limestone, the shales of the Utica formation appear dipping S. 13° W. $<$ 35°.

Deschambault. Where this step comes upon the road between the first and second concessions of Deschambault, the limestone is seen again, with the shales in front of it, on the road which turns from the water side to the interior, about half a mile below Deschambault church. The exposure is about a mile from the river-side road. As in the quarry, the beds are massive; but there appears an irregularity at the spot, perhaps occasioned by a transverse fault, the dip being N. 56° E. $< 46°$, while the general extended course of the strata is north-eastward.

The gneiss of the Deschambault anticlinal comes out about a quarter of a mile behind the limestone, and continues in the same relation to it and to the Utica formation, up to the division line between Deschambault and Portneuf. Beyond this, the Trenton limestone is exposed in the seigniory of D'Auteuil, above and below the bridge over the river Portneuf on the St. Basil road, where it stretches along the road for between twenty and thirty acres. South of the river, there are indications of a transverse breadth of from sixty to seventy chains of the limestone; the dip at the bridge being S. 44° E. $< 2°$. The gneiss rises about two miles to the north-west, but the interval is concealed. D'Auteuil.

On the axis of the Cap Santé anticlinal, the gneiss is succeeded by a few calcareous beds, in which the fossils are obscure; but strata with Trenton fossils make their appearance at the upper bridge on the Jacques Cartier River, and afford a deep channel for the river down to the middle one. Here, making a detour round a narrow neck of land, the water, confined by the solid masses of rock on each side to a breadth of fifteen feet, rushes with great violence under the bridge, descending many feet in a short distance, and causing a considerable difference of level on the opposite sides of the neck. Across this neck, a body of water sufficient to drive a mill finds a subterranean passage, and pours out from an opening in the vertical cliff on the lower side. A short distance below the mill which has been erected here, the summit of the Trenton, leaving the right bank of the river, appears to run along a line very nearly coincident with the road on this side, for rather less than three miles. It then folds over the axis of the anticlinal about half-way between this road and the next parallel with it on the north-west, and about half way in a straight line between the upper bridge and Cap Santé church. On the axis of the anticlinal, the distance between the highest Trenton beds and the gneiss is about four miles and a half. Cap Santé anticlinal. Jacques Cartier River.

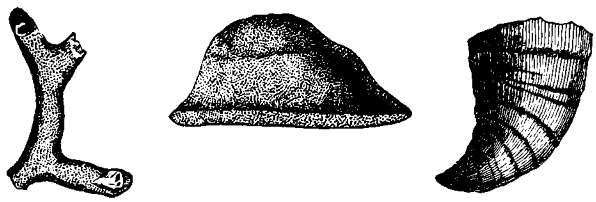
A great development of limestone occurs at Pointe aux Trembles. It occupies somewhat less than three miles along the margin of the St. Lawrence, presenting a low cliff, and the promontory near the church stands almost in the middle of it. The fossils, which are abundant, shew the rock to belong to the Trenton formation, and it here constitutes that part of the Trenton zone which folds over the Pointe aux Trembles anticlinal. On the north-westerly side of the anticlinal, the summit of the formation, striking into the country, appears to run in a north-easterly direction, and to cross the St. Nicholas road about two miles from the St. Lawrence, which would give about a mile and a half as its distance from the gneiss on that side of the axis. Farther on, it would again cross the road in sweeping round with the trend of the gneiss to gain the same part of the forma- Pointe aux Trembles anticlinal.

tion on the Jacques Cartier. On the north-west side of the anticlinal, and not far removed from the gneiss, massive beds of limestone of a grey color and granular texture occur on the land of Mr. J. Gagné and others, affording excellent building material. The stone resembles that of the grey beds of the Trenton at Montreal.

On the south-east side of the anticlinal, the dip is more precipitous than on the north-west, and the strata on that side are broken and let down by a fault. The position and course of this dislocation are plainly seen on the beach at and near a spring a short distance above Mr. Dubord's ship-yard, where strata of the Utica formation are brought against those of the Trenton without any of that interstratification of calcareous and argillaceous layers which indicates the passage from the one to the other. The course of this dislocation, in its continuation, strikes the south-east side of the Bonhomme Mountain; and near the line of division between Pointe aux

116-118.—ZOOPHYTA (TR.)

116 117 118



116.—*Stenopora fibrosa* (Goldfuss).
117.—*S. petropolitana* (Pander).
118.—*Petraia corniculum* (Hall).

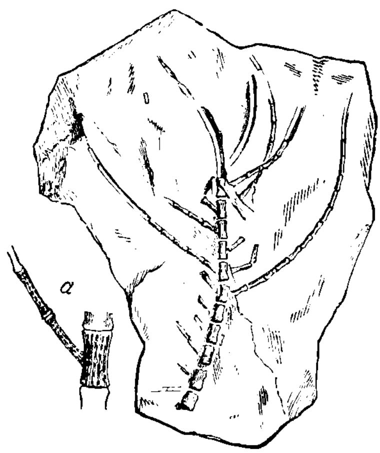
St. Augustin. Trembles and St. Augustin, the Trenton formation is wanting, and the Utica shales come in contact with the gneiss. In this relation, these rocks cross the seigniory of St. Augustin; the Utica shales, which on the west side of the seigniory are not more than one sixth of a mile wide, gradually increasing to more than a mile on the east. A considerable distance farther on, a narrow strip of Trenton limestone becomes interposed between the shales and the gneiss, both rocks being tilted up to a high angle as they approach the gneiss.

St. Ambroise. Arriving at St. Ambroise the limestone gets wider, and a few beds of white sandstone (already alluded to) of the Potsdam formation, in all about twenty feet thick, present themselves. These are overlaid by a bed or two of grey granular limestone with *Leperditia Canadensis*, associated with *Orthis testudinaria*, and *Camerella hemiplicata*. These grey beds are followed by black limestones with *Orthoceras Bigsbyi* and *Lituites undatus*, belonging to the Black River; but in the same fragment of rock with the former there is *Orthis testudinaria*, and with *Lituites* are

Trinucleus concentricus and *Conularia Trentonensis*, which are characteristic Trenton forms. On the river St. Charles, close by, these black limestones rest upon the gneiss without the intervention of the Potsdam, and they are followed by beds belonging to the Trenton, showing a united breadth of about 700 yards, and dipping at an angle varying from fifteen to twenty degrees, which gives about 600 feet of thickness.

On the Rivière des Mères, the width of the limestones increases, the summit being below the mill on the Jeunne Lorette and Charlebourg road. At Charlebourg, the summit passes near the church; on the Bourg Royal

119.—ZOOPHYTA (TR.)



119.—*Arthroclema pulchella* (Billings); *a*, a portion of the principal stem and of one of the branches enlarged.

road, it is about half a mile from the gneiss; and beyond this, the formation sweeps round in accordance with the anticlinal of Montmorenci, attaining a breadth of perhaps about four miles on the synclinal axis, which would cross the road from Beauport to Laval, about two miles and a half from the St. Lawrence. This breadth it maintains until reaching the anticlinal axis. The summit of the formation comes upon the Quebec and Beauport Beauport. road, a little west of the river Beauport; and in a quarry on the north side of the road, at the turn to Beauport bridge, there appears to be an irregularity in the dip, connected probably with some dislocation. From S. 13° W. $<$ 28° on the west side of the quarry, it becomes N. 84° W. $<$ 6° on the east.

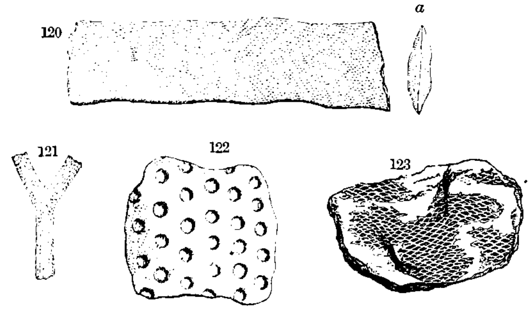
The Montmorenci anticlinal, like that at Pointe aux Trembles, shows a more precipitous dip on the south-east than on the north-west side; and it seems also, as in that instance, to be accompanied by a dislocation throwing

Montmorenci anticlinal and dislocation.

the measures down to the south-eastward. This fault is traceable north-easterly from Beauport church, from which the road to Montmorenci runs nearly the whole way on a bare ledge of Trenton limestone with a very small dip; while close on the south-eastern side of the road, the Utica shales are in many places seen in a narrow strip, tilted up at a high angle. The details of the fault are well displayed at Montmorenci Falls. Here the channel of the river is cut down through the black limestone beds of the Trenton formation to the gneiss of the anticlinal ridge, and the water at and below the bridge flows down and across the gneiss, and leaps at one bound to the foot of a precipice, which, immediately behind the water, is composed wholly of this rock.

At the summit of the cascade, the Trenton beds on the west side have a thickness of nearly fifty feet, marked by *Leptæna sericea*, *Strophomena alternata*, *Orthis testudinaria*, *Conularia Trentonensis*, and *Calymene*

120-123.—BRYOZOA (TR.)

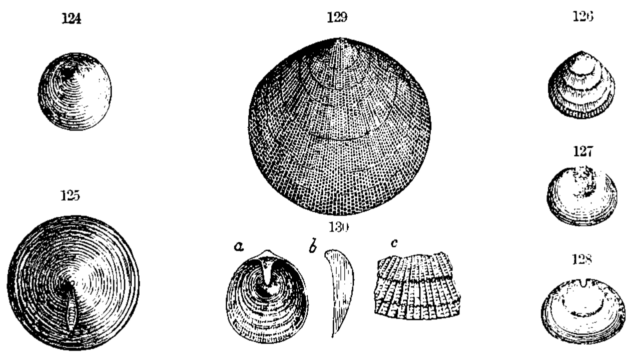


120.—*Ptilodictya recta* (Hall); *a*, transverse section.
121.—*P.* ——— *acuta* (Hall).
122.—*Coscinium proavium* (Eichwald), a fragment.
123.—*Intricaria? reticulata* (Hall).

Blumenbachii. The dip of these beds is down the stream, at a very small angle; but at the foot of the precipice, and in immediate contact with the gneiss, about the same thickness of limestone is tilted up to an angle of fifty-seven degrees. It is followed by a similar amount of black bituminous shale with the same slope. In this attitude, the rocks climb up the face of the precipice, presenting their edge to the chasm on each side. They are followed by about eight feet of strong hard grey sandstone, weathering brown, in beds of from ten to eighteen inches, interstratified with black shales, to which succeed grey arenaceo-argillaceous shales, composing the sides of the chasm out to the water of the St. Lawrence. The limestones hold characteristic fossils of the Trenton, the black shales belong to the Utica, and the grey shales to the Hudson River formation.

About half a mile beyond the bridge, the tilted limestones and black shales cross the road; immediately on the north side of which, the gneiss rises from beneath them, here showing the point around which the basset edge of the limestone sweeps as it folds over the anticlinal axis. These two formations keep close on the north side of the road for nearly a mile and a half, when they suddenly become removed between one and two furlongs to the north-westward by a twist or dislocation. Proceeding beyond this, they gradually increase in width, while the gneiss as gradually recedes from the coast, until, becoming affected by the anticlinal of Chateau Richer, they sweep round to the road. The upper part of the black shales comes upon the road about half way between the churches of Ange Gardien and Chateau Richer, and that of the limestone about three eighths of a mile above the latter place. On the south-eastern side of the gneiss, which rises Chateau Richer anticlinal.

124-129.—BRACHIOPODA (TR.)



124.—*Discina Pelopea* (Billings). 127.—*Trematis terminalis* (Emmons).
125.—*D.* —— *Circe* (Billings). 128.—*T.* —— *Montrealensis.*
126.—*Trematis filosa* (Hall). 129.—*T.* —— *Ottawaensis* (Billings).
130.—*T.* —— *Huronensis* (Billings); *a*, lower valve; *b*, longitudinal section, showing the curvature of both valves; *c*, a portion of surface enlarged.

into a moderate hill, the Trenton limestone leans at a considerable angle, and continues so until reaching the synclinal curve, where it comes upon the Sault à la Puce River, and where the beds are found to be more arenaceous than usual.

On the south-eastern side of the anticlinal of Chateau Richer, the measures are broken by the effect of a fault, which again throws them down on that side, bringing the Hudson River shales to abut against the gneiss. At the cascade of the Sault à la Puce, the water is precipitated over the gneiss rock with a fall of sixty feet; and above the cascade for some short distance this rock occupies the left bank of the river, while the arenaceo-calcareous beds are seen on the right. At the foot of the cascade, the Dislocation.

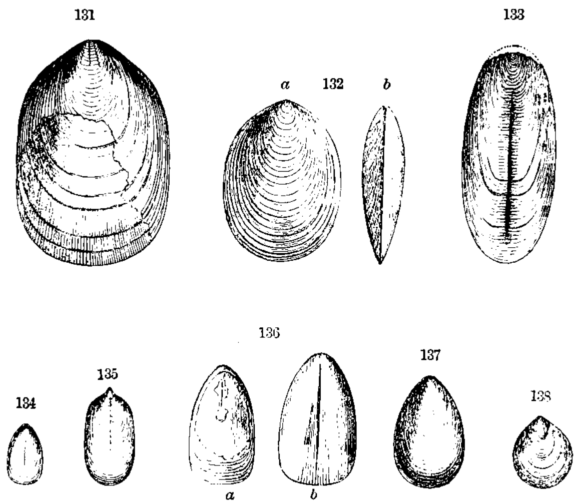
stream makes a sudden turn to the eastward; and the rock on the right bank, in face of the fall, appears to belong to the Hudson River shales, which constitute both banks of the stream for the remainder of the distance to the St. Lawrence. In the course of the fault to the north-eastward, these shales continue in contact with the gneiss for two miles farther. A thin strip of Trenton limestone is then interposed, and continues, with but little augmentation in its breadth, all the way to the Rivière à la Rose. Both formations maintain a high angle of inclination; but they diminish in slope and increase in width as they fold over the anticlinal of this vicinity; again however narrowing and becoming more precipitous as they proceed eastward on the south side of the axis.

Ste. Anne. On the Ste. Anne, the limestone is seen leaning against the gneiss at the foot of the lowest cascade. At the contact it has a southern dip of from thirty to seventy degrees, and the breadth of the band does not exceed twenty or thirty yards. Farther down the stream, the total thickness of the Utica formation (to be hereafter described) is well displayed, with measures belonging to the Hudson River formation beyond. Between the river Ste. Anne and Cape Tourmente, both the Trenton and the Utica formations are once more seen on the road from St. Joachim to Bay St. Paul, where the road rises from the plain between the rivers Blondelle and Marsolette. The limestone is seen for the last time in this neighborhood where the Friponne descends from the gneiss. In both localities, the limestone, dipping nearly south, rests on the gneiss at an angle of about thirty degrees; and at the Friponne the strata are abundantly stored with fossils, such as *Orthis testudinaria*, *Lingula curta*, *Discina filosa*, *Conularia Trentonensis*, *Calymene Blumenbachii*, *Trinucleus concentricus;* and with them occurs *Acidaspis Horani.*

Bay St. Paul. Descending the St. Lawrence to Bay St. Paul, which is about thirty miles below Cape Tourmente, a great development of limestone is met with on the east side at Cap aux Rets, between which and the gneiss running out into Cap Rouge the cliff exposes a section nearly at right angles to the strike of the strata. The general dip is westward, increasing irregularly from sixteen to sixty degrees as it approaches the gneiss. Between the limestone and the gneiss there is an interval of concealment of about fifty yards, across the measures; but independent of what may be in this, and making allowance for one or two twists visible in the cliff, there is breadth enough completely denuded to give a thickness approaching 600 feet, the whole of which consists of dark grey and black bituminous limestone, with the exception of a band of white sandstone within about thirty feet of the bottom. The rock is fossiliferous, and among the remains are *Graptolithus amplexicaule*, *Leptæna sericea*, *Orthis testudinaria*, *Avicula Trentonensis*, *Calymene Blumenbachii*, *Acidaspis Horani*, and *Trinucleus concentricus.*

On the west side of the bay, a portion of the same bituminous limestone is met with at the mill on the Rivière au Moulin. The deposit is here seen to dip eastward, and there is evidence to prove that it is brought into place by a dislocation. The beds abut against the gneiss; and at the point of contact, the slope, which near the mill does not exhibit more than from twenty to thirty degrees, is suddenly turned up at the cascade, on one side of the stream to sixty, and on the other to ninety degrees, while in one spot, the strata, conforming to the face of the cliff, even overhang the **Dislocation.**

131-138.—BRACHIOPODA (TR.)



131.—*Lingula quadrata* (Eichwald).
132.—*a*, *b*, *L. Coburgensis* (Billings).
133.—*L. Philomela* (Billings).
134.—*L. Progne* (Billings).
135.—*Lingula elongata* (Hall).
136.—*a*, *b*, *L. Briseis* (Billings).
137.—*L. obtusa* (Hall).
138.—*L. curta* (Conrad).

perpendicular. The direction of the junction of the two rocks is N. 80° W.; but following up the ravine above the edge of the cascade, in a direction nearly transverse to this, after passing over a few yards of gneiss, the limestone again occurs, and continues present on one side of the ravine while gneiss occupies the other for the space of nearly fifty yards, to the second vertical leap in the fall. Here a face of gneiss presents itself, **Mineral veins.** running N. 54° W.; and on the north and south sides of the limestone thus limited, mineral veins occur, holding small quantities of galena. The gangue in which the ore is distributed is composed of calcspar, mingled with apple-green fluor spar. The veins on the south side of the limestone are smaller than those on the north, but they are all probably connected with one great line of disturbance. On the north side, there are two parallel veins in the space of six feet, one of them being three feet wide, including a fragment of gneiss which occupies half the breadth. In the valley of the Gouffre, the bituminous limestone, which at the mouth of the river has a breadth of two miles, has been traced up to St. Urbain, a distance of about ten miles, reaching it without any apparent disruption of its continuity. It is contracted however to a width of half a mile a little over half-way up, at St. Croix and the river Remy, but it widens again to a mile before it terminates above the church of St. Urbain.

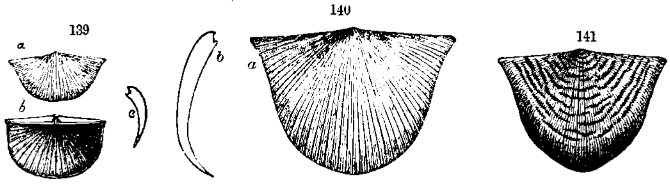
Eboulemens. Limestones present themselves again between three and four miles below the Gouffre, entering upon the land a little above Les Eboulis. They extend along the coast about fifteen miles, in a strip, of which the greatest breadth, somewhat exceeding a mile, occurs between two small streams upwards of a mile apart, one of them called the Ruisseau du Moulin and the other the Ruisseau de l'Eglise, in the seigniory of Les Eboulemens. After an interval of about five miles, the same rocks again come upon the coast, along which they occupy a distance of about six miles, and run up the valley of Murray Bay River. The strata at the base are seen in the neighborhood of White Point, on the west side of the bay. They are as a whole composed of calcareous sandstone, but the arenaceous layers are interstratified with occasional bands of limestone. In one or two of the arenaceous beds there are quartz pebbles as large as hen's eggs; but in general the grains range from the size of snipe shot to that of pigeon shot, and are usually rounded, so as to give an oolitic aspect to the rock. They consist sometimes of limestone and sometimes of quartz, the latter usually prevailing to a considerable extent. The color of the rock is a dirty white.

Murray Bay.

On the east side of the bay, a coarse conglomerate fills up inequalities in the surface of the Laurentian quartzite, and appears to be composed of various moderately sized fragments, and even considerable boulders or large angular blocks of the quartzite, held in various attitudes in a partially calcareous cement. The best section on the east side of Murray Bay is at Les Ecorchés, where the lower part of the deposit consists of calcareous sandstone, with a band or two of conglomerate holding pebbles as large as pigeon's eggs, followed by grey and whitish layers which weather to a yellowish-white, assuming a light drab when the stone is wet. These are followed by a set of calcareo-arenaceous beds, which, though of a nearly uniform light grey in fresh fracture, weather to a yellowish-white and a reddish-white; the two colors alternating with one another in the upper part of the deposit. The total thickness of this part is about sixty feet. The calcareous sandstones are followed by dark grey bituminous limestones, which are highly fossiliferous, and these in some parts display a considerable thickness, attaining perhaps nearly 200 feet.

From these beds Dr. Dawson of McGill College has collected an instructive series of fossils. Among those from the calcareous sandstones are *Stenopora fibrosa*, *Receptaculites occidentalis*, *Tetradium fibratum*, *Lingula Eva*, (a new species), *Ctenodonta nasuta*, *Pleurotomaria staminea*, *P.* allied to *aperta*, *Bellerophon bilobatus*, *Illænus Milleri*, and *Leperditia Canadensis*. Among those from the dark grey limestones are *Stenopora fibrosa*, *Petraia corniculum*, *Glyptocrinus ramulosus*, *Leptæna sericea*, *Strophomena alternata*, *Orthis testudinaria*, *O. pectinella*, *O. tricenaria*, *Camerella Panderi*, *Ambonychia radiata* (never before found so low), *Modiolopsis nasuta*, *Bellerophon bilobatus*, *Calymene Blumenbachii*, *Bronteus lunatus*, *Illænus Milleri*, *Trinucleus concentricus*, *Encrinurus vigilans*, and *Asaphus platycephalus*. From this it would appear that the lower beds belong to the Birdseye and Black River, and the upper to the Trenton formation. These deposits run for six miles up the valley of Murray Bay River, and in this distance the breadth of six miles, which they present on the coast, gradually diminishes to a mile and a half. At the

139-141.—BRACHIOPODA (TR.)



139.—*Leptæna sericea* (Sowerby) ; *a*, ventral valve ; *b*, dorsal ; *c*, section.
140.—*Strophomena alternata* (Conrad) ; *a*, ventral valve ; *b*. section.
141.—*S.* ——— *deltoidea* (Conrad).

bridge however, near the mouth of the river, an undulation brings to the surface a narrow belt of gneiss, which, running in an easterly course, approaches the coast beyond Le Heu. There appears to be another parallel undulation below Les Ecorchés.

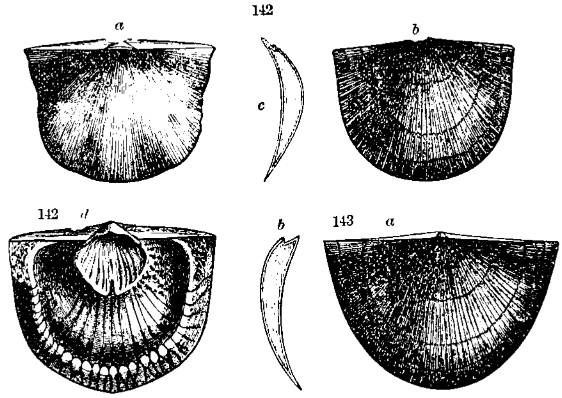
Proceeding along the road from the Murray Bay River, by the Ruisseau des Frênes, there occurs beyond the extremity of the preceding spur, a small patch of the limestone before reaching the Little Lake, and a large one appears to extend from this lake to Nairne's Lake. The latter patch is not over ten miles from the limestone of St. Urbain, and it is not impossible that there may be others between the valleys of the Gouffre and Murray Bay River, in the depression that runs from the one to the other. The interval has however not yet been examined. **Lake Nairne.**

Between Murray Bay and the Mingan Islands, the series of rocks under description is not yet recognised, and the only position that has been heard of, as possibly presenting them, is at the entrance of the Bay of Seven

Mingan Islands.

Islands, where limestones are said to exist resembling those of Mingan, but there has not yet been any opportunity of inspecting them. In the southern part of Large Island of the Mingan group, the beds which have been given as belonging to the Chazy formation are followed by about thirty feet of yellowish-white pure limestone, some portions of which are filled with *Maclurea Logani*. The beds making up this mass are therefore supposed to belong to the Birdseye and Black River formation. Before however this is rendered certain, it would be necessary to obtain a larger number of characteristic fossils from the locality, which is the only one in which these strata have been observed among the Mingan islands.

142, 143.—BRACHIOPODA (TR.)

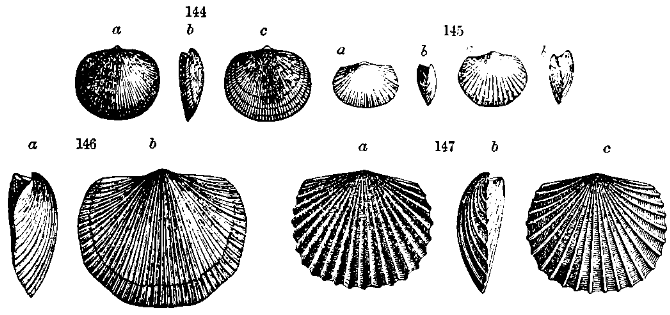


142.—*Strophomena filitexta* (Hall); *a*, ventral aspect; *b*, dorsal aspect; *c*, section of a slightly convex specimen; *d*, interior of ventral valve.
143.—*Strophomena Thalia* (Billings); *a*, ventral aspect; *b*, section.

Saguenay: Lake St. John.

On the Saguenay, at Lake St. John, which is nearly a degree west of the longitude of Quebec, and somewhat less than two degrees of latitude to the north of it, there is an outlying patch of Lower Silurian strata, to which attention was first drawn by Captain, now Major General Baddeley, R. E., in the year 1828. It probably underlies the whole lake, but the strata belonging to it have as yet been observed only on the east and west sides of it. The lower rocks of the series are limestones, and their fossils indicate that they belong to the Birdseye and Black River and Trenton formations. On the east side, the Trenton occupies a position on a flat island about half a mile to the west of the Little Discharge. On the west, the whole series of limestones extends in a belt from the Hudson's Bay Company's post at the mouth of the Metabechouan to a position a little south of Blue Point, a distance of about eighteen miles, whence it has been traced only five miles farther, striking westward. The details of its distribution beyond this have yet to be ascertained. The summit of the formation is well defined by the presence of the Utica shales, and its thickness does not appear to exceed a hundred feet. In the lower parts, there appears to be an intermingling of the fossils of the Birdseye and Black River with those of the Trenton. For example, about two miles west of the Metabechouan River, in eight feet of brown compact bituminous limestone at the base of the series, occur *Stromatopora rugosa*, *Petraia profunda*, *Receptaculitus occidentalis*, and *Orthoceras Bigsbyi*, associated with *Leptæna sericea*, *Strophomena alternata*, and *Calymene Blumenbachii*. The chief part of the limestones are of a yellowish-grey, and at the Ouiatchouan in a three feet bed of this description at the base of the series, associated with *Stenopora fibrosa*, *Petraia profunda*, *Orthis lynx*, *Murchisonia gracilis*, *M. bellicincta*, and *Trochonema umbilicata*, there was met with *Halysites catenulatus*, in no other place found so low on the American continent.

144-147.—BRACHIOPODA (TR.)



144.—*a, b, c, Orthis testudinaria* (Dalman):
145.—*a, b, a, b, O.* —— *plicatella* (Conrad), different views of two specimens.
146.—*a, b, O.* —— *subquadrata* (Hall).
147.—*a, b, c, O.* —— *pectinella* (Conrad).

In the trough between the Ottawa and the St. Lawrence Rivers, the Birdseye and Black River formation follows the contour which has been given to the Chazy, and the Trenton probably fills up the centre of the southern of the two subordinate synclinals into which the general trough is divided by the Rigaud anticlinal, while in the northern it is overlaid by three isolated patches of the succeeding Utica shales. The principal one of these is in the vicinity of Ottawa city, and comes to within from a quarter to half a mile of the Ottawa River, near the mouth of its tributary the Rideau; leaving but a narrow space for the Trenton limestone. The upper part of this, east of the Rideau, appears to be buried by an east and west fault, which comes upon the main stream about half a mile below the tributary, and shows a downthrow to the south. The limestones are affected by two parallel dis- Ottawa.

Dislocations. locations between 500 and 600 yards apart, west of the Rideau. One of them, coming to the Ottawa a little below the exit of the canal, is a small upthrow to the south, and the other, about 600 yards above it, beyond Barrack Hill, is a downthrow of seventy feet in the same direction. Farther west, the series of limestones which we are tracing comes up against the Gloucester and Hull fault, with a breadth of probably seven or eight miles, extending from the vicinity of the west side of the junction gore of Gloucester, across the Ottawa, to the front of the sixth lot of the fifth range of Hull. This fault being with an upthrow to the west, the limestones show a less width on that side of the fault; and as already indicated in speaking of the Chazy, they present two areas, one on each side of the Ottawa, between which there is probably an undulation bringing up the lower measures seen on the river.

Thickness of formations. In consequence of these disturbances, it is difficult to measure correctly the thickness of the series in this neighborhood. In the Barrack Hill there is visible an uninterrupted succession of beds, in all making 187 feet of thickness; and on the south side of the downthrow fault occurring above the hill, the beds continue to accumulate at a pretty regular rate for nearly a mile across the measures, and probably to the Little Chaudière upthrow, which would be half a mile more. If an inclination of no more than three degrees be given to these strata, the thickness resulting, combined with that of the beds in Barrack Hill, after deducting the seventy feet repeated by the Barrack Hill fault, would be upwards of 500 feet. Approaching the Little Chaudière fault, however, the inclination appears to increase, while a part of the Trenton is buried in the fault, and it is therefore probable that the total volume of these limestones at Ottawa will not fall short of the 600 feet given to them at Montreal.

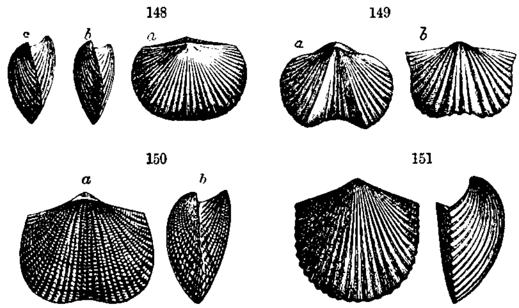
Between the base of the Utica formation and the beds of the Barrack Hill there appear to be a few bands of smooth even-bedded compact black limestone; while the strata of the hill, for about 150 feet down, are of a nodular character, having the beds usually parted by black bituminous shale. The lower part of the section, for about twenty feet, consists of strong bands highly charged with chert, underlaid by beds crowded with broken stems of encrinites, many of which are of large size and sometimes in a good state of preservation. The layers between the nodular and chert beds are thin, and are enriched with a great variety of crinoids, star-fishes, and cystideans, of which the bodies and stems are sometimes

Fossils of Ottawa. nearly whole. These beds have greatly extended our knowledge of these families in the Lower Silurian series, and among other remarkable forms there have been obtained from them *Pleurocystites squamosus*, *P. robustus*, *P. filitextus*, *P. elegans*, *Glyptocystites multiporus*, *Comarocystites punctatus*, *Amygdalocystites radiatus*, *Glyptocrinus marginatus*, *G. ornatus*, *Hybocrinus conicus*, *H. tumidus*, *Carabocrinus radiatus*, *Porocrinus coni-*

cus, *Dendrocrinus gregarius*, *D. rusticus*, *Palæocrinus angulatus*, *Cleiocrinus regius*, *Lecanocrinus elegans*, *Rhodocrinus pyriformis*, *Reteocrinus fimbriatus*, *Agelacrinites Dicksoni*, *Edrioaster Bigsbyi*, *Stenaster pulchellus*, *Petraster rigidus*, and *Palasterina stellata*. These fossils are figured in Decades III. and IV. of the Survey. In the same beds is obtained *Bronteus lunatus*, the only species of this genus yet known in the Lower Silurian series of America.

On the downthrow side of the Barrack Hill fault, and somewhat higher on the river, grey yellow-weathering bituminous limestones occur, which are lower in the series than those of the Barrack Hill cliff. They contain numerous fossils, among which are *Strophomena alternata*, *Rhynchonella increbescens*, *Murchisonia gracilis*, *M. bellicincta*, *M. bicincta*, *Pleurotomaria Americana*, *Ophileta Ottawaense*, *Eunema strigillata*, *Bellerophon disculus*, *Helicotoma planulata*, *Trochonema umbilicata*, *Ctenodonta nasuta*, *Ma-*

148-151.—BRACHIOPODA (TR.)



148.—*a*, *b*, *c*, *Orthis borealis* (Billings).
149.—*O.* —— *lynx* (Eichwald); *a*, specimen with cardinal angles rounded; *b*, the more common form.
150.—*a*, *b*, *O.* —— *insculpta* (Hall).
151.—*a*, *b*, *O.* —— *tricenaria* (Conrad).

theria brevis, *M. obtusa*, *Orthoceras Ottawaense*, and *Phacops callicephalus*. The fossils being replaced by sparry dolomite, which is less soluble in water than the carbonate of lime in which they are imbedded, weather into relief and, becoming brown from the presence of carbonate of iron, which is converted into the peroxyd, are strongly contrasted with the rock.

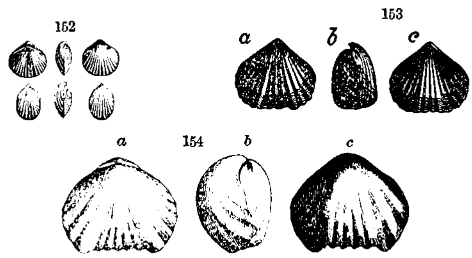
Descending the valley of the Ottawa, the sandstone of the Chazy generally presents a distinct escarpment. The overlying limestone of the same formation sometimes occurs in the same escarpment as the Birdseye and Black River, but occasionally by itself, while the Trenton, with its lower part sometimes in the same escarpment with this formation, often presents, at some distance back, another escarpment composed of higher por- Escarpments.

tions of the formation. On the south-east side of Green's Creek three escarpments appear. The first, which has a height of forty feet, presents the Chazy sandstone; the second, which is thirty feet, shows the Chazy limestone; and the third, of forty-eight feet, the Birdseye and Black River. The last of these is removed from the Ottawa about a mile, being on the line between the first and second ranges of East Gloucester, where it is traceable along the strike for about a mile and a half. The formation again appears in an escarpment on the second lot of the first range, but is here not more than the third of a mile from the margin of the river, and forms a point, from which it runs eastward on the one hand and southward on the other. These two escarpments are on the opposite sides of the Templeton and East Gloucester anticlinal. It is not certain how far they would run before meeting on the axis of the anticlinal, but it would probably be somewhere in the east end of the third range of the township.

Gloucester.

Anticlinal.

152-154.—BRACHIOPODA (TR.)



152.—*Rhynchonella recurvirostra* (Hall).
153.—*a, b, c, R.* ———— *increbescens* (Hall).
154.—*a, b, c, Camerella hemiplicata* (Hall).

The lower part of the Trenton does not appear to display any corresponding escarpments succeeding these. But about five miles and a half from the Ottawa, on the south side of the anticlinal, an escarpment of the upper part of the formation, varying from thirty to ninety feet, crosses the road between the eighth and ninth ranges of Cumberland, on the seventh lot. This is traceable in a pretty straight line for between seven and eight miles, to the line between Cumberland and Clarence, on the thirteenth lot, upwards of six miles from the Ottawa. Here it makes a sudden turn to the southward, and has been traced in this direction for about a mile. From 200 to 400 yards southward from the edge of this escarpment, the black shale of the Utica formation can be traced the whole way, presenting a very small dip to the southward until coming to the turn. A mile eastward of the turn a lower escarpment occurs, with another still lower, a mile beyond; both run north-westward for upwards of a mile, and present a small dip to the southward of west, indicating the crown of the anticlinal arch. The thickness in the three escarpments would probably be about a hundred and fifty feet.

A great swamp extends nearly across Cumberland on the crown of the anticlinal; but on the north side of the anticlinal, limestones, which correspond with those of the uppermost of the escarpments, form a point on the third lot of the sixth range of Cumberland, about three and a half miles from the Ottawa. They present a considerable area of bare rock, and upwards of a mile to the eastward are divided by a point of black shale. The limestones on the south side of the shale soon become covered up, in their progress eastward; but those on the north present an escarpment of about forty feet, facing the north, which is traceable for a couple of miles to the road from the Ottawa to Dunning's mills, where the road runs through the fourth range of Cumberland. On this road the escarpment is on the second lot; the outcrop of the black shales is about 650 yards southward from it on the third, where they form part of the smallest of the three patches of the Utica formation already mentioned, this smallest one being separated from the largest by the limestones on the Clarence and Cumberland anticlinal. Cumberland.

Between the black shales and the Ottawa, the road which has been mentioned runs very nearly at right angles across the measures, and the breadth on it of the Trenton formation, with the Birdseye and Black River, is just about 5000 yards. The dip, which is from the Ottawa, does not, on the average, exceed one and a half or two degrees, while there is a difference in level of about a hundred feet between the summit and the base. The total volume of the series would thus be between 650 and 700 feet, which accords very well with the supposed thickness both at Montreal and Ottawa. Thickness.

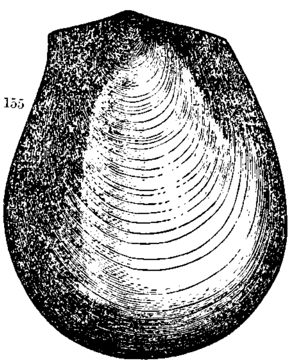
About two miles southward from McCaul's wharf in Clarence, the Chazy presents an escarpment of fifty feet, the base of which is occupied by the sandstone of the formation, and a short distance from this step there rises up another, the height of which is about a hundred feet. The lower part of it is occupied by the Birdseye and Black River formation, and the upper by a portion of the Trenton. This escarpment is on the south-west side of the Buckingham and Clarence anticlinal, and is well marked for at least two miles to the south-east. It is not yet ascertained how far the Birdseye and Black River formation is carried in this direction before meeting the dislocation which is connected with this anticlinal; but however far it may be, this formation is thrown northward again, beyond McCaul's mills, by the fault, the rock at the mills being Trenton. Clarence.

Freed from the effects of this fault, the same series presents itself in another escarpment, which, from a position about a mile west of McCaul's mills, runs in a nearly straight line to the tenth lot of the fifth range of Plantagenet, the distance being about eleven miles, and the bearing about

Plantagenet. five or six degrees south of west. The escarpment for some distance is about a mile from the Ottawa; but opposite the mouth of the South Petite Nation it is nearly two miles. It runs up the valley of the river, and gradually approaches to within less than a mile of the stream. On a road which runs between the thirteenth and fourteenth lots of the third range of Plantagenet, the outcrop of the Utica shales is met with about 300 yards south of the edge of the escarpment. They here constitute a part of the rim of the third isolated patch of those shales, already mentioned. This area of shales is no doubt separated from the second by the effect of the Buckingham and Clarence anticlinal, but its breadth is somewhat uncertain. Fragments of shale, however, on the sixteenth lot of the sixth range of Plantagenet, show that it will probably attain at least three miles.

155, 156.—LAMELLIBRANCHIATA (TR.)

155



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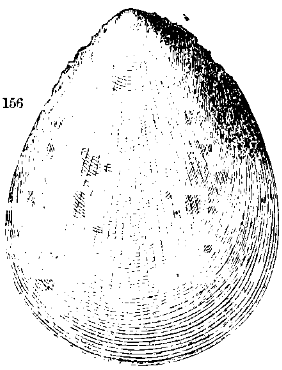


155.—*Avicula elliptica* (Hall).
156.—*A.* —— *Hermione* (Billings).

Where the escarpment on the left side of the South Petite Nation reaches the fifth range of Plantagenet, it takes a turn to the south-eastward, and can be followed for nearly two miles in that direction. As the upper part of the Trenton would here be nearly half-way across the space between the anticlinals to the north-east and the south-west, it is probable that in its farther progress it will turn farther round and thus limit the Utica shales on the east.

Cambridge. At the High Falls on the South Petite Nation, in the twelfth lot of the sixth range of Cambridge, the river runs northward on the face of a single bed of Trenton limestone for about 300 yards, descending about twenty feet. The position and dip of this rock make it probable that it is on the north side of the main Rigaud anticlinal. The want of exposures in the stream for a considerable distance below the High Falls renders it uncertain where the axis of the Templeton and Gloucester, and that of the Buckingham and Cumberland anticlinal would strike the stream. It is conjectured however that the former would cross it near the mouth of Cobb's creek, in the twenty-third lot of the twelfth range of Plantagenet, and the latter not far from the elbow in the stream, near the south-east corner of Plantagenet. The Lochaber and Plantagenet axis would apparently run up the valley not far from the stream, nearly to Hatville, which is six miles from the mouth, beyond which it would probably keep rather to the north-east side of it. There are exposures both at Hatville and a mile and a half farther up, and the strata in both places belong to the Trenton. Their dip appears to indicate that they are on the south-west side of the axis, and it is probable that the base of the formation would fold over it farther down the valley. Anticlinals.

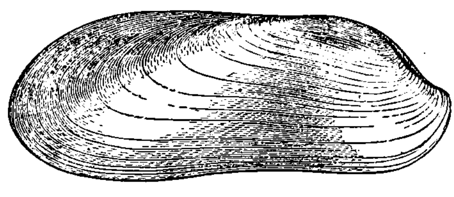
About two miles from the mouth of the South Petite Nation, the Birdseye and Black River formation crosses the stream, dipping southward at an angle of four degrees. Trenton beds are seen resting on it, and they underlie the road up the valley for more than a mile, in which they appear to be quite horizontal. These rocks are seen in the same relation on the east side of the township, in an escarpment below the road, crossing the line between Plantagenet and Alfred, about two miles from the Ottawa. The escarpment and the road keep in the same relation for two miles and a half farther to the south-eastward, up the valley of the brook flowing into George Lake; but three miles farther east, on the second range of Alfred, the escarpment is south of the road, and on the summit there occurs a bare triangular surface of Trenton limestone, of a mile and a half long. In the township of L'Orignal, the escarpment approaches nearer the Ottawa, being about a mile from it on the west side, and a mile and a half on the road which runs back from the village. In the rear of Hamiltonville in West Hawkesbury, it is two and a half miles from the margin. Its position in East Hawkesbury is not so well ascertained; but the base of the series very probably reaches the boundary between the western and eastern divisions of the province, in sweeping round the extremity of the trough north of the Rigaud anticlinal. On the south side of the trough, limestone beds are met with at McDonald's mills, on the Rivière à la Graisse, in the fifteenth lot of the seventh range of East Hawkesbury. These are at the base of the Trenton; and very nearly in the strike of these beds, there is an exposure of Trenton limestone in the thirty-second lot of the ninth range of Lochiel. Hawkesbury.

In the southern division of the general trough between the Ottawa and the St. Lawrence, it is computed that the Birdseye, Black River, and Trenton formations spread over an area of about 600 square miles, the Trenton occupying the chief part; but the area is so much covered over with drift that its perimeter has not yet been ascertained. Following the exposures

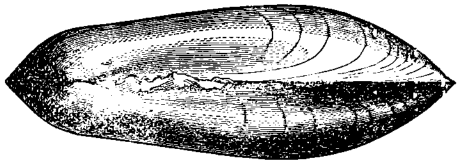
Lochiel. nearest the supposed base of the series, we have black Trenton limestone on the thirteenth lot of the first range of Lochiel, on the Rivière de l'Isle, and good grey granular beds of the same formation, fit for building stone, at and near Alexandria, on the river Garry, on the thirty-seventh and thirty-eighth lots of the second range of Lochiel, as well as farther up on the stream, on the fourth and sixth lots of the second range of Kenyon. The Birdseye and Black River limestones, with *Columnaria alveolata*, are exposed on the river Beaudette, in the twenty-ninth lot of the seventh range of Lancaster, and Trenton on the twenty-second lot of the second range of Charlottenburgh, where a bed of fifteen inches yields a good building stone. The thick black beds of the Birdseye and Black River

157.—LAMELLIBRANCHIATA (TR.)

a



b



157.—*Modiolopsis Gesneri* (Billings); *a*, side view; *b*, dorsal view.

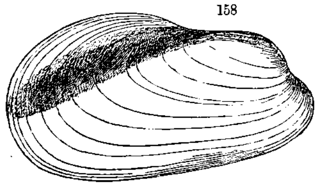
Cornwall. formation on the sixth and twenty-fourth lots of the fourth range of Cornwall, have already been alluded to. In the former of these two localities *Columnaria alveolata* is a common fossil, and many of the specimens obtained present the peculiarity of having the cells of the coral lined with transparent crystals of quartz, and filled with a brilliant black carbonaceous matter, looking like coal. *Leptæna sericea*, *Strophomena alternata*, and *Orthis testudinaria* occur in the other locality, and the beds may therefore belong in part to the Trenton. The massiveness of some of the beds makes them resemble those of the previous locality, and among the fossils there is a large *Orthoceras* (*O. magniventrum*,) the chambers of which hold mineral carbon. A siphuncle of one of these, on being slit open, was found to contain *O. Bigsbyi*. Both of these are Black River species, and it is therefore probable that we have here the junction of the Black River and Trenton. Farther westward, on the twenty-sixth lot of the fifth range of Osnabruck, black Trenton beds show *Stenopora petropoli-*

tana, *Leptæna sericea*, *Strophomena alternata*, *Orthis testudinaria*, *Lingula* like *L. quadrata*, *L. elongata*, and *Avicula elliptica*.

Sixteen miles farther in the same direction, black limestone occurs in the northwest corner of Williamsburgh, about a mile from the right bank of the South Petite Nation River. Being the most westerly exposure of black limestone met with, connected with the southern division of the Ottawa and St. Lawrence trough, it is probable that it may belong to the Birdseye and Black River formation. There is nothing to contradict this view in the aspect of the rock, but no fossils have been obtained to confirm it. Farther down the river, at the eleventh lot of the second range of Winchester, similar beds hold *Leperditia;* but here also the formation is uncertain. Still farther down, at Armstrong's mills, on the twelfth lot of the fourth range, and in several places in the neighborhood, quarries are opened in black limestone beds, but there they are characterized by Trenton fossils. From this vicinity, similar limestones occur at intervals all the way to Crysler's mills in Finch, and nearly the whole of the township Winchester.

158, 159.—LAMELLIBRANCHIATA (TR.)

158



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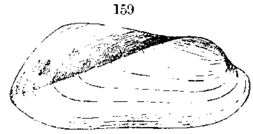


158.—*Modiolopsis Meyeri* (Billings).
159.—*Modiolopsis carinata* (Conrad).

appears to be underlaid by such strata in a generally horizontal attitude. At Crysler's mills, on the twelfth lot of the tenth range of the township, a section shows alternations of grey or bluish and black limestones, dipping N. 40° E. at an inclination of a little over forty feet in a mile. Lumps of iron pyrites occur in the beds, and the strata are intersected by a set of small parallel veins of calcspar, running about N. W. and S. E.

Westward of the High Falls, at Cook's mills on the Castor, in the eighth lot of the ninth range of Russell, which would be in the strike of the strata at the High Falls, already alluded to, there is a section of about five feet, consisting of dark blue limestone alternating with black shale. Several of the shale beds are very fossiliferous, and the shells in most abundance are *Leptæna sericea* and *Orthis testudinaria*. On the south bank of the Castor, in the next range to the west, thick beds of dark blue limestone dip N. 40° W. < 32° ; and farther west, at Louck's mills, on the eleventh lot of the fourth range, the dip, which, on the south side of the stream, is S. 34° W., at an inclination varying, in the distance of a hundred yards, Russell.

from sixty to five degrees, is on the north side N. 40° W. < 17°. While the north bank is occupied by thick bluish beds of granular limestone, the section on the south is as follows, in descending order :—

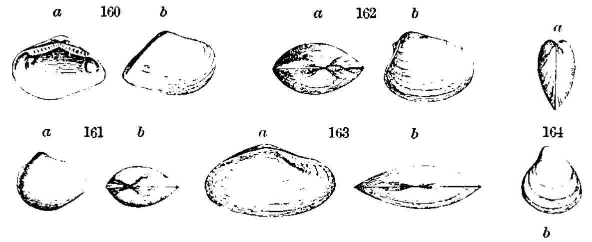
	Ft.	in.
Black shale supplied in abundance with a coral, of which the specimens have been lost; the upper part holds large concentric concretionary nodules of fine grained black limestone, passing in parts into a bed of black limestone eight inches thick,	3	6
Bluish-black limestone holding *Leperditia Louckiana* in abundance, some of the specimens a quarter of an inch long,	1	10
Black bituminous limestone in a strong bed somewhat nodular in structure,	3	0
Black shale,	0	4
Bluish-black limestone, with imperfect divisions of black shale,	1	6
Dark bluish-grey limestone weathering black, with divisions of calcareous shale holding imperfect fossils,	2	4
	12	6

These exposures on the Castor, which are in a nearly straight line from the High Falls, and in the direct continued bearing of the Rigaud and Fitzroy anticlinal, are shown by the irregularity of the dips to be probably affected by it. Two of them no doubt belong to the Trenton formation; but it is uncertain whether that at Louck's mill is to be placed immediately beneath the Trenton or at its summit. The thickness of the black shale associated with the limestone, and the fact that superior black shales occur not far to the north of the anticlinal, would seem to countenance the latter supposition, but at the same time the supposed position of the Chazy is not far removed to the west. To perplex the question still farther, a dislocation seems to be connected with the anticlinal near the spot, and it is not certain on which side of the black limestone it may run.

Dislocation. This dislocation, as has already been stated, appears to be a downthrow to the north-eastward, and to continue so to the vicinity of the south-east corner of West Gloucester. It here splits into two branches, and while that which runs into Hull continues a downthrow on the same side as before, the other, running to Fitzroy, becomes a downthrow to the south-west side. Hence, as was stated in speaking of the Chazy formation, an escarpment on the twenty-second lot of the fifth range of Nepean shows this formation, with the Birdseye and Black River above it, and the Trenton following, on the southward side of the fault. All these dip at a small angle towards the Potsdam on the north, and each in its turn comes up against the Potsdam a little to the eastward. From this position the Trenton continues along the fault, first in contact with the Potsdam and then with the gneiss, until reaching the neighborhood of the boundary between the townships of Huntley and Fitzroy, where the line between the eighth and ninth ranges of these townships intersects it. In this vicinity, the Birdseye and Black River formation, and then the Chazy, again meet with the fault.

Starting from the fault, the series of limestones more particularly under Fitzroy. description stretches across Huntley into Fitzroy, in a trough-like form, and then crosses the southern part of Fitzroy into Pakenham, returning again by the north-east corner of Ramsay into the west part of Huntley, modified in the perimeter by the effect of several anticlinal and synclinal forms, which have been explained in giving the distribution of the Chazy. The Trenton formation appears to be confined to the two outside synclinals, while the Birdseye and Black River forms a vinculum between them. The latter appears to form an isolated patch on the Chazy, in the neigh- Pakenham. borhood of Dickson's mills in Pakenham; where, as has already been stated, it is brought, by a dislocation, against the Calciferous, on the south side. Near the mills, the Birdseye and Black River formation yields very large masses of *Columnaria alveolata*, and some of its beds abound with great orthoceratites, the chambers of which have occasionally been found by Mr. Dickson to hold large quantities of petroleum.

160-164.—LAMELLIBRANCHIATA (TR.).



160.—*Ctenodonta contracta* (Salter); *a*, interior, and *b*, exterior of right valve.
161.—*Ctenodonta abrupta* (Billings); *a*, dorsal view; *b*, side view.
162.—*C.* ——— *levata* (Hall); *a*, side view; *b*, dorsal view.
163.—*C.* ——— *dubia* (Hall); *a*, side view; *b*, dorsal view.
164.—*C.* ——— *astartæformis* (Salter); *a*, dorsal view; *b*, side view.

This oil is probably derived from animal remains, and by its alteration may account for the presence of the mineral carbon in the orthoceratites and corals near Cornwall. Among the orthoceratites at Dickson's mills, *Orthoceras Bigsbyi* ranges from nine to eighteen inches in length, and *O. fusiforme* is met with two feet long.

On the Silurian outlier of the Lac des Chats, the Birdseye and Black Outliers, River formation rests on the Chazy in two patches, and constitutes the high- Bonnechère. est rock. On each of the three outliers of the Bonnechère, the Birdseye and Black River follows the rim of the Chazy, and beds of the Trenton formation rest upon it at Jessop's Rapids, on the farthest up outlier, but none were met with on the other two. In the Birdseye and Black River limestone of the second outlier, there is, at the Fourth Chute of the

Bonnechère, a remarkable subterranean channel, where a portion of the water turns abruptly off at right angles to the general course, running northerly, for about ten chains, through a great cavern. This cavern is naturally nearly dry, excepting during freshets, but has been turned to advantage by throwing a dam across the main body of the river near the middle of the fall. This turns through a sufficient quantity of water to convert the channel into a mill race, and the fall at the lower end of the channel is applied to drive the wheel of the mill.

Allumettes. The Birdseye and Black River formation rests in two patches on each of the two outliers between the Bonnechère and Lake Allumettes, and no Trenton beds succeed. In the Allumettes outlier, however, it forms only one patch, which covers the chief part of Allumettes Island, and, crossing the Ottawa at Paquette's Rapids, extends into Westmeath. Although it is not supposed that any true Trenton beds cap the strata of this outlier,

165-167.—LAMELLIBRANCHIATA (TR.)

165.—*Ctenodonta gibbosa* (Hall).
166.—*C.* ——— *nasuta* (Hall); *a*, side view; *b*, dorsal view.
167.—*Lyrodesma poststriata* (Emmons); *a*, exterior, and *b*, interior.

there is here a commingling of Birdseye, Black River, and Trenton species among the fossils, which has not been observed so conspicuously elsewhere. At Paquette's Rapids, the fossils are most beautifully preserved, being replaced by silica, in a nearly pure calcareous matrix, and weathered out into high relief. The species are numerous and in great abundance, and the locality has afforded a rich collection. The best specimens however are obtained in the bed of the river, so that it is only when this is partially dry, in times of very low water, that they can be easily procured.

New York. From the province line, where it crosses Lake Champlain in Eastern Canada, the Birdseye, and Black River, and Trenton formations, striking through the valley of this lake and the valleys of the Mohawk and Black Rivers, reach the waters of the St. Lawrence, and cross over into Western Canada. On the United States side of the St. Lawrence, they occupy a breadth extending from the Thousand Islands to Sandy Creek, and on the Canadian side, from the neighborhood of Kingston to the outside of the Prince Edward peninsula.

It has already been stated that between the Potsdam formation and the strata characterized by the fossils of the Birdseye and Black River formation, to the westward of the Laurentian ridge of the Thousand Islands, there are about eighty feet of strata, the age of which is not very clear. These appear in two succeeding escarpments, and are traceable for a considerable distance. At Vanluvin's mills, in Storrington, where they rest on intrusive flesh-red granite, the sequence in ascending order is as follows:— Lower escarpments. Storrington.

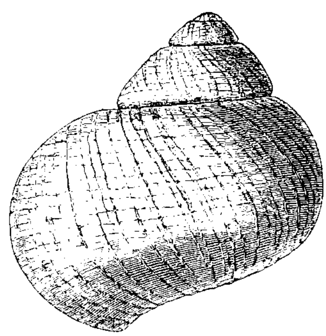
	Ft.	*in.*
Green shaly conglomerate; the pebbles are chiefly of white quartz, and generally rounded, the largest being about the size of a walnut; they lie in a green calcareo-arenaceous shale as a paste,	0	6
Green shaly conglomerate of the same materials; the conglomerate, however, is finer, and contains some angular fragments of quartz about two inches long; a reddish tinge pervades some parts, and divisional planes of nearly a grass-green color occur,	2	0
Greenish calcareous sandstone, with small rounded grains or pebbles of white quartz,	1	0
Measures concealed by drift,	20	0
Dark brownish-black fine grained compact bituminous limestone, with a somewhat nodular surface where exposed to the action of the atmosphere, and slaty towards the top. Organic remains are seen on the upper surface, consisting of *Tetradium fibratum*, *Strophomena* like a small *S. filitexta*, *Pleurotomaria pauper*, *P.* like *P. Americana*, *Leperditia Canadensis*, and *Bathyurus Angelini*,	5	0
Brownish-black compact bituminous limestone, with small crystals of calcspar disseminated,	2	6
Measures concealed,	5	0
Grey slightly arenaceous limestone,	0	3
Grey compact limestone; a good building stone,	0	10
Dark brownish-grey bituminous limestone with the same *Strophomena* as before, and other fossils. The beds make good building stone, and yield good lime of a darkish color,	0	11
Dark grey thin-bedded bituminous limestone, with large fucoids on the upper surface,	0	3
Pale bluish-grey very compact bituminous limestone,	0	9
Dark brownish-grey bituminous limestone, with fragmentary fossils, chiefly of the same *Strophomena* as before, and large fucoids on the upper surface. Minute crystals of calcspar are disseminated through the bed,	1	0
Dark grey compact limestone, with one division of calcareous shale; the beds hold many specks of iron pyrites,	2	9
Grey brown-weathering shaly limestone,	0	3
Pale grey limestone,	1	1
Bluish-grey calcareous shale, weathering to a rusty-brown color,	0	9
Brownish-black bituminous limestone, with small translucent crystals of calcspar,	1	6
Black shaly limestone, approaching to a shale,	2	0
Dark grey or blackish brittle thin bedded limestone, with a splintery fracture,	1	8
Dark grey or blackish brittle limestone of a fine texture, with a conchoidal fracture,	1	0

	Ft.	in.
Measures concealed,..	30	0
Dark brownish-grey bituminous limestone, having a conchoidal fracture; the exposed surfaces and edges are peculiarly marked with sharp deep angular cavities, supposed to have held lenticular crystals of calcspar,............	0	8
	81	8

Kingston. These two escarpments, sometimes running into one, appear to come round from the lake shore near Kingston, and at Kingston Mills an exposure of twelve feet in thickness, of much the same character as the lower portion of the strata, is seen resting on gneiss, in the excavation made for the Grand Trunk Railway. In this a fossil occurs, somewhat resembling the siphuncle of *Piloceras Canadense*, but it may be a fragment of the internal cast of the siphuncle of an *Orthoceras*. The former would seem to ally the deposit with the Calciferous formation, but a single fossil is too slight an evidence to fix its age. *Leperditia Canadensis* ranges from the Chazy into the Birdseye and Black River, but the presence of *Pleurotomaria pauper* and *Bathyurus Angelini* in the upper

168-170.—GASTEROPODA (TR.)

169



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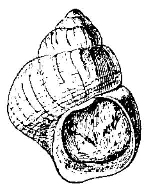

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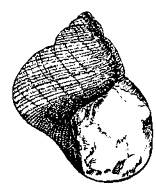


168.—*Cyclonema Halliana* (Salter).
169.—*C.* ——— *Hageri* (Billings).
170.—*C.* ——— *Montrealensis* (Billings).

portion might lead us to refer this to the Chazy, notwithstanding the occurrence of *Tetradium fibratum*, which has not hitherto, in other places, been found lower than the Birdseye and Black River formation; unless indeed some of the perforations taken for *Scolithus* in the Potsdam be not rather impressions of that fossil.

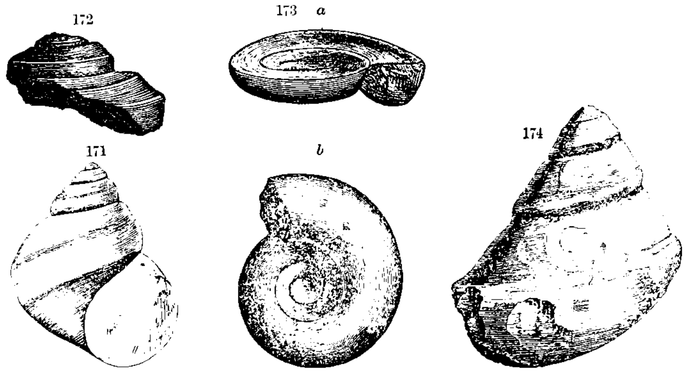
Going westward from Vanluvin's mills, these rocks keep on the south side of Loughborough Lake. The lower portion comes out to the shore, and is seen resting on the Potsdam sandstone at Knapp's Point. The upper and more calcareous portion forms a sharp escarpment at no great distance south from the other, and is traceable to a bay on the twenty-sixth lot of the sixth range of Loughborough. Here the Laurentian gneiss appears, and runs back to a small sheet of water called Round Lake, situated on the town line between Storrington and Loughborough; but on the west side of this bay, the two escarpments again rise over the gneiss, and continue to run nearly parallel with the lake, at a distance south of it from 200 to 300 yards, to the eighteenth or nineteenth lot of the fourth range of Loughborough. From the north side of the lake, the continuation of the escarpments is traceable to the south-east end of Sloat's Lake; and at the base of the cliff, on this lake, a calcareous conglomerate occurs, resting on flesh-red gneiss. The pebbles of the conglomerate are chiefly of gneiss, of the same character as the rock it rests upon, with some of white quartz, imbedded in a matrix of green and reddish calcareo-arenaceous shale. A conglomerate of a somewhat brecciated character is observable in many other parts, coming out from below the limestone; its pebbles being evidently derived from the Laurentian rocks, with which it is frequently found in contact. Loughborough.

The escarpments are traceable to the head of Knowlton Lake, and there, running nearer to one another, again rest on the Potsdam formation. As already stated, the Potsdam appears to cease altogether near the foot of this lake; but the two succeeding deposits continue in separate escarpments, by Pond Lily Lake and Mud Lake, to Centreville in Amden, where the upper one is marked by *Leperditia Canadensis*. From this, they turn up northward, by Tamworth and Beaver Lake, to Clare River, shewing, in a three-feet calcareo-arenaceous bed in the lower portion, in the neighborhood of Tamworth, forms imperfectly resembling *Scolithus*, and in the upper, not far from Beaver Lake, the same *Leperditia* as before, in some abundance. Where the line between the third and fourth ranges of Sheffield comes upon Clare River, there occurs the greatest thickness of the beds observed in one mass in this part. It presents a cliff of about forty feet, the upper part of which holds *Leperditia* in compact brownish-grey limestone; while on the same bank of the river, within seventy yards, the rock is gneiss. Tamworth.

Turning westward, the two escarpments take a course somewhat parallel with Clare River, to Sugar Island on the south side of Stucco Lake, but the lower occasionally crosses to the north side, on the way. On the east side of the Moira River, the escarpments are more widely separated than hitherto, the lower occurring about a quarter of a mile, and the higher five miles down the stream from the lake. On the west side, the second escarpment rises abruptly from the river in the third range; the beds of the lower deposit are cut nearly in two, upwards of a mile from the river, by a projecting ridge of gneiss, which extends for three miles to the south-west from Stucco Lake. At the termination of this Laurentian spur, on the third lot of the fifth range of Hungerford, an escarpment rises about fifty feet high in nearly horizontal strata. The lower beds, exposed at a distance of about a hundred yards from the gneiss, consist of pale bluish drab calcareous rock, without fossils, and may belong to the lower deposit; while the strata at the summit are dark brownish-grey or blackish limestone, in pretty regular courses of from two to three feet thick, holding *Leperditia* and some small univalves.

Hungerford.

171-174.—GASTEREPODA (TR.)



171.—*Eunema Erigone* (Billings).
172.—*Trochonema umbilicata* (Hall).
173.—*Ophileta Ottawaensis* (Billings); *a*, side view; *b*, view of umbilicus.
174.—*Pleurotomaria subconica* (Hall).

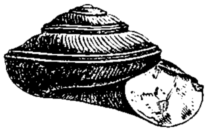
Below Hungerford Mills, on the twelfth lot of the tenth range of Hungerford, which is on the north-west side of the Laurentian spur, strata are exposed at the edge of the river, which must be near the base of the lower deposit. They are in ascending order as follows :—

	Ft.	*in.*
Dark blue limestone,	0	7
Drab colored limestone of very fine texture, in courses of three inches thick, supposed to be fit for lithographic purposes,	0	9
Red arenaceous limestone, passing into calcareo-arenaceous shale at the top, ...	0	8
Grey limestone,	4	0
	6	0

Professor Chapman of Toronto states that in the red calcareo-arenaceous rock of this place there is between forty and fifty per cent. of magnesian carbonate of lime. The lowest and nearest Silurian dolomite to the eastward, of which the horizon is certain, belongs to the Calciferous, and this fact would rather strengthen the evidence afforded by the *Piloceras* at Kingston Mills, as to the age of the Hungerford strata. Some of the Potsdam sandstone near Vanluvin's mills has a red color, but a red tinge there prevails also in a part of the succeeding rock; while the escarpment to which these strata at Vanluvin's mills and at Hungerford are subordinate, can be traced, with occasional difficulties, the whole way.

175, 176.—GASTEROPODA (TR.)

175



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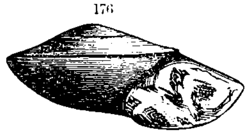


175.—*Pleurotomaria supracingulata* (Billings).
176.—*P.* ———— *Progne* (Billings).

At the lower end of Hog Lake on the south side, on the nineteenth lot of the thirteenth range of Huntingdon, beds very nearly corresponding in character with those of the Hungerford section, form a low cliff close to the beach. The same rock appears to form the base of several outlying Silurian patches in Madoc, and to be traceable to Marmora.

The section at the Marmora iron works, on the bank of the Crow River, is in ascending order as follows:— Marmora.

	Ft.	in.
Shaly limestone, filling depressions in the surface of contorted Laurentian gneiss, which contains beds or veins of fine grained syenite, ...	1	0
Red sandstone, soft and calcareous; the color is deep red in the divisions of the beds, and lighter towards the middle of them; one or two thin interstratified layers are greenish,..	8	3
Yellowish-white compact limestone of a character fit for lithography. This increases to four inches about twenty yards to the N. N. W. in the strike, where however it appears to have too many crystals for lithographic purposes. It has rough slightly dentated interfitting surfaces, with a greyish-brown film between in some parts; it has also small light green and some dark olive-green patches, ...	0	1
Greenish calcareo-arenaceous shale, spotted with red, with a few quartz pebbles, and a few cavities, as if calcareous pebbles had been worn out of them. At the top there is a thin layer of snuff-brown earth, probably manganesian, passing into green shale, ...	3	5
Mottled grey and greenish-white argillaceous limestone, slightly bituminous,...	1	5
Dark grey bituminous limestone, somewhat shaly in part,....................	2	0
Light grey compact slaty limestone; this would probably form good building stone; it is strong and very even but rather thin bedded; some of it appears fine enough for lithography,..	2	0

	Ft.	in.
Light brownish-grey compact limestone in a single bed; this is apparently fine enough in texture for lithographic purposes, but not of the right color; it has a small quantity of bitumen in it. Though seemingly one bed, it splits apart in some places, and shews surfaces with short tooth-like interfitting columnar projections, having a thin film of bituminous matter between,	1	7
Light brownish-grey calcareous shale, the last inch and a half becoming a hard limestone in an even bed,	0	10
Columnar structure. Lithographic stone. Light brownish-buff compact very fine limestone, the grain wholly impalpable; the lower half is more homogeneous than the upper, which holds thin lenticular crystals of calcspar; the upper inch, which is just above the part holding most crystals, fits upon it in tooth-like projections of a marked character, the projections having columnar sides at right angles to the bed, an inch long in some places; a thin film of bituminous shale darkens the surface; in the lower part there are obscure tooth-like divisions. This is the *Marmora lithographic bed*, the best stone being in the lower portion. When exposed to the weather, this part is generally affected by gash-like cracks, which appear to terminate both ways, and run in two general directions, dividing the mass into rhomboidal forms; but there are other gashes which run at a small angle to these; the stone weathers nearly white,	2	0
Light grey limestone; the fracture is conchoidal and slightly scaly; the stone is strong and tough, and it would make a good building stone. It weathers slightly yellowish at the joints and bed divisions; the beds are from three to four inches thick, but aggregated beds of a foot and more occur; some of them separate in tooth-like projections, with a film of bituminous shale between. Large slabs may be obtained, some of them six feet square; some of the surfaces are waved,	5	0
Light greyish-brown compact smooth limestone, weathering into gashes like the lithographic stone, and more divided into joints than the bed below,	2	2
Brownish-grey compact limestone, rather lighter in color than the previous bed, with lenticular crystals of calcspar; this would make lithographic stone were it not for the crystals,	0	7
Brownish-buff compact limestone with a conchoidal fracture; there are lenticular crystals of calcspar in the bed, but much smaller than those of the previous layer. This might yield lithographic material; it is doubtful, however, whether the crystals are not too numerous,	0	7
Darkish grey very compact limestone with a conchoidal fracture,	5	8
Measures concealed,	5	0
	41	7

These beds, in which no organic remains have been detected, are succeeded by about forty feet of limestone having much the same lithological characters, in which fossils are sufficiently abundant, though many of them are obscure. Those which have been recognised belong to the Birdseye and Black River formation. In this section there appears to be such a passage from the arenaceous beds at the bottom to the compact limestones, which become fossiliferous at the top, as to induce the supposition that the whole belong to the formation named, notwithstanding the two Chazy species found at Vanluvin's mills. The rock of Kingston, which appears to be nearly destitute of fossils, presents many instances of the columnar structure so prevalent at Marmora. It frequently contains small masses of yellow blende. Geodes holding sulphate of strontian occur in the limestone at Kingston and near Sydenham, but these minerals have not been met with in what is considered its equivalent to the westward.

Kingston; celestine and blende.

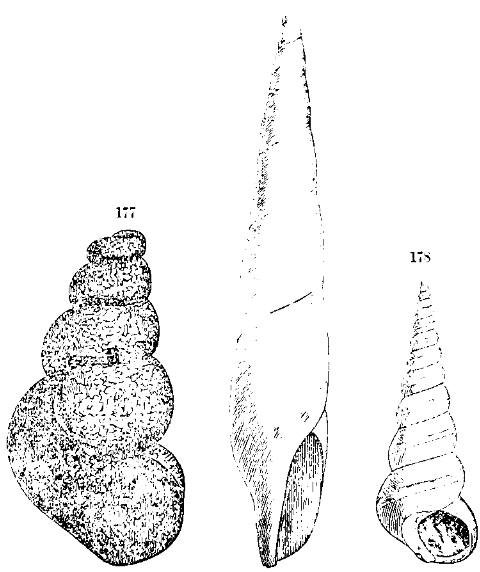
That part of the Birdseye and Black River formation which is well marked by its fossils, after crossing the upper part of Wolf Island, reaches Cataraqui Point, a little above Kingston, and strikes for the west end of Loughborough Lake. From this, westward, it constitutes a third escarpment,

177-179.—GASTEROPODA (TR.)

179

177

178



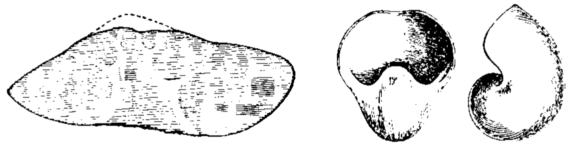
177.—*Murchisonia bellicincta* (Hall).
178.—*M. gracilis* (Hall).
179.—*Subulites elongatus* (Emmons).

which rises at a varying, but usually not very great distance, back from the two escarpments in which the less fossiliferous strata occur, presenting a bolder and usually more rocky front than either of them. The attitude of the whole series, including the Trenton, which does not usually show any marked escarpment, is for the most part nearly horizontal, the inclination in many instances being so small as to be almost inappreciable. In consequence, it happens, that, except in the escarpments and in sections worn out in the courses of streams, the rock is seldom seen, being concealed by a great deposit of drift. The general strike, through the country to Lake Huron, is about north of west, and the dip, on an average, is about two degrees to the southward. There is however a series of gentle parallel undulations, which affect the strata, running nearly at right angles across the general

Undulations.

180, 181.—GASTEROPODA (TR.)

180 a 181 b

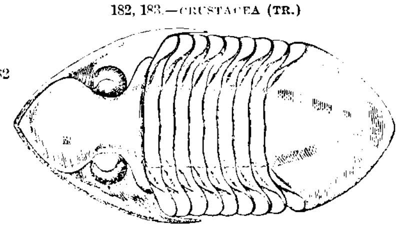


179.—*Pleurotomaria Americana* (Billings); section through the middle, showing the form of the umbilicus.
180.—*Bellerophon bilobatus* (Sowerby); *a*, view of aperture; *b*, side view.

strike, the usual bearing being about N. N. E. and S. S. W. Where these undulations occur, the lower rocks come to the surface in long narrow ridges, sometimes extending for several miles to the southward; and on

182, 183.—CRUSTACEA (TR.)

182



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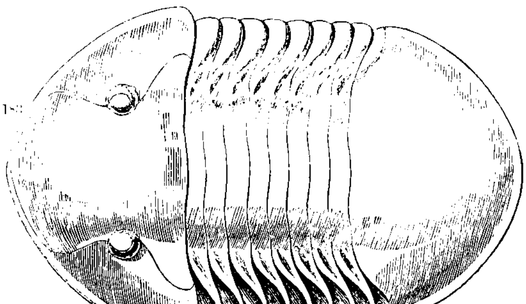


182.—*Asaphus megistos* (Locke).
183.—*A.* —— *platycephalus* (Stokes).

either side of them the fossiliferous escarpments rise, usually at no great distance, sloping gently in directions obliquely opposite to one another.

These features are more particularly observable in Loughborough, Camden, and Sheffield, and in Hungerford, Madoc, and Marmora, extending thence on the Crow River into Seymour. The most conspicuous of these undulations are between the townships of Camden and Belmont, where the terminal outcrop is in consequence, though tolerably straight in its general bearing, very irregular in detail.

Higher fossiliferous escarpment.

The more conspicuous and more fossiliferous escarpment presents itself about two and a half miles west of south from the upper one of the other two, on the third and fourth lots of the third range of Loughborough, where beds of brownish-grey bituminous limestone, approaching to brownish-black, crop out. Among other fossils, they hold *Tetradium fibratum*, *Ptilodictya reticulata*, *Strophomena alternata*, *S. filitexta*, *Cyrtodonta Huronensis*, *Helicotoma planulata*, *Orthoceras Bigsbyi*, *Asaphus platycephalus*, and *Leperditia Canadensis*, leaving no doubt that the escarpment belongs to the Birdseye and Black River formation. These beds strike over to the first and second lots of the eighth range of Portland; and beds resembling them are met with on the road between Portland and Loughborough, in the ninth range, about a quarter of a mile from the second escarpment. In these also occur *Ptilodictya reticulata*, *Stenopora fibrosa*, *Strophomena alternata*, and *Orthoceras Bigsbyi*. On Mr. Purdy's farm, in the eleventh lot of the eighteenth range of Portland, on Pond Lily Lake, the third or uppermost escarpment is from a quarter to half a mile south from the middle one.

Camden.

From this, these two escarpments, passing diagonally through Camden, gradually separate more and more. The main or superior one, passing close by Centreville, strikes for the north-west corner of Camden, and the inferior for Beaver Lake. They thus become from four to six miles apart; but south of Stucco Lake, they approach one another again to within a mile. The Moira River, discharging Stucco Lake, runs on the axis of one of the gentle undulations which have been mentioned. Both escarpments run a considerable distance down the stream, and cross it five miles from one another; but the upper escarpment, turning northward on the west side, joins the other, and both run in one, for a short distance, in the fourth range of Hungerford.

Moira River.

On the Moira, the strata which constitute the escarpment marked by the well known fossils of the Birdseye and Black River formation, have a thickness of about sixty-five feet. In ascending order, they are :—

	Feet.
Brownish-black very close textured limestone with a conchoidal fracture, weathering ash-grey, in regular beds varying from six inches to a foot in thickness; some of the beds hold *Leperditia Canadensis*, and *Orthoceras Menelaus*,.....	30
Dark grey or blackish brittle limestone of a fine texture, with a conchoidal fracture. No fossils are detected on breaking the stone in the lower two thirds of the mass; in the upper part there are obscure fossils,..................	11

	Feet.
Greenish-drab compact limestone, weathering white, in massive beds with numerous fossils, many of them replaced by silica,	10
Brownish-grey and brownish-black limestone holding many nodules of black chert; a strong three-feet bed at the bottom abounds in *Columnaria alveolata* and *Stromatopora rugosa*. The beds in the middle are thin and somewhat irregular; those at the top vary from six to eight inches, and hold *Stromatopora rugosa*, *Strophomena alternata*, and *Orthis tricenaria*,	14
	65

The beds which succeed these are well marked by fossils of the Trenton formation; they are as follows:—

	Feet.
Grey limestone of a crystalline texture, derived from the peculiar crystallization of the echinodermata, which, in a comminuted condition, constitute the mass of the rock. The beds vary in thickness from six to eight inches, the thickest being at the bottom, and they are separated by thin layers of grey calcareous shale. The limestone weathers to a yellowish-grey tinge. The fossils which can be identified are *Stenopora fibrosa*, *Ptilodictya recta*, *Glyptocrinus ramulosus*, *Glyptocystites multiporus*, *Leptæna sericea*, *Strophomena alternata*, *Orthis testudinaria*, *O. lynx*, *Rhynchonella increbescens*, and *R. recurvirostra*,..	20
Bluish limestone in thin beds and often nodular, interstratified with layers of shale, increasing towards the top near Belleville; the dip of the strata is down the stream with an inclination of from one to two degrees. In the lower part the limestone weathers whitish, and in many instances the fossils are replaced by silica; being much weathered and blackened by vegetable matter, they are brought into strong relief. The most common are *Orthis testudinaria* and *Strophomena alternata*,	594
	614

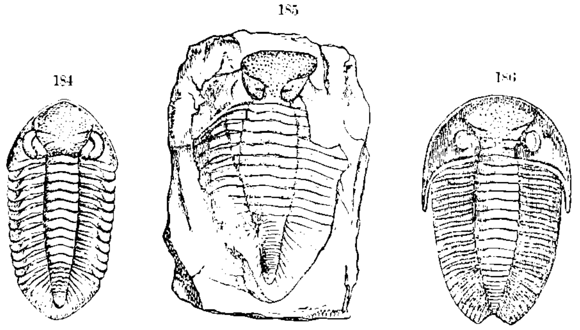
To this volume it is probable that there would be still something to add, to give the full thickness of the formation, as the whole of the Prince Edward peninsula belongs to it. The beds of the peninsula seem, in general, to be of a nodular character, and the summit of the deposit would appear to conform in its strike with the south-west front, the limit being concealed under the waters of the lake, probably not very far out from the land.

In running north through Hungerford, the two upper escarpments separate to the extent of about half a mile, but approach across Huntingdon, Marmora. and run into one in some parts of Marmora. Succeeding the unfossiliferous section already given there, near the iron works, the beds are:—

	Feet.
Brownish-grey limestone not well exposed, but fossiliferous,	30
Brownish-grey bituminous limestone with fossils,	5
Brownish-grey bituminous limestone with nodules of chert and various fossils, among others *Tetradium fibratum*, *Petraia profunda*, *Columnaria alveolata*, *Murchisonia gracilis*, *Helicotoma planulata*, and *Orthoceras recticameratum*,..	4
	39

The summit of this mass of strata crosses Crow River at the fall, north of the town line of Marmora and Rawdon, with a slope of forty-two feet in a mile. The river here flows on the axis of an undulation, on which twenty-two feet of the same beds again come to the surface, resting on a protrusion of Laurentian syenite in Rawdon, on Laurentian iron ore at Allan's mills in Seymour, two miles farther down, and on fine grained augitic trap, still two miles beyond. Large fragments of the trap, cemented together by limestone, form a brecciated bed at the base of the fossiliferous rock. Near its junction with the trap, the Silurian limestone assumes a variety of colors, red, orange, blue, green, and yellow; and it sometimes happens that all these colors are displayed on one surface, giving an appearance a good deal resembling rude mosaic. In the strata south from the trap, the black chert, and the silicified fossils blackened with vegetable matter, lie on a ground of white-weathering limestone in great abundance. *Columnaria alveolata*, *Stromatopora rugosa*, and Breccia.

184-186.—CRUSTACEA (T. R.)



184.—*Phacops callicephalus* (Hall).
185.—*Dalmanites Bebryx* (Billings).
186.—*Dalmanites Achates* (Billings).

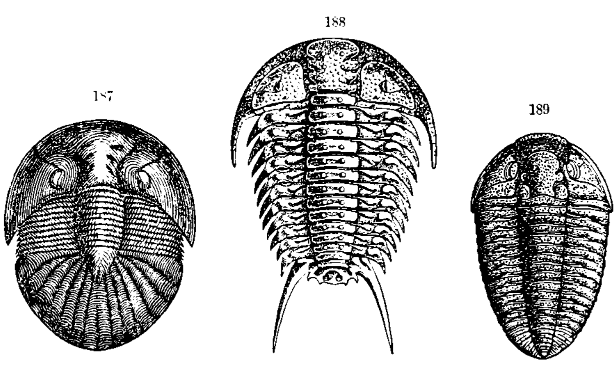
Petraia occur, with *Orthoceras*, *Strophomena*, and *Orthis*. A fragment of an orthoceras here met with was three feet long, the diameter of the upper part being about ten inches.

The banks of the Trent below Healy's falls, which are a little above Crow Bay at the junction of Crow River, rise in vertical limestone cliffs sometimes upwards of forty feet, the strata of which are filled with the fossils of the Trenton formation. The lowest beds of the cliffs are from four to eight inches thick, the surfaces being thickly studded with black weathered fossils, chiefly an *Orthis*. Above these beds is a strong one about three feet thick, holding *Leptæna sericea*, *Strophomena alternata*, River Trent.

Orthis testudinaria, and *Rhynchonella recurvirostra*. The rest of the exposure consists of dark grey or blackish and blue limestones, alternating with dark green calcareo-argillaceous shale. These beds are very fossiliferous, the most numerous species being the four just named. From Crow Bay to Ramsay's falls, on the ninth lot of the sixth range of Seymour, a distance of about four miles and a half, the measures accumulate at the rate of about forty feet in a mile; and at the latter place they rise in vertical cliffs on each side of the river to the height of forty or fifty feet. All the beds are filled with Trenton fossils, and some are almost a mass of *Leptæna sericea*.

At Chisholm's Rapids on the Trent, on the eighth lot of the eighth range of Sidney, a section of about six feet of thin bedded bituminous grey limestone is exposed, the prevailing fossils being the same four species as before. Below Chisholm's Rapids, the rock is occasionally seen on the bank of the river, holding in all parts abundance of characteristic fossils of the Trenton formation, and dipping gently a little west of south, at an average not exceeding forty feet in a mile. If this dip were continuous, and no

187-189.—CRUSTACEA (TR.)



187.—*Bronteus lunatus* (Billings).
188.—*Cheirurus pleurexanthemus* (Green).
189.—*Calymene Blumenbachii* (Brongniart).

undulations existed, causing repetitions of the strata, the thickness from Healy's falls to the mouth of the river would be 960 feet. There appears however to be at least one slight undulation on the east and west reach of the river, north of the town line of Murray and Seymour, which would reduce the thickness to about 750 feet.

In their western run from Healy's falls, the escarpments we have been following approach Stoney Lake; the main one presenting an abrupt rocky cliff from two to three miles from the south margin of the lake, and the other, of small elevation, approaching the margin to within about a mile. After sweeping round a small sheet of water called White Lake, in the township of Dummer, the two escarpments partially unite, striking Salmon Trout or Clear Lake at about the fourth range of that township, keeping the south shore of the lake to its western extremity. The corresponding escarpment rises on the north-west side of Salmon Trout Lake, and then follows the sinuosities of the chain of lakes and the river up to Buckthorn Lake, keeping the south side, at a distance seldom exceeding a quarter of a mile. It crosses Buckthorn Lake at the strait, about two miles and a half above Buckthorn Falls; and then, again separating into two parts, the main one strikes nearly straight by Sandy and Pigeon Lakes to the head of Balsam Lake, the inferior escarpment keeping about a couple of miles to the north-east. In the general course westward from Belmont Lake, the rocks composing the lowest escarpment thin out and disappear before reaching the western end of Salmon Trout Lake. Here the base of the series is composed of very regular beds of buff colored limestone, bearing the lithological characteristics of the succeeding portion; while the upper tier of beds contains black chert and silicified corals of those species which peculiarly distinguish the Birdseye and Black River formation. The whole height of the escarpment, from this, seldom exceeds fifty feet. Dummer.

On the Ottonabee, the thick bedded coral-bearing stratum with chert, containing chiefly *Columnaria alveolata* and *Stromatopora rugosa*, crops out on the twenty-second lot of the sixth range of Douro, where the river opens into a small lake called Kawchewahnook. Below this, assisted by the effect of a gentle undulation on the axis of which the river runs, there is a continued section of limestones and shales all the way to Peterborough, holding many characteristic fossils of the Trenton formation. Between Peterborough and Rice Lake, the Ottonabee nowhere exhibits a rock section, nor was there one observed at any place between Rice Lake and the shore of Lake Ontario at Cobourg; but at the latter place, and between it and Port Hope, there are some small exposures of blackish-grey thin bedded nodular limestone and shale, which, among other Trenton fossils, hold *Lingula Canadensis* and *Asaphus megistos*. Douro.

The farthest-up exposures of Trenton limestone, near the lake shore, occur about a mile south of the village of Oshawa in Whitby, where the dip is N. $< 5°$; and at Bowmanville, where a quarry has been opened for the purposes of the Grand Trunk Railway, at the summit of the formation. The strata here dip to the north-westward at a small angle, and, as they must finally crop out with a southward dip, it is plain that the beds of the quarry are on the southward side of a synclinal form, and that, after running to the north-east on the strike for some uncertain distance under the Bowmanville.

drift, they must ultimately turn northward to conform to the deeper strata seen farther northward.

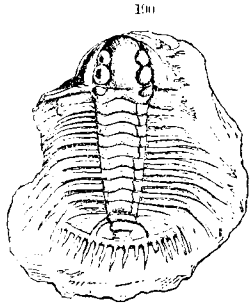
The limestone escarpment south of Burleigh Falls, in the township of Smith, is about eighty feet high. On the summit, thin beds of limestone and shale occur, holding one or two varieties of *Leptæna* or *Strophomena*, with fragments of trilobites, encrinites, and corals, but not sufficiently characteristic to determine the formation. Except at the top, the rock is more or less covered by moss and small trees; but about twenty or thirty feet below, strong beds of limestone occasionally come out in points, and probably represent the cherty beds of the Birdseye and Black River formation. In the continuation of this course westward, the cherty beds with their characteristic corals are displayed at the top of the cliffs which rise over the exit of Buckthorn Lake. They are seen too on Pigeon Lake and at Bobcaygewan Rapids, near the foot of Sturgeon Lake. On the north part of Balsam Lake, in a great bay on the west side, they occur on the land of Mr. Stephenson, in block E of Bexley, where they incline at a very small angle southward, and display *Columnaria alveolata* and *Stromatopora rugosa*.

Balsam Lake.

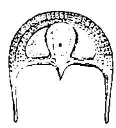
The base of the inferior escarpment is seen at the foot of Mud Turtle Lake, near where the continuation of the line between the eighth and ninth ranges of Somerville would cross it, about three miles north from the

190, 191.—CRUSTACEA (TR.)

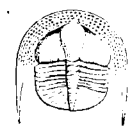
190



191 *a*



191 *b*



190.—*Acidaspis Horani* (Billings).
191.—*Trinucleus concentricus* (Eaton); *a*, head showing the spine; *b*, a specimen without the spine.

north-east bay of Balsam Lake. The base consists of pale drab limestone of fine texture, in very regular layers of from three to six inches, without fossils, and over it an escarpment rises a little way south to the height of forty or fifty feet. The upper beds are massive and fossiliferous, but the fossils are very obscure. Among the fossils a small *Leptæna* was observed to be very abundant, and another bivalve was occasionally found with encrinites and fucoids, but the specimens are too ill defined to be easily identified.

At the rapids at the outlet of Balsam Lake there are flat surfaces of limestone exposed just over the edge of the water, with fossils weathering in relief, among which *Stenopora fibrosa*, *Glyptocrinus ramulosus*, *Leptæna sericea*, *Orthis testudinaria*, and *Asaphus platycephalus* are observed. At Fenelon Falls, near the exit of Cameron's Lake, where there is a section of about twenty feet in the gorge of the river below the cascade, the following Trenton species occur :—*Ptilodictya acuta*, *Stenopora fibrosa*, *S. petropolitana*, *Heterocrinus Canadensis*, columns of *Glyptocrinus*, *Leptæna sericea*, *Strophomena alternata*, *S. filitexta*, *Orthis testudinaria*, *O. lynx*, *O. pectinella*, *O. subquadrata*, *Rhynchonella increbescens*, *R. recurvirostra*, *Pleurotomaria subconica*, *Murchisonia gracilis*, and *M. bellicincta*.

On Sturgeon Lake, opposite the mouth of the Scugog River, where the strata are of greenish calcareous shale, with very thin beds of limestone, the fossils in greatest abundance are *Stenopora fibrosa*, *Petraia corniculum*, *Glyptocrinus ramulosus*, *Leptæna sericea*, *Orthis testudinaria*, *Rhynchonella increbescens*, *Calymene Blumenbachii*, and *Encrinurus vigilans*.

At the village of Lindsay, on the Scugog River, in Ops, there is a small exposure of blue limestone in beds of six or seven inches, interstratified with blue calcareo-argillaceous shale, holding abundance of fossils : among them are *Stenopora fibrosa*, *S. petropolitana*, *Glyptocrinus ramulosus*, *Leptæna sericea*, *Strophomena filitexta*, *Orthis testudinaria*, *O. plicatula*, *Rhynchonella increbescens*, *R. recurvirostra*, *Camerella hemiplicata*, *Pleurotomaria Americana*, *P. subconica*, *Bellerophon bilobatus*, *Orthoceras Ottawaense*, *Encrinurus vigilans*, and *Bathyurus spiniger*. Lindsay.

Between Balsam Lake and Lake Simcoe, a distance of nearly thirty miles, the detailed distribution of the outcrop of the formations which we have been tracing, has not been ascertained. The base of the series is supposed to be limited northward by the south branch of the Black River, a tributary of the Severn. It comes upon the east side of Lake St. John, in the fifth range of Rama, and continues from the west side to a cove in Lake Couchiching, on the thirtieth lot of the lake front. Crossing this lake, it would strike the fifth lot of the tenth range of Orillia, where it is concealed, and pass to the mouth of the Coldwater in Matchedash Bay. Lake Couchiching.

On Lake St. John, the lowest Silurian beds, not far removed from the Laurentian gneiss, consist at the base of a yellowish fine grained and somewhat arenaceous limestone, passing in a few feet to a drab colored compact limestone with a conchoidal fracture, some of the strata resembling the Marmora lithographic stone. The thickness seen is about twenty feet. Fossils are rather scarce in the rock, and somewhat obscure, the only one which has been identified being *Strophomena filitexta*. In one of the beds, the fossils are coated with a leek-green mineral, and the same substance invests what appear to be very small fissures in the rock. On Lake Couchiching there is exposed above the water nearly the same thickness of a similar limestone, which is quarried for building and lime burning, for both of which purposes it is well suited.

Sandstones and shales. At the mouth of the Coldwater, a green fine grained sandstone rests upon the Laurentian gneiss, in beds of from four to twelve inches thick, interstratified with green arenaceous shales. This sandstone is in great request among the Indians for the purpose of manufacturing tobacco pipes. It is soft and porous when first taken from the bed, but becomes hard after exposure for some time to the air. The Indians carve out their pipes with a common knife, to which the stone yields easily ; and it is not improbable that vessels of larger capacity and greater utility, such as would be suitable for various purposes on a farm, might be made with great facility. The sandstones and shales do not exceed eight or ten feet in total thickness, and they appear to be destitute of fossils.

These beds are probably immediately beneath those of lakes St. John and Couchiching, as they are beneath those met with to the westward on the two horns of Hog Bay (or Coll's Bay, as called in Bayfield's map), one of the deep recesses on the south side of Gloucester Bay. These two points consist of limestone similar in character to that of Rama. The fossils in some of the beds are coated with the same green mineral, and among the species there occur *Strophomena alternata*, *S. filitexta*, *Rhynchonella recurvirostra*, *Cyrtodonta subcarinata*, *Ctenodonta contracta*, *Leperditia Canadensis*, *Beyrichia Logani*, *Asaphus platycephalus*, and *Bathyurus spiniger*, leaving no doubt that these limestones belong to the Birdseye and Black River formation. The dip of the beds in Matchedash Bay appears to be south, while that of the more western strata seems to point to the south-westward. The inclination in both cases does not probably exceed from thirty to thirty-two feet in a mile.

Mara. On the east side of Lake Couchiching, these beds reach to the line between the townships of Rama and Mara, where they become covered over with drift, so that their precise summit has not been determined. Proceeding southward, the strata, after an interval of concealment, are again exposed in Mara, striking to the northward of east, and coming upon the banks of the Talbot River, about three miles and a half from the lake shore. The sections are seldom over five feet in thickness, and a better display exists at the northern extremity of Canise Island, opposite the mouth of the Talbot, where the beds present an aggregate of ten feet over the water's edge. The upper layers are thin, coarse, and irregularly deposited; but the lower ones are thicker, and afford good limestone for burning. This locality, with those on the Talbot, is very fossiliferous, the species being such as characterize the Trenton formation.

A ridge of the Trenton formation is met with near the Beaver River in Thorah; and on Graves Island, which is considerably to the south of Canise, are to be seen some calcareous rocks, which are probably pretty high up in the series. South-eastwardly, similar beds strike the main shore on the twenty-second lot of the first range of Thorah, not far from the lake corner of Brock; and it is said that similar limestone is met with on the twenty-third lot of the eighth range of the last mentioned township. On the former lot, the beds are from three to eight inches thick, and constitute an aggregate of ten or twelve feet over the surface of Lake Simcoe. They yield excellent lime when burnt, and are occasionally fit for building. At this place a favorable opportunity is afforded to determine the dip. It would appear to be south-westerly: and as the strata seen on the lake shore crop out about half a mile from it, where they stand at a height of thirty feet over the lake, the difference between this and their height at the margin would be about eighteen feet, so that the slope may be taken as something between thirty and thirty-five feet in a mile. This would give a volume of about 150 feet for the Birdseye and Black River formation on Lake Couchiching, and from 500 to 600 feet for the Trenton formation on Lake Simcoe. The country to the southward of the exposures mentioned being covered over with drift, it is difficult to say whether this would comprehend the total thickness.

Westward from Hog Bay, the whole of the peninsula of Penetanguishene appears to be enveloped in drift; but on an island in Georgian Bay beyond it, called the Giant's Tomb, the base of this series of limestones is met with, resting on the Laurentian gneiss, which occupies the north-eastern half of the island. The upper members of the series are on the south-east side of Georgian Bay. They there compose the little islands called the Hen and Chickens, and may be observed about eight miles west of the Nottawasaga River, at McGlashan's mills, as well as at Hurontario, in the township of Nottawasaga; and at the contiguous corners of Nottawasaga and Collingwood, where they are seen to pass under the black shales of the Utica formation. The transverse breadth of the series is thus about thirty miles, and the thickness, supposing the dip to be south-westward at the rate of thirty feet in a mile, would be 900 feet; but it is not unlikely that the strata may be affected by very gentle undulations, and it would therefore be scarcely safe to state the amount at more than about 750 feet. Collingwood

A group of islands situated about eight miles from the east coast of Georgian Bay, between Parry Sound and Franklin Inlet, and designated on Bayfield's chart as the Limestone Islands, very probably belongs to the series of rocks under description. South from Collins' Inlet there are two groups, called the Fox Islands and the Papoose Islands; the former about three, and the latter about seven miles from the general run of the coast. On Bayfield's chart they are described as being composed of limestone.

These also very probably belong to the series, and the distance between them may indicate its breadth in this part. None of these groups however have yet been visited by the officers of the Survey, but strata belonging to the series have been observed by them on Squaw Island, which is westward of the Papoose group.

Manitoulin Islands.

Farther to the west, the rocks of the series come upon the Great Manitoulin Island, and compose the chief part of the promontory separating Wequamekong and Manitouwaning Bays, with one of the points of the mainland opposite; where, as well as on several islands near, they are seen resting on the Huronian quartzites. With the exception of a narrow strip at the south end, which is occupied by black shales, they compose also the island of Shequenandod, and pass thence to that promontory of the Great Manitoulin which is immediately south of Lacloche Island. They constitute likewise the south side of this island. The whole breadth of the series is observable on Lacloche and the Great Manitoulin, where the rate of inclination, although inappreciable to the eye, is uniformly nearly south, descending at the rate of thirty-five or forty feet in a mile. Taking the maximum as the rate of dip, the total thickness would be about 320 feet. The upper part of this consists of bluish, buff, and brownish limestones, which generally weather yellowish. The beds at the top of the series are strongly bituminous; they are generally of a dark grey in fresh fractures, but weather to an orange red. A large portion of the whole series of limestones in this part is more or less magnesian, and towards the bottom the rock becomes a nearly pure dolomite.

Lacloche Island.

Dolomites and sandstone.

The whole series of strata is here very fossiliferous; it is chiefly however from the lower part that specimens have been collected. On Lacloche Island and the extremity of Lacloche peninsula, the dolomitic base of the series, as has been already stated, is seen resting upon twenty or thirty feet of the red, greenish, and whitish sandstones which are considered equivalent to those of Sault Ste. Marie. Some few of the fossils characterizing the dolomite descend into the uppermost arenaceous bed, which is red, and are tinged with this color. The dolomite displays a thickness of about thirty feet; and the fossils which occur in it, immediately above the red strata on Lacloche Island, are *Stenopora fibrosa*, *Tetradium fibratum*, *Stromatopora rugosa*, *Columnaria alveolata*, *Strophomena alternata*, *S. filitexta*, *Orthis subæquata*, *O. tricenaria*, *Rhynchonella plicifera?* *Vanuxemia inconstans*, *Orthoceras multicameratum*, *O. Bigsbyi*, *O. recticameratum*, *O. Murrayi*, *Illænus Milleri*, *Cheirurus pleurexanthemus*, and *Leperditia Canadensis*, leaving no doubt that the beds belong to the Birdseye and Black River formation.

In this region, the formation appears to have a somewhat greater thickness than has been noticed elsewhere, and its characteristic fossils are associated with a greater number that ascend into the Trenton formation. Five or six islands which lie in the strait separating Lacloche from the Great Manitoulin, may be considered to be somewhat less than half way between the base and the summit of the series. The fossils which occur in the strata composing them, and at the same horizon on the islands immediately west of Lacloche, are *Stenopora fibrosa*, *Receptaculites occidentalis*, *Strophomena filitexta*, *Rhynchonella increbescens*, *R. recurvirostra*, *Orthis borealis?* *Vanuxemia inconstans*, *Cyrtodonta subangulata*, *Ctenodonta nasuta*, *Murchisonia gracilis*, *Bellerophon bilobatus*, *Orthoceras proteiforme*, *O. arcuoliratum*, *O. multicameratum*, *O. Huronense*, *O. Bigsbyi*, *O. anceps*, *Asaphus platycephalus* and *Leperditia Canadensis*. These strata also would thus appear to belong to the Birdseye and Black River formation; but about half a mile inland from the south side of the strait there rises an escarpment of 155 feet of limestone, which probably attains the summit of the series, and may represent that portion which is to be considered as Trenton. The strata of this escarpment, where they come upon the coast, are however covered up with drift, and no specimens have been obtained from them in the interior to determine the fossils.

Seven or eight islands which range in a line a little north of west from Lacloche, are composed of the same series of limestones. On the largest of them however, being the one immediately north of Maple Point, the shales of the Utica formation occupy the south front. Mississague Island, about three and a half miles south from the river which gives it a name, with Grant's Islands, a group about thirteen miles farther on, and the Snake Islands a mile beyond, show the trend of the limestones westward. On the Snake Islands about twenty feet of limestone rest almost horizontally upon the tilted rocks of the Huronian series, about eight feet at the base being made up of fragments of the Huronian quartzites cemented together by fossiliferous limestone. The fossils here are *Petraia profunda*, *Columnaria alveolata*, *Strophomena filitexta*, *S. alternata*, *Orthis testudinaria*, *O. tricenaria*, *Rhynchonella increbescens*, *R. recurvirostra*, *Subulites elongatus*, *Orthoceras Huronense*, *Asaphus platycephalus*, *Illænus angusticollis*, *I. Americanus*, and *Bathyurus spiniger*, shewing the strata, as before, to belong to the Birdseye and Black River formation.

Snake Islands.

In the next nineteen or twenty miles, Bigsby, Thessalon, and Serpent Islands, with the south-western island of the Palladeau group, mark the prolongation of the same limestones. The fossils met with on Thessalon Island are *Tetradium fibratum*, *Strophomena filitexta*, *Orthis tricenaria*, *Vanuxemia inconstans*, *Cyrtodonta Huronensis*, *Orthoceras Bigsbyi*, and *Asaphus platycephalus*; and on the south-western Palladeau, *Tetradium fibratum*, *Stenopora fibrosa*, *Lingula Huronensis*, *Cyrtodonta Huronensis*, *Vanuxemia inconstans*, *Pleurotomaria staminea*, *Orthoceras Bigsbyi*, *O. recticameratum*, *Asaphus platycephalus*, and *Leperditia Canadensis*.

Palladeau Islands.

St. Joseph Island.

The northern half of St. Joseph Island is occupied by this series of limestones. That part however which may belong to the Trenton formation is much covered with drift, and it is chiefly from the lower portion of the series that fossils have been obtained to establish its age. As already stated, the fossiliferous limestone here rests upon about eighty feet of sandstone, the outcrop of which, there is little doubt, runs to a junction with the sandstone of Sault Ste. Marie, while an outlying patch of the same two rocks occurs to the north, on the island of Campement d'Ours. As will be seen in the accompanying figure, the exposures on the two islands lie in the same plane of stratification, dipping at a very small angle to the south, the separation between them being the result of denudation.

Campement d'Ours.

192.—SECTION OF SILURIAN AND HURONIAN ROCKS.

Horizontal and vertical scale, 1 inch to a mile.

a, Birdseye and Black River limestone.
b, Ste. Marie sandstone.
c, Huronian conglomerates.
H, Level of Lake Huron.
S, Level of the sea.

The following ascending section gives the characters of the limestone in the exposures observed at Campement d'Ours, the fossils leaving little doubt that it belongs to the Birdseye and Black River formation :—

	Feet.
Bluish-grey shales interstratified with thin beds of yellowish compact limestones, presenting an escarpment over the sandstone. The fossils observed are *Stenopora fibrosa*, *Ptilodictya fenestrata*, *P. acuta*, *Strophomena alternata*, *Rhynchonella plicifera*, *Murchisonia gracilis*, and a small undetermined species of *Lingula*, ...	20
Measures concealed,..	60
Ash-grey compact limestone, in beds of from three to five inches, interstratified with a five-inch bed of drab-colored compact limestone; among the fossils are *Stenopora fibrosa*, *Glyptocrinus ramulosus*, *Strophomena alternata*, *Pleurotomaria subconica*, *Subulites elongatus*, *Ambonychia amygdalina*, *Cyrtodonta Huronensis*, *Vanuxemia inconstans*, *Orthoceras Bigsbyi*, *O. Murrayi*, *Leperditia Canadensis*, and *Asaphus platycephalus*,............................	4
Ash-grey compact limestones, in beds of from four to six inches, underlaid by a dark brownish-grey arenaceous limestone bed of about ten inches, and divided by thin layers of grey calcareo-argillaceous shale. All the strata of this division are very fossiliferous, and contain *Glyptocrinus ramulosus*, *Ptilodictya multipora*, *Coscinium flabellatum*, *Strophomena alternata*, *S. filitexta*, *Rhynchonella recurvirostra*, *Orthis subæquata*, *Vanuxemia inconstans*, *Cyrtodonta Huronensis*, *C. subcarinata*, *Pleurotomaria subconica*, *Trochonema umbilicata*, *Murchisonia perangulata*, *Orthoceras recticameratum*, *Cheirurus pleurexanthemus*, and *Leperditia Canadensis*....................	30

	Feet.
Ash-grey compact limestones of the same character as the preceding, but still more fossiliferous. The beds contain *Tetradium fibratum*, *Stenopora fibrosa*, *Columnaria alveolata*, *Petraia profunda*, *Ptilodictya labyrinthica*, *Strophomena alternata*, *S. filitexta*, *Rhynchonella recurvirostra*, *Ambonychia amygdalina*, *Cyrtodonta Canadensis*, *C. Huronensis*, *Vanuxemia inconstans*, *Ctenodonta nasuta*, *Modiolopsis mytiloidea*, *Pleurotomaria subconica*, *Eunema strigillata*, *Subulites elongatus*, *Orthoceras Bigsbyi*, *O. Murrayi*, an undescribed *Cyrtoceras*, *Asaphus platycephalus*, and *Leperditia Canadensis*, ...	16
	130

The strike of these limestones on St. Joseph would carry them across the southern half of Neebish Island into Michigan, but no exposures of them have been observed either on the island or on the mainland.

CHAPTER X.

THE UTICA AND HUDSON RIVER FORMATIONS.

BLACK GRAPTOLITIC SHALES; ARENACEOUS SHALES AND SANDSTONES.—DISTRIBUTION OF THE TWO FORMATIONS.—MONTMORENCI; ORLEANS ISLAND; ST. MAURICE.—OVERLYING RED SHALES.—DESCHAMBAULT ANTICLINAL.—MONTREAL ISLAND; CHAMBLY.—LAKE ONTARIO; WHITBY; TORONTO.—LAKE HURON; OWEN SOUND; MANITOULIN ISLANDS.—OTTAWA OUTLIERS.—SAGUENAY; LAKE ST. JOHN.—ANTICOSTI.

The limestones of the Trenton formation are in general separated by thin layers of black and blackish-brown bituminous shale. These layers in some places become thicker towards the top, and present a passage to the succeeding deposit, which consists of black brittle bituminous shales, constituting what has been called in New York the Utica slate formation. These shales pass into others of a less bituminous character, which become interstratified with dark grey arenaceous shales, and with light grey sandstones weathering to a drab, and usually not very thick: with them are occasionally associated some few beds of arenaceous conglomerate with calcareous pebbles. These strata constitute the Loraine shales, or the Hudson River formation of the New York geologists. The most complete section of the Utica formation occurs on the River Ste. Anne (Montmorenci), between the lowest fall on the stream and the mouth of its tributary the Rivière à la Rose. At the foot of the fall the upper portion of the Trenton formation is seen leaning at a high angle against the Laurentian gneiss, which is the rock of the cascade, and it is succeeded by the following strata in ascending order:—

River Ste. Anne.

	Feet.
1. Black brittle bituminous shale with an undetermined *Lingula* and *Graptolithus pristis*,..	19
Black brittle bituminous shale with two bands of yellow-weathering limestone, black within, probably magnesian, and fit for hydraulic purposes,........	8
Black brittle bituminous shale,..	23
Black brittle bituminous shale, breaking into small fragments in consequence of an imperfect cleavage independent of the bedding,..................	11
Black brittle bituminous shale with *Graptolithus pristis*,....................	245
Grey hard sandstone, interstratified with bands of black shale,..............	5
Black brittle bituminous shale, interstratified with beds of sandstone,........	7
	—— 318

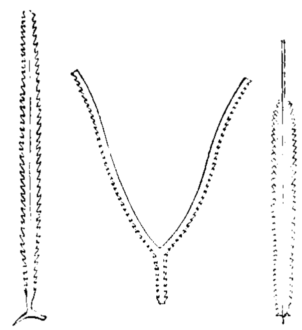
	Feet.	
2. Light grey yellow-weathering sandstone, with black argillaceous nodules at the top; in some parts the sandstone beds hold fossils, which are obscure, but appear to be *Leptæna sericea* and *Orthis testudinaria*,..............	10	
Measures concealed,..	13	
Black brittle bituminous shale,..	6	
Dark grey arenaceous shale,..	51	
Dark grey arenaceous shale,..	192	
Dark grey arenaceous shale, with thin beds of sandstone,..................	8	
Light grey sandstone in a massive bed, weathering greenish in the air and reddish in the water; two bands of conglomerate occur in the middle, holding pebbles of limestone and of quartz. Some parts appear to weather faster than others, in bands conformable with the bedding,............	18	
Dark grey slightly greenish arenaceous shale,............................	58	
Light grey conglomerate beds, with about two feet of fine grained sandstone at the bottom; the conglomerate parts hold pebbles of limestone and quartz of various sizes up to two inches in diameter, those of limestone being in greater abundance than the quartz,................................	5	
Grey sandstone in a massive bed, becoming a conglomerate in parts,..........	14	
Grey calcareous conglomerate as before,................................	3	
Light grey sandstone weathering brownish,..............................	3	
Grey calcareous conglomerate, with soft shaly sandstone as a matrix,........	2	
Greenish arenaceous shale, striped with dark grey bands,..................	84	
Greenish arenaceous shale, striped with dark grey, and having a six-inch band of hard light grey reddish-weathering sandstone at the top, and another at the bottom,..	18	
Greenish arenaceous shale, striped with dark grey, with occasional bands of hard light grey sandstone, weathering reddish-brown as before,.......	125	
Greenish arenaceous shale, striped with dark grey, with thinner and finer bands of light grey sandstone,....................................	39	
Greenish arenaceous shale with dark stripes without any bands of sandstone,..	70	
		719
3. Black brittle bituminous shale, weathering reddish and yellowish-brown, and holding *Graptolithus ramosus* and *G. bicornis*, with a small *Discina* and *Triarthrus Beckii*,..	16	
Black bituminous and slightly arenaceous shale, not quite so brittle as the preceding, except in a few hard black bands, which hold graptolites,......	17	
Black bituminous and slightly arenaceous shale, with two bands of a harder, more brittle, and more bituminous character, the latter with graptolites, .	4	
Dark grey bituminous and slightly arenaceous shale, finely striped with black lines,..	33	
Black brittle bituminous shale, weathering a light or yellowish-brown, without grit, and holding *Graptolithus* and *Orthoceras*,........................	7	
		77
		1114

The first division of the above section presents the lithological characteristics of the Utica formation, and the second those of part of the Hudson River. The third so thoroughly resembles the first division that it is very difficult to distinguish them, particularly as there is a resemblance between the two in the few fossils which are met with. An additional amount of dark grey bituminous and arenaceous shales, interstratified with occasional light grey brown-weathering sandstones, overlies the third division, on the Ste. Anne, occupying the distance between the mouth of the Rivière à la Rose and the St. Lawrence. In the channel between the margin of the St. Lawrence and the island of Orleans, deposits of a similar character probably prevail, and they come upon the island at Ste. Famille, about five miles above the point opposite the mouth of the Ste. Anne. Along the north margin of the island black bituminous shales occur, with some thin beds of black bituminous limestone, interstratified with occasional grey yellow-weathering arenaceous limestones from three to twelve inches thick. In the black shales there occur *Graptolithus bicornis*

Orleans Island.

193-195.—BRYOZOA ? (U.)*

193 194 195



193.—*Graptolithus bicornis* (Hall).
194.—*G.* ——— *ramosus* (Hall).
195.—*G.* ——— *pristis* (Hall. Hisinger?)

and *G. ramosus*. The direct breadth across the deposit, from the Rivière à la Rose, is probably about three miles and a half. In the part between this tributary and the mouth of the Ste. Anne there appear to be at least two undulations, and others probably occur under the St. Lawrence; so that it is difficult to state with precision the whole thickness to be assigned to the Hudson River formation. It is probably however not over-estimated at 2000 feet, while that of the Utica formation, as already shewn in the section, is over 300 feet.

North-eastward from the river Ste. Anne (Montmorenci) these two formations come out obliquely upon the St. Lawrence, the Utica shales

* The fossils of the Utica formation are given in this chapter before those of the Hudson River, and are distinguished by the letter U, those of the latter formation being marked by the initials H. R.

reaching the margin a little above Cape Tourmente, and about eight miles from the Ste. Anne. To the south-westward they occupy the space between the Trenton formation and the margin of the St. Lawrence, as far as Quebec. Their distribution as far as Beauport church has already been given in describing that of the Trenton, and it is sufficient for the present purpose to state, that opposite to the fall of the Montmorenci the Hudson River formation occurs on the north side of the island of Orleans, at the upper end, giving there to this formation a breadth of about two miles.

After leaving the Montmorenci dislocation at Beauport, from which they turn north-westward in a narrow band with a sharp dip, the Utica shales gradually spread out, by the diminution of their slope, to a breadth of about a mile and a half on the axis of the synclinal beyond. Near Charlebourg church the breadth diminishes again to about a quarter of Charlebourg.
a mile; but on the St. Charles River it once more reaches a mile and a half, through the effect of an undulation. Between this and Pointe aux

196, 197.—BRACHIOPODA (U.)

196 197

a b

196.—*Lingula Progne* (Billings); *a*, dorsal valve; *b*, ventral valve.
197.—*L.* —— *curta* (Hall).

Trembles, the Utica shales are seen in many places, more particularly in St. Augustin, where they abut against the Laurentian gneiss.

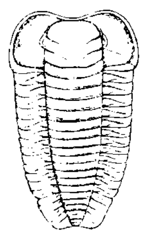
From Beauport to Pointe aux Trembles, the space between the Utica Quebec.
shales and the St. Lawrence is occupied by the Hudson River formation, with the exception of Cape Diamond, on which Quebec is situated, and the ridge which runs from it, by the plains of Abraham, to the Cape Rouge River; as well as a strip extending about a mile and a half along the St. Lawrence, beyond that river. These belong to the Quebec group, hereafter to be described, and behind them the Hudson River rocks present a lower surface, with a breadth of between four and five miles. A south-westward continuation of the Montmorenci dislocation would run between the two. The rocks of Quebec are, however, not brought into their position by this, but by another and very remarkable break in the same place, which will be more particularly mentioned in a future chapter. Where the Hudson River formation comes upon the St. Lawrence, above Cape Rouge, it presents a bold, nearly vertical cliff of about a hundred feet, the base of which, for two miles up, is washed by the flood at high tides. Near to the dislocation the rock consists of black bituminous shales, some of which hold *Graptolithus ramosus* and *G. pristis*. Associated with the shales are two

thick beds of a hard jaspery character, and olive-green color, with short cracks in various directions, occasionally holding a black carbonaceous matter resembling anthracite. The shales a little higher up, on the margin of the river, become interstratified with occasional calcareous sandstones, and one or two beds of limestone conglomerate, in which *Leptæna sericea*, *Strophomena alternata*, and *Orthis testudinaria* occur in some abundance.

Grondines. From Pointe aux Trembles to the Grondines, the two formations fill up the space between the summit of the Trenton group and the St. Lawrence, generally presenting, in the lower half of the distance, a bold nearly vertical front to the river. In this neighborhood the passage from the Utica to the Hudson River formation, by a diminution of bituminous matter, is so gradual, that the division between them has to be somewhat arbitrarily assumed. The position taken as indicating this would leave the

198-200.—CRUSTACEA (U.)

198



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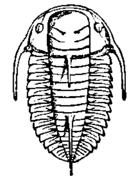

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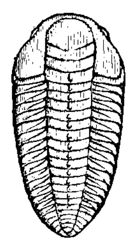


198.—*Triarthrus glaber* (Billings).
199.—*T.* ——— *spinosus* (Billings).
200.—*T.* ——— *Beckii* (Green).

latter formation spread out in two separate areas on the north-west bank; one in the synclinal between Pointe aux Trembles and Cap Santé, and the other, which is but little exposed, between Cap Santé and Deschambault. Where the Utica shales fold over the Pointe aux Trembles anticlinal, they are concealed beneath the waters of the St. Lawrence ; but they strike into the land again on the north-west side of the anticlinal, with a breadth occupying about a mile and three quarters on the margin of the river. The Hudson River area, between the Pointe aux Trembles and Cap Santé anticlinals, extends four and a half miles along the margin ; and behind the village of Les Ecureuils, which is in the middle of the distance, it has a breadth of two miles. Sweeping around this area, the Utica shales come upon the Jacques Cartier River, which in the last six miles of its course runs through them, in a deep ravine with nearly vertical sides. Folding over the Cap Santé anticlinal, they have a breadth of probably five miles, about a mile and a half of which is concealed under the St. Lawrence; and from the axis of the anticlinal, their breadth gradually diminishes as the formation sweeps round the synclinal to Portneuf River, where it may be upwards of a mile. This breadth is probably maintained along the south-east side of the Deschambault anticlinal as far as the Grondines.

Between the Jacques Cartier River and Cap Santé, the Utica shales are interstratified with a bed or two of black limestone, sometimes reaching a foot in thickness; and on the beach at Cap Santé village there is a thickness of about twenty feet of argillaceous limestone of a lighter color. In the vicinity, layers of this lighter colored limestone of from four to six inches thick, are met with at intervals, above the twenty-feet band; and they afford in several places close to the cliff, and out between high and low water mark, beautifully even slabs, fit for door lintels, window sills, and such purposes. The slope of the strata being very moderate, considerable areas are exposed on single beds: these are often cut up by joints, the planes of division running in three principal directions. Cap Santé.

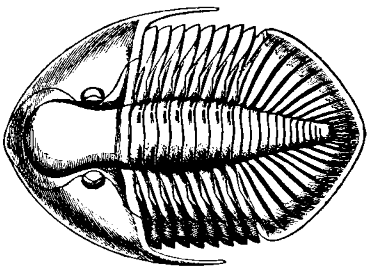
The great dislocation, which limits the Hudson River formation above the Cap Rouge River, crossing the St. Lawrence obliquely, reaches the opposite side a little above the church of St. Nicholas. From this point the formation constitutes a bold cliff running along the south side of the St. Lawrence by St. Antoine, St. Croix, and Lotbinière, to the Grande Rivière du Chêne, the distance being upwards of thirty miles. Inland, the southern limit of the formation is traceable to St. Antoine, where it is about two miles and a half from the river. It is here marked by a black limestone, holding, among other fossils, *Stenopora fibrosa*, *Petraia corniculum*, *Strophomena filitexta*, *Camerella extans*, *Bellerophon bilobatus*, and *Trinucleus concentricus*. Farther up it becomes obscured by drift. It probably, however, reaches the Grande Rivière du Chêne in a pretty straight line, and runs westward on the south side of it, conforming in its distribution to the effect of the Pointe aux Trembles and Cap Santé anticlinals. On the south-east side of the Deschambault anticlinal, the limit of the dark shales is removed about seven miles from the St. Lawrence, on the line between the seigniories of Deschaillons and St. Pierre les Becquets; the axis of the anticlinal being about half that distance from the river.

The strata at the summit of the Hudson River formation here dip S. $< 8°$, and are followed by a set of red shales, which appear to overlie them conformably. Where the road running near the top of the lower formation crosses the Little River du Chêne, the beds are fossiliferous. Among the fossils found here, and at various places along the margin of the river between St. Nicholas and Rivière du Chêne, are *Leptæna sericea*, *Strophomena alternata*, and *Orthis testudinaria*. Beds of drab-weathering sandstone are occasionally interstratified among the shales of the cliffs on Red shales.

the south side of the St. Lawrence, between the Grande Rivière du Chêne and St. Nicholas, and frequently present the fossils just named, in some abundance.

St. Maurice. On the north side of the St. Lawrence, from the Grondines to the island of Montreal, a distance of about a hundred miles, the space between the margin of the river and the exposures which have been mentioned as belonging to the Trenton formation, is so much covered with drift, that in an area of about 1000 square miles, only two exhibitions of the strata have been discovered, both belonging to the Utica formation. One of these is on the St. Maurice, and the other on the Achigan. That on the St. Maurice occurs on the left bank, at Pointe à la Hache, about nine miles from the St. Lawrence, and nearly opposite to the St. Maurice forges; it occupies about 200 yards of the margin. The dip varies from S. 30° E. to S. 45° E., with a slope of two degrees, and the deposit consists of black bituminous shales, interstratified with occasional layers of black bituminous limestone. The limestone has a smooth surface and a smooth conchoidal

201.—CRUSTACEA (U.)



201.—*Asaphus Canadensis* (Chapman).

fracture, and becomes reddish-yellow under the influence of the weather. The fossils which characterize the beds are *Graptolithus pristis*, a small *Discina*, and *Triarthrus Beckii*. It is probable that the deposit extends farther up the stream; for 300 yards above Pointe à la Hache, on the right side, fragments of similar shales are strewed on the bank, and there is a ripple across the river, perhaps occasioned by an outcrop of the shales in the bottom. The exposure on the Achigan, as has already been mentioned, occurs on the boundary line between the seigniories of L'Assomption and St. Sulpice, not far from the highest Trenton beds seen in that neighborhood. It presents a thickness of about twelve feet, and consists entirely of black brittle bituminous shales.

These two exposures give but imperfect data to determine the distribution of a hundred miles of the formation to which they belong. Their positions appear sufficient however to establish the probability that there must be some breadth of the Hudson River formation on the north side of the St. Lawrence in this part, and that it may occupy several miles at the mouths of the St. Maurice, Batiscan, and Champlain Rivers. A set of fossiliferous strata, such as sometimes indicate an approach to the summit of the formation, is met with on the south side of the St. Lawrence, just opposite to the St. Maurice. The beds appear to be in a nearly horizontal attitude, and are marked by *Stenopora fibrosa*, *Leptæna sericea*, *Strophomena alternata*, *Orthis testudinaria*, *O. occidentalis*, *Athyris Headi*, *Rhynchonella capax*, *Avicula demissa*, *Orthoceras crebriseptum*, and *Asaphus platycephalus*. They rise into a low ridge occupying the chief part of the space between the shore and Lake St. Paul; on the south side of which lake, the red shales, already mentioned as overlying the Hudson River formation, form a marked escarpment. In this relation, dipping southward at an angle of one or two degrees, the fossiliferous beds and the overlying red strata, are traceable down the St. Lawrence nearly as far as the Gentilly River. The escarpment of red shales can be followed in an opposite direction to the Nicolet. Four and a half miles from the mouth of this river, rocks of a red color are exposed on its banks. St. Grégoire.

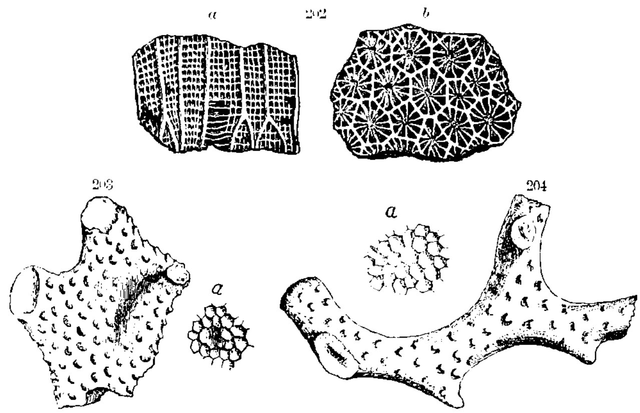
The patch of red shale to which this escarpment belongs, lies in a shallow synclinal form, with a breadth of nearly eight miles. It is separated from the red shales of St. Pierre les Becquets, in the prolongation of these to the south-westward, by fossiliferous grey shales of the Hudson River formation, brought to the surface by the Deschambault anticlinal on the Bécancour, in the sixth range of Maddington, and again on the Nicolet, about fourteen miles from its mouth. Although no fossils have as yet been detected in these two patches of red shale, their color and position make it probable that they should be classed with the succeeding formation, which is the Medina sandstone. In its continuation south-westward from the Nicolet, the axis of the Deschambault anticlinal, which runs between them, appears to cross the St. Francis toward the north-west side of Wendover and Grantham, where it is marked by Hudson River graptolites. Farther on, the axis reaches St. Dominique in the seigniory of St. Hyacinthe, and thence its course would carry it to the neighborhood of Phillipsburgh, near the province line. In the seigniory of St. Hyacinthe, not far to the south-east of this axis, and parallel with it, will probably run the continuation of that great break in the strata which has already been alluded to as occurring at Quebec. Synclinal. Red shales, probably Medina. St. Dominique.

About six miles north-eastward of St. Dominique, the Deschambault anticlinal brings to the surface the Trenton formation. The limestones belonging to this, as well as those of the Birdseye and Black River, and occasionally the Chazy, all determined by characteristic fossils, are traceable in a comparatively narrow strip from this position, with few intervals of interruption, by St. Dominique and St. Pie, to the boundary between Anticlinal.

Chazy St. Hyacinthe and Farnham. Among the Chazy fossils met with are *Ptilodictya fenestrata*, *Orthis borealis*, *O. platys*, *Strophomena alternata*, *Vanuxemia Montrealensis*, and *Pleurotomaria Crevieri:* with these are Sandstone. associated *Ampyx Halli.* A sandstone, of which about thirty feet are seen, underlies the fossiliferous limestones, and is supported by a very pure dove-grey limestone, without observed fossils. Along the whole range of the exposures, the dip appears to be to the eastward; but in the neighborhood of St. Pie, some of the dove-grey limestone, a little removed to the westward of the range, has a westerly dip. This is considered sufficient to show the existence of an anticlinal. There may however be a dislocation connected with it, throwing up the measures on the east side.

Between the summit of the Trenton formation, as already traced in its distribution from the west side of Lake Champlain to the Maskinongé on the one hand, and the Deschambault anticlinal from the St. Francis to

202-204.—ZOOPHYTA (H. R.)



202.—*Favistella stellata* (Hall); *a*, longitudinal section through several of the tubes; *b*, transverse section.
203, 204.—Varieties of *Stenopora fibrosa* (Goldfuss); *a*, *a*, portions of the surface magnified.

Farnham on the other; the whole country, comprising an area of about 2500 square miles, appears to be underlaid by the Utica and Hudson River formations, with the exception of the intrusive masses of Montarville, Rouville, Rougemont, and Monnoir Mountains. In this area is included another small shallow synclinal mass of the overlying red shale, crossing the St. Francis about seven miles from its mouth.

Along the eastern front of the island of Montreal there is space above the highest exposures of the Trenton limestone for a part of the Utica formation; but no exhibition of its strata occurs before reaching the city.

The first exposure of them, proceeding along the margin of the island, is at Point St. Charles, and several are met with between that point and the head of Sault St. Louis. The black shales extend from the water's edge at least as far back as the city aqueduct and the third lock of the Lachine canal; the upper part of the aqueduct and the lower part of the canal having been, in some parts, excavated in these shales. In front of Montreal, the deposit forms St. Paul's Island, and it was met with in the bed of the St. Lawrence, at the foundation of every one of the piers of the Victoria Bridge. On the right bank of the river it is seen at Longueuil, with some of its characteristic graptolites, and its summit may here attain the distance of a mile from the water. This would give to the Utica formation, in this part, a total breadth of about four miles. The dip of the strata, which is about east, exhibits a slope in several places of between three and five degrees; but there may be several gentle undulations under the river, and one of the depressions probably underlies St. Helen's Island, which, with Round Island immediately below, constitutes an isolated patch of a much newer formation. These undulations would materially diminish the average inclination of the strata, and make it probable that the thickness of the deposit at Montreal does not exceed that assigned to it near Quebec. Montreal Island.

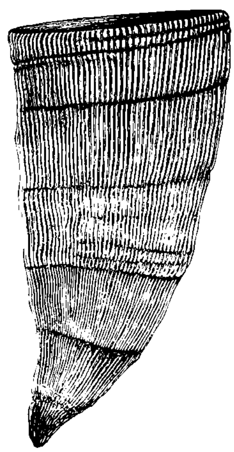
In the neighborhood of Montreal, the Utica shales, like the limestones beneath them, are much intersected by trap dykes, and intercalated with trap floors. Instances of the former are seen on the right bank of the river opposite and below St. Helen's Island; and of the latter, about a quarter of a mile forward, on the cutting for the St. Lawrence and Atlantic Railroad, as well as at Moffatt's Island, where the trap is a trachyte, and at Laprairie. On the left side, they are met with at Point St. Charles, on St. Paul's Island, and higher up the river. Where the outcrops of these floors come into the bed of the stream, and at any place cross its course, the unequal wearing of the soft shale and hard trap leaves projections and steps in the bottom, which frequently occasion leaps and rapids, impeding the navigation of the river. The Sault Normand, out in front of Point St. Charles, appears to be of this description, the ledge occasioning it being probably connected with the trap at the point. More important instances occur in several parts of the Sault St. Louis. On the aqueduct near Lachine there is met with a set of white trachyte and phonolite dykes, hereafter to be described, which cut not only the shales of this formation, but the more ancient dolerites and melaphyres by which these shales are penetrated. A dyke of a similar description, near the reservoir, intersects the trap of Mount Royal, and an isolated patch of the Utica shales which abuts against the mountain, shews, what the limestone beneath leaves doubtful, that this great mass of trap breaks through the strata. The shales are considerably indurated near the junction, and at the point of Trap floors. Point St. Charles. Intrusive dykes.

contact of similar shales with an intercalated layer of trap at Point St. Charles, well formed crystals of pyroxene penetrate the shale to a distance of half an inch.

Above Longueuil, the Utica shales sweep round by Laprairie, La Tortue, and St. Philippe, to the Richelieu River, where they are seen in the excavations of the Chambly canal, and are again intersected by dykes of trachytic trap. Folding over the axis of the Chambly anticlinal, the formation runs up the east side of the Richelieu, with a width extending beyond Henrysville, where *Triarthrus Beckii* occurs, and the formation apparently constitutes all that point on Lake Champlain lying between the exit of the lake and Missisquoi Bay.

Although it is stated as probable that the upper limit of the Utica formation does not extend beyond a mile from the St. Lawrence at Longueuil, the strata characterized by the fossils of the Hudson River formation are

205.—ZOOPHYTA (H. R.)



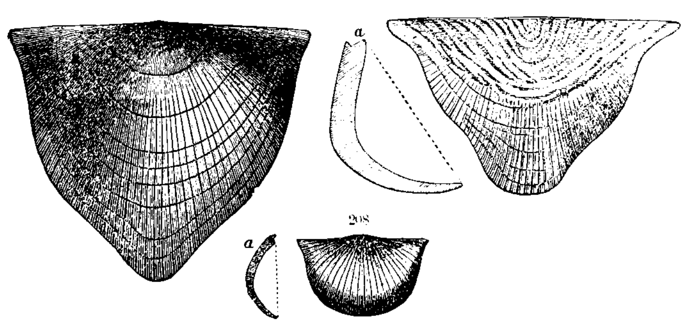
205.—*Petraia Canadensis* (Billings).

not met with nearer than four miles beyond this. These fossiliferous beds are laid bare in the cutting for the St. Lawrence and Atlantic Railway; and kept at the surface by undulations, they occur at intervals, across the measures, as far as the Yamaska. There is a development of them on both sides of the Richelieu, at the rapids above the basin of Chambly. The strata are there nearly flat, and consist of alternating layers of bluish and grey argillaceous and calcareous shales. The calcareous beds are at the same time arenaceous, and exhibit many organic remains, among which are the

Chambly.

characteristic species *Avicula demissa*, *Modiolopsis modiolaris*, *Orthonota nasuta*, and *Ambonychia radiata*. On the Rivière des Hurons, about half way between the Richelieu and the Yamaska, there is another exhibition of the same fossiliferous beds, near the village of St. Jean Baptiste, where, among other forms, *Modiolopsis complanata*, *M. securiformis*, and *Murchisonia Beatrice* occur. A third locality is on the east side of Rougemont Mountain, precisely in the strike of a fourth locality at St. Hyacinthe on the Yamaska, where the strata consist of dark greyish-blue argillaceous shales, interstratified with occasional thin layers of limestone. At Turcotte's mills, Yamaska.

206-208.—BRACHIOPODA (H. R.)



206.—*Strophomena Hecuba* (Billings).
207.—*S.* ——— *fluctuosa* (Billings); *a*, longitudinal section.
208.—*S.* ——— *nitens* (Billings); *a*, longitudinal section.

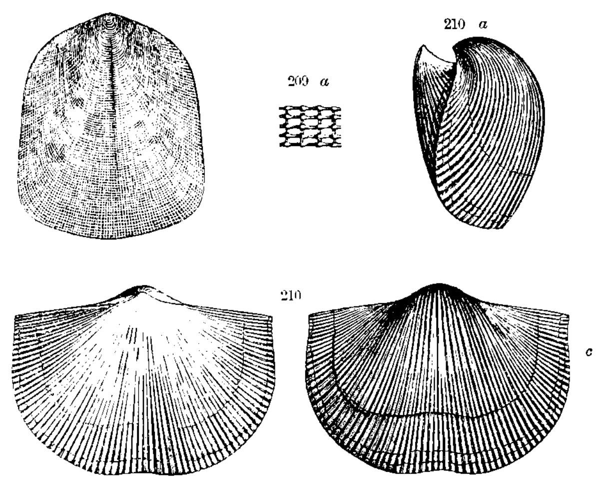
lower down the stream, bluish-grey shales are associated with calcareous sandstones. Among the organic remains in these last two localities are the characteristic species, *Ambonychia radiata* and *Trinucleus concentricus*. In both places the measures are disturbed by undulations, causing slopes at high angles, sometimes on one side and sometimes on the other; the strike, which remains pretty uniform, running with the general course of the river. The limited areas of these exposures make it difficult to say what may be the average dip, either in direction or amount. It is not improbable that the Yamaska, the Hurons, and the Richelieu may run upon three parallel anticlinals, so that the spaces between the rivers around the mountains of Rougemont and Rouville would be occupied by somewhat higher strata than those holding the fossils.

These isolated mountains, with those of Montarville and Monnoir, are composed of diorites and dolerites, resting on sedimentary rocks at the base, and will be described farther on. At Chambly, about half a mile above the fort, there is an interstratified floor of trachyte, similar to that in the Intrusive rocks.

Utica formation, already mentioned on the Chambly canal. At St. Hyacinthe, a dark colored compact two-feet dolerite dyke cuts the strata: small disseminated crystals of feldspar give a porphyritic character to the rock, and are associated with grains of olivine.

New York. The two formations which we are tracing, passing out of the province, ascend Lake Champlain and come upon the Hudson River, from which the

209, 210.—BRACHIOPODA (H. R.)



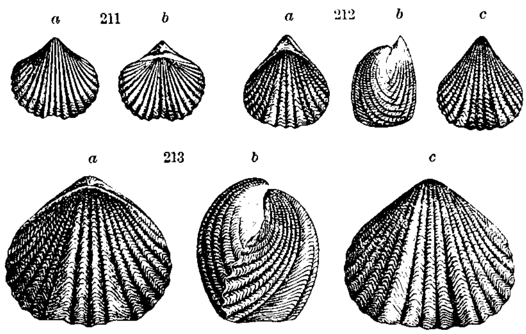
209.—*Lingula Canadensis* (Billings); *a*, portion of the surface enlarged.
210.—*Orthis occidentalis* (Hall); *a*, side, *b*, ventral, and *c*, dorsal view.

upper portion takes its name. Turning thence to the valley of the Mohawk, the lower formation passes under the town of Utica, from which its title is derived. The two formations reach the shore of Lake Ontario, between Sandy Creek and Oswego, and are next met with on the north shore of the lake, extending between Bowmanville and the river Credit.

ke Ontario. The most eastern exposures of the Utica formation, on the north shore, are just above those of the Trenton already mentioned as occurring to the south of Oshawa, and near to Bowmanville; both on the south side of the synclinal which has been indicated there. An outcrop of some of the strata of the formation is met with on the creek, at Nash's brewery, in the village of Windsor, which is on the twenty-seventh lot of the lake-front range of Whitby; and at Bowerman's mill, on the thirty-second lot of the third range, a well has been sunk in the formation to the depth of fifty feet. The rock in this part of the country, as elsewhere, is a dark brownish-black hard brittle and very bituminous shale, which splits into thin laminæ. When dried and again wetted, the shale soon cracks and falls to pieces; so that when exposed to the weather it rapidly decomposes, and at length forms a dark-colored clay, which constitutes a good soil.

The exposures which have been mentioned are all that are yet known near the lake shore, and they are too few to make the distribution of the formation in this part perfectly intelligible. The dip of the strata in the well at Bowerman's mill has not been ascertained, and it is therefore

211-213.—BRACHIOPODA (H. R.)



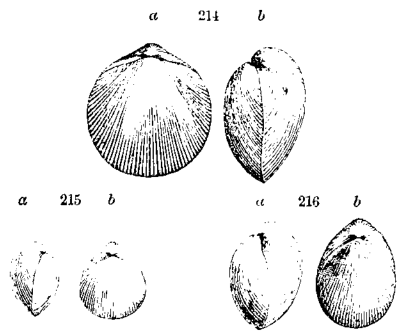
211.—*Rhynchonella? modesta* (Conrad); *a*, dorsal, and *b*, ventral view.
212.—*R.* ——— *Anticostensis* (Billings); *a*, dorsal, *b*, side, and *c*, ventral view.
213.—*R.* ——— *capax* (Conrad); *a*, dorsal, *b*, side, and *c*, ventral view.

difficult to say whether this locality is, like the others, on the south side of the synclinal, or to determine where the base of the formation may sweep round in its progress towards the next known outcrop of the rock, which does not occur until reaching Nottawasaga Bay on Lake Huron. The exposures in this bay are seen along the coast, in the third and fourth ranges of Collingwood, and, from the limestone beneath, occupy a breadth of about a mile. The slope perhaps somewhat exceeds the rate which has been given as the average inclination of the subjacent limestone, and the thickness of the deposit is supposed to be between fifty and a hundred feet.

The Utica formation, both here and at Windsor, is very fossiliferous. Among the species which characterize it, there is a great abundance of *Asaphus Canadensis*, of which chiefly the tails are preserved. This trilobite is accompanied by *Triarthrus Beckii*, *Leptæna sericea*, *Strophomena alternata*, *Orthis testudinaria*, *Rhynchonella increbescens*, and one or two species of *Discina*, *Orthoceras*, and *Cytheropsis*, which have not yet been named. In Collingwood, the deposit consists of dark brownish-black shales, interstratified with occasional beds of compact brownish limestone, Collingwood. and the shale yields by distillation such an amount of bitumen as to have induced the establishment of a manufactory at Collingwood, for its extraction. Judging from specimens, the strata at Windsor would be equally well adapted for the purpose. Iron pyrites occasionally occurs in some abundance, coating the fossils of this formation.

Toronto. Between the river Rouge in the township of Pickering on the east, and the river Credit in the township of Toronto on the west, sections of the Hudson River formation may be seen on almost all the intervening streams.

214-216.—BRACHIOPODA (H. R.)

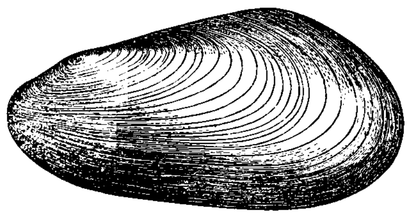


214.—*Athyris Headi* (Billings); *a*, dorsal, and *b*, side view.
215.—*A.* —— *Anticostensis* (Billings); *a*, dorsal, and *b*, side view.
216.—*A.* —— *borealis* (Billings); *a*, dorsal, and *b*, side view.

The formation here consists of a series of bluish-grey argillaceous shales, enclosing bands of calcareous sandstone, sometimes approaching to a limestone, at irregular intervals and of variable thickness. In some instances the bands are of a slaty structure, splitting into thin laminæ in the direction of the beds; in others they have a solid thickness of a foot; but in few cases do they maintain either character for any great distance. The sandstones, while in the beds, are hard and solid, and upon fracture exhibit a grey color, with much of the appearance of limestone; but by long exposure to the weather they turn to a dark brown, and ultimately crumble and decay. These sandstones generally abound in calcareous fossils, which in some places predominate so as to give rise to beds of impure limestone: these beds are, however, rare. A workable limestone bed of this kind, in the vicinity of Toronto, would be of great value, as the stone yielding the lime for the consumption of the city is at present transported from some distance. The slaty variety of the sandstones is well adapted for flagging, and, by a careful selection, some of the arenaceous bands may yield abundance of good building material, but the stone cannot be said to be generally adapted for the purpose.

The banks of the Credit, the Etobicoke, the Minaco, the Humber, and the Don, for certain distances from the lake shore, expose sections exhibiting sixty feet or more of these strata; but advancing northward, the formation becomes concealed by the great accumulation of drift, of which the interior of the country is composed. At Weston on the Humber, near to the townships of Etobicoke and York, some good limestone occurs; and at Fisher's mill, below Dundas Street, on the same river, there is more of Humber.

217.—LAMELLIBRANCHIATA (H. R.)



217.—*Modiolopsis modiolaris* (Conrad).

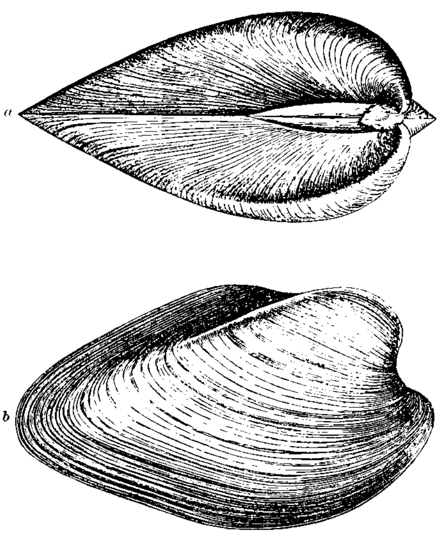
the same material. At the latter place, the banks of the stream rise to a height of more than a hundred feet, of which from fifty to sixty are composed of the Hudson River shales and sandstones, while the upper part consists of sand and gravel.

Most of the localities named abound in the characteristic fossils of the formation. On the Don, some thin calcareous beds are almost a mass of Don. *Leptæna sericea*, which is accompanied by *Rhynchonella modesta*, *Ambonychia radiata*, and *Modiolopsis modiolaris*. On the Humber, *Orthoceras crebriseptum* occurs in great abundance, and among other species are *Stenopora fibrosa*, *S. petropolitana*, columns of *Glyptocrinus*, *Leptæna sericea*, *Strophomena alternata*, *Rhynchonella increbescens*, *Avicula demissa*, *Ambonychia radiata*, *Modiolopsis modiolaris*, and *Lyrodesma poststriata*. On the Credit, in addition to many of the preceding species, are found an undetermined *Tetradium* and *Faristella stellata*.

Escaping from beneath the great mass of drift, which conceals the formation between Lake Ontario and Lake Huron, the whole thickness of the deposit can be determined on the east side of the township of Collingwood, where it rises, in nearly horizontal strata, to the height of 770 feet, in the flank of a hill overlooking the Utica shales, which have been mentioned as exposed at the level of the lake. Farther on, the deposit shows itself near Cape Boucher in Nottawasaga Bay, where cliffs, rising abruptly to the height of about 150 feet, present sections of buff or drab-colored argillaceous shale, interstratified with thin beds of grey yellow-weathering sandstone. The formation next makes its appearance at Point Rich, and continues exposed in a high, and nearly vertical cliff to Point William, where we find bluish and drab argillaceous shales, with thin beds of limestone and calcareous sandstone, in a precipitous hill, which slopes back from the vertical part. The strata are piled on one another to the height of 335 feet over the lake, and they are capped by twenty feet of red and bluish-green clays, with an occasional band of harder rock: these belong to the succeeding formation.

Exposures of Hudson River strata occur on the road between concessions B and C of Sydenham, from the sixteenth to the twenty-third lot,

218.—LAMELLIBRANCHIATA (H. R.)



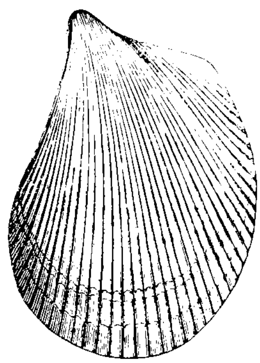
218.—*Cyrtodonta Hindi* (Billings); *a*, dorsal, and *b*, side view.

having between them and the lake a long outlier of the succeeding formation, which there constitutes a considerable hill. On the lake side of the hill, no Hudson River strata have been observed; but the summit of this formation is supposed to occur at the margin of the water, about three miles Owen Sound. below the town of Owen Sound, and to cross thence to the opposite side of the bay, where Hudson River strata are seen at intervals to Cape Commodore. They are met with also on the islands opposite to Colpoy's Bay, at Cape Crocker and Point Montresor, as well as Barrier Island, but higher formations occupy the remainder of the coast to Cabot's Head. If a straight line were drawn from Point Boucher to Point Rich, to represent the outcrop of the base, the formation would have a breadth of about seventeen miles at Owen's Sound; which, at the supposed slope of thirty feet in a mile, would give a thickness of about 500 feet.

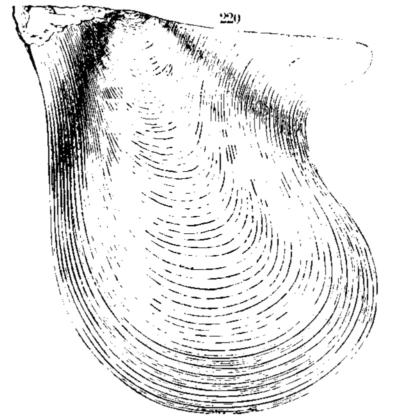
In some of the beds at Point Boucher concretionary nodules of calcspar are observed, and similar nodules at Point Rich are associated with others of orange-red gypsum and of heavy spar. These occur also at Cape Commodore, but no masses of the gypsum of a workable description have been Point Boucher

219, 220.—LAMELLIBRANCHIATA (H. R.)

219



220



219.—*Ambonychia radiata* (Hall).
220.—*Avicula demissa* (Conrad).

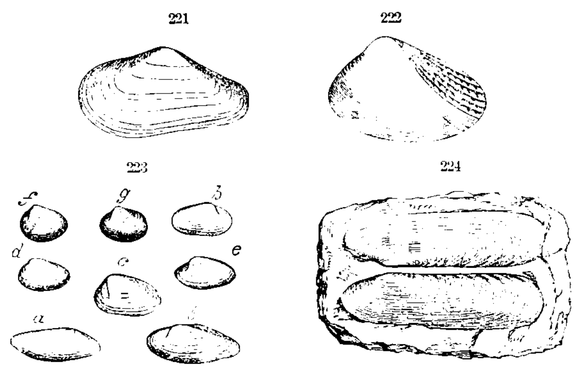
met with. The materials of economic importance presented by the strata along the coast, are confined to stone for building, for tiles, and for flagging, with occasional beds of limestone fit for burning into lime.

Fossils in great abundance, but unequally distributed, are found in the formation in this region. In the section near Point Boucher, some of the sandstone surfaces are marked by *Graptolithus mucronatus;* but the organic remains consist chiefly of columns of different species of crinoids. Testacea are rare, those observed being confined to a few specimens of *Ambonychia radiata*, *Modiolopsis modiolaris*, *Rhynchonella modesta*, *Strophomena alternata*, *S. filitexta*, and one or two undetermined bivalve shells, with *Stenopora fibrosa*, and a species of *Asaphus*. At Point Rich, Point Rich. and thence gradually rising in the strata, to Point William, testacea are more plentiful, but not in great abundance. The most numerous fossil is *Orthoceras crebriseptum*, which is accompanied by *Stenopora fibrosa*, *S. petropolitana*, and a species of *Petraia*, *Leptæna sericea*, *Strophomena alternata*, *S. filitexta*, *Orthis lynx*, *O. occidentalis*, *Rhynchonella modesta*, *Ambonychia radiata*, *Modiolopsis modiolaris*, *Avicula demissa*, two species of *Cyrtodonta*, three species of *Murchisonia*, *Bellerophon ornatus*, and *Orthoceras bilineatum*. At Cape Commodore, which is higher in the series, there occurs, with most of these, *Avicula elliptica;* and at Cape Crocker and Point Montresor, on the same horizon as Cape Commodore, nearly all the species above named are met with in great abundance.

Manitoulin Island.

The next exposures of the two formations under description occur on the east end of the Great Manitoulin Island, and on some of the small islands adjacent. The Utica formation presents itself at Cape Smyth, on the

221-224.—LAMELLIBRANCHIATA (H. R.)



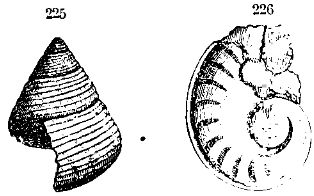
221.—*Ctenodonta Iphigenia* (Billings).
222.—*Lyrodesma poststriata* (Emmons).
223.—*Cleidophorus?* several small species.
224.—*Orthonota parallela* (Hall)?

east side of Wequamekong Bay. It has here a breadth of about a mile, at the point of the Cape, and, with a similar breadth, follows the Trenton formation across the neck of the promontory between Wequamekong and Manitouwaning Bays. It appears again at the southern extremity of Shequenandod Island, and forms a small island in Shequenandod Bay. Entering upon the west side of the bay near the village of Shequenandod, it crosses to Beaufort Bay, resting unconformably on the south side of a quartzite ridge of the Huronian series, near the village, and on the Trenton limestone, as it enters the latter bay. Where these shales rest on the Huronian rocks, the beds are slightly turned up at the outcrop, dipping S. < 15° : but this dip does not extend above two chains from the ridge, beyond which the strata again become nearly horizontal. Beyond Beaufort Bay, the shales run along the south side of the small island north of Maple Point on the Great Manitoulin, which has already been alluded to, where they rest on the Trenton beds. From Cape Smyth to this position, the thickness of the deposit does not anywhere exceed about fifty feet.

Some of the beds of the formation in this part are more than usually bituminous, and on the island north of Maple Point a spring of petroleum rises from them. At Cape Smyth, the usual very bituminous black shales of the formation are interstratified with a few bands of a less bituminous character, grey in color, and with an occasional thin layer of brownish limestone. These contain, in great abundance, a few species of fossils, consisting of *Orthis testudinaria*, *Pleurotomaria Hebe*, *P. Artemis*, Cape Smyth.

225, 226.—GASTEROPODA (H. R.)

225 226



225.—*Cyclonema bilix* (Conrad).
226.—*Cyrtolites ornatus* (Conrad).

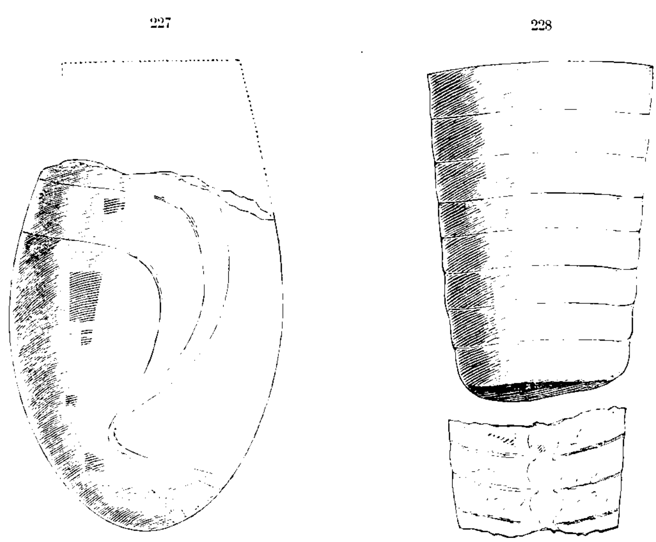
and *P. tenuis*, with columns of *Heterocrinus*. At Shequenandod, the prevailing species belong to *Graptolithus* and *Orthoceras*; while on the islands off Maple Cape the only species observed are orthoceratites, with *Triarthrus Beckii*, which is met with at all the localities.

Between the Maple Cape Islands and the island of St. Joseph nothing St. Joseph. more is seen of the Utica formation before reaching one or two small islands off the east coast of St. Joseph. Though much covered with drift on this latter island, there are indications on the two sides of it that the band passes across in a due east and west course, nearly opposite to the southern point of Neebish Island, whence it strikes into the northern peninsula of Michigan in the bight of Mud Lake Bay.

More than half way across from Cabot's Head to the Great Manitoulin, the Hudson River formation constitutes the strata of Lonely Island, which rises to a considerable height. It forms also an island about four or five miles farther west, as well as Rabbit Island about three miles beyond, where bluish argillaceous shales are interstratified with thin bands of grey drab-weathering limestone and calcareous sandstone. Among their fossils we find for the first time, *Beatricea undulata*, which is accompanied by *Favistella stellata*, *Ambonychia radiata*, *Vanuxemia amygdalina*, *Pleurotomaria Americana*, and *Orthoceras bilineatum*.

These beds belong to the upper part of the deposit, but it is not certain how far they may be from the summit. The base of the Hudson River formation is seen resting on the Utica shales at Cape Smyth; so that the breadth of the formation in this part is at least nine miles, and the thickness about 300 feet. At Cape Smyth, the deposit consists of bluish and greenish argillaceous shales interstratified with grey drab-weathering calcareous sandstone, and abounds in fossils, many of them well preserved. Twenty-six species have here been met with: among them are *Tetradium fibratum*, *Stenopora fibrosa*, *Favistella stellata*, undetermined species of *Petraia* and *Stromatopora*, *Leptaena sericea*, *Strophomena alternata*, *S. filitexta*, *Orthis lynx*, *O. occidentalis*, *O. insculpta*, *Rhynchonella modesta*, *R. recurvirostra*, *Modiolopsis modiolaris*, *Avicula demissa*, undetermined species of *Orthonota* and *Cyrtodonta*, *Pleurotomaria Americana*, *P. Helena*, *Cyclonema bilix*, an undetermined *Murchisonia*, *Orthoceras bilineatum*, *O. crebriseptum*, and an undetermined *Asaphus*.

227, 228.—CEPHALOPODA (H. R.)



227.—*Ascoceras Canadensis* (Billings).
228.—*Orthoceras crebriseptum* (Hall).

Proceeding westward, a high and bold escarpment marks the lower part of the formation between Wequamekong and Manitouwaning Bay, as well as on the west side of the latter bay. It is continued south of Shequenan-

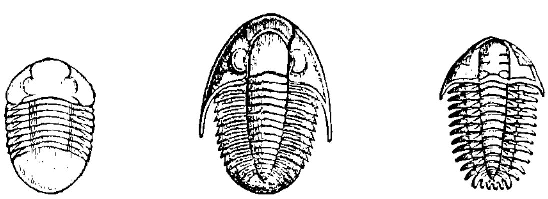
Beaufort Bay. dod Bay, and farther to Beaufort Bay, while a depression, overlooked by the escarpment of a more recent rock, follows the summit from Manitoulin Gulf to Manitouwaning, thence to the north part of Tecumseth Lake, and farther to the upper part of Beaufort Bay. In this part of its range, the Hudson River formation, gradually narrowing, diminishes in volume, and south of Lacloche Island its thickness probably does not exceed 200 feet.

Between Beaufort Bay and Bayfield Sound, the same formation composes all the north side of the Great Manitoulin, with a breadth of five or six miles south from Maple Point. It also forms Barrie Island and the northern salient points of the Great Manitoulin beyond, Cape Robert being the most conspicuous. It constitutes also the northern capes of Cockburn Island, and nearly one half of the north and south breadth of Drummond Island. North of Drummond Island, the base reaches Sulphur Island, where it

Drummond Island.

229-231.—CRUSTACEA (H. R.)

229 230 231



229.—*Asaphus platycephalus* (Stokes).
230.—*Proetus Alaricus* (Billings).
231.—*Cheirurus Icarus* (Billings).

abuts against the Huronian quartzites. Farther westward, it underlies rather less than the southern half of the island of St. Joseph, striking thence into the northern peninsula of Michigan.

Ottawa outliers.

In describing the distribution of the Trenton group of limestones, allusion has already been made to the occurrence of the Utica and Hudson River formations in those outlying patches of Lower Silurian strata which occur in the northern division of the great basin which occupies the country between the Ottawa and the St. Lawrence. Enough has been said to indicate the position of these outliers. The two smaller patches, one lying in Clarence and Plantagenet, and the other in Cumberland, consist wholly of the Utica formation. The third and largest, a part of which touches the city of Ottawa, though chiefly composed of the same formation, presents a set of grey brownish-weathering calcareous sandstones, obscurely exposed in the north-eastern part of Russell, and extending from the twelfth to the twenty-first lots of the second and third ranges. These sandstones are marked by *Strophomena alternata*, *Athyris Headi*, *Ambonychia radiata*, *Modiolopsis modiolaris*, and *Calymene senaria*, the chief part of which clearly show these strata to belong to the Hudson River formation. To the northward of them, red shale is met with between the twenty-first and twenty-second lot of the third range. Red shale occurs also in the rear of the fourth lot of the eighth range of Osgoode, probably connected with the shale of Russell; but the rocks in this part are so covered with drift, that the complete distribution of the Hudson River strata, and their relation to the red shales, have not yet been made out. The fossils of the Utica shales in this region are several species of *Graptolithus*, *Leptæna sericea*, *Strophomena alternata*, *Orthis testudinaria*, undetermined species of *Lingula*, *Ctenodonta* and *Orthoceras*, *Asaphus Canadensis*, *Triarthrus Beckii*, and *T. spinosus*.

Saguenay. **Lake St. John.** The trend of the Utica formation on the south side of the Lower Silurian trough of Lake St. John, has been given in tracing the distribution of the Trenton limestone. The apparent flatness of the trough makes it probable that the formation may occupy a zone of some two or three miles wide, chiefly under the waters of the lake, surrounding a considerable nucleus of the Hudson River deposits. The Utica formation on the lake, in every observed exposure, consists of the usual black and strongly bituminous shales, lying in beds from a sixteenth to an eighth of an inch thick, and the whole mass is estimated to be about a hundred feet. The change from the limestones below them is sudden, there being no interstratification of calcareous layers at the base. From a quarter to half an inch at the bottom is filled with fragments of crinoidal columns, which, being white, give to the layer a dotted grey aspect, and supply it with calcareous matter. Graptolites abound in the beds: among them is *Graptolithus mucronatus*, and there are probably some undescribed species. *Dictyonema* occurs, and among the fossils are also *Discina filosa*, *D. lamellosa*, an undetermined *Lingula*, with several new species of *Orthoceras* and *Triarthrus Beckii*.

The only spot on Lake St. John where the Hudson River formation is met with is at Snake Island, where there occurs an argillaceous yellow-weathering limestone, of which only a small exposure has been seen in place. The island, which is about a mile long and a furlong wide, is covered with fragments of the same kind, and from those around the island a considerable collection of good fossils has been obtained, some of the forms among which are characteristic of the Hudson River formation. Among the fossils are *Beatricea undulata*, *Petraia corniculum*, *Ptilodictya acuta*, *Halysites catenulatus*, *Orthis occidentalis*, a large variety of *O. lynx*, *O. testudinaria*, *Athyris Headi*, *Rhynchonella increbescens*, and *Ambonychia radiata*.

It has been stated in a previous chapter that the highest rocks of the Mingan Islands belong to the Birdseye and Black River formation. The measures there dip towards the island of Anticosti, which is to the south of the Mingan group, with an average slope of about ninety feet in a mile. **Anticosti.** Much higher deposits in Anticosti stand very much in the same attitude, and it is therefore presumed that this slope of the strata is preserved in the bottom of the intermediate channel, which is nineteen miles across. The thickness of the intervening strata would thus be about

1700 feet. This volume probably consists of the upper part of the Birds-eye and Black River, with the Trenton, the Utica, and the lower part of the Hudson River formation; what is considered the upper part of the latter, being the first rock met with on the north side of Anticosti.

Loose fragments of black strongly bituminous graptolitic shales, in every way resembling those of the Utica formation, and of some of the interstratified beds of the Hudson River, are met with on the beach on the north side of Anticosti. These are probably washed up in storms, or pushed up by the ice, from the intermediate channel, and seem to offer some evidence that the Utica formation, and the Hudson River, in its lower portion, have continued to preserve the aspect which they present near Quebec. The portion of the Hudson River formation which is seen on the island, has however a character differing in some degree from that which it possesses elsewhere in Canada; the strata being much more calcareous, and containing several new organic forms.

The following ascending section, obtained at the western end of the island of Anticosti may be taken as representing the measures :— Ascending section.

	Ft.	in.
Grey limestone beds of two and three inches thick, interstratified with greenish shale. The limestone beds are in places filled with fossils in patches of from two to three feet in diameter, while no fossils are observed in the same bed for considerable intervals. The limestone is hard and compact, and the fossils are in consequence with difficulty got out; among them are *Stenopora fibrosa*, *Leptæna sericea*, *Strophomena nitens*, *S. fluctuosa*, *S. planumbona*, *Orthis subquadrata*, *Rhynchonella recurvirostra*, *R. Anticostensis*, *Athyris Headi*, *Murchisonia multivolvis*, *M. rugosa*, *Orthoceras xiphias*, and *Asaphus platycephalus*,	44	0
Grey limestones and shales of a similar character, with the addition of interstratified layers of conglomerate limestone of two or three inches thick, in which the pebbles consist of grey limestone and greenish shale, and measure more in the plane of the beds than transversely to them; the diameter of the largest is about three inches. The pebbles lie in a grey argillaceous matrix, ...	25	6
Grey limestones, shales, and conglomerates as before. This part is very fossiliferous, and among the remains are *Stenopora fibrosa*, *Leptæna sericea*, *Strophomena nitens*, *S. fluctuosa*, *S. planumbona*, *Orthis subquadrata*, *Rhynchonella recurvirostra*, *R. Anticostensis*, *Athyris Headi*, *Obolus Canadensis?* *Ambonychia radiata*, *Cyrtodonta sigmoidea*, *C. obtusa*, *Murchisonia gracilis*, *M. varians*, *M. multivolvis*, *M. rugosa*, *M. modesta*, *Pleurotomaria Americana*, *Orthoceras formosum*, *O. balteatum*, *O. xiphias*, *O. Anticostense*, *Ascoceras Canadense*, *Asaphus platycephalus*,	10	0
Grey argillaceous limestone interstratified with greenish argillaceous shale; in these beds fossils are not so numerous, but they contain, among other species, *Stenopora fibrosa*, *Favosites Gothlandica*, *Strophomena planumbona*, *Obolus Canadensis*, *Murchisonia modesta*, *M. gracilis*, *M. varians*, *Pleurotomaria Americana*, *Orthoceras xiphias*, *Asaphus platycephalus*, *Cheirurus pleurexanthemus*, with undescribed species of *Encrinurus* and *Dalmanites*, ...	63	0

	Ft. in.	
Grey argillaceous limestone and greenish argillaceous shale, similar to the last; interstratified with beds of pure limestone and of limestone conglomerate. In different parts of the measures up to this point, besides the fossils already mentioned, there occur *Halysites catenulatus*, *Ambonychia ungulata*, *Cyrtodonta obtusa*, *Asaphus obtusus*, *Cheirurus Icarus*, *Illænus grandis*, *I. orbicaudatus*, and the following undescribed species, 1 of *Ptylodictya*, 1 *Heliopora*, 4 *Cyrtodonta*, 1 *Modiolopsis*, 1 *Orthonota*, 1 *Avicula*, 1 *Pleurotomaria*, 1 *Bellerophon*, 1 *Cyrtolites*, 1 *Metoptoma*, 2 *Orthoceras*, ...	86 0	
Bluish-grey hard brittle argillo-calcareous bed, smooth on the surface, with remarkable impressions like the track of an animal, consisting of two parallel rows of semicircular pits, each pit about half an inch broad ; the one row separated from the other about half an inch, and so arranged that the curves of the pits are on the outside, while the centre of each pit is opposite the interrupted circumference of two pits on the other side. The bottoms of the pits on opposite sides slope away from one another, leaving a species of ridge between them. These double rows of alternate pits are usually from about ten to about eighteen inches long, and are more deeply impressed at one extremity than at the other ; the impressions are so numerous on some parts of the surface that scarcely a square yard is without them, ...	0 6	
		229 0
Bluish-grey somewhat argillaceous limestone, in hard and compact beds of from three to six inches thick, interstratified with partings of green shale. Towards the top there are bands of light reddish-grey limestone, rather purer than those below. Some of the bands contain fragments of trilobites, and other fossils, of which it is difficult to procure good specimens from the hardness of the rock ; the surfaces of some of the beds show fucoids, ...	50 0	
Grey limestone beds of from three to six inches, with shale partings between, much like the preceding in character ; the top bed contains numerous beautiful specimens of corals of a pure yellowish-white color, standing out in relief on the surface. The corals are *Favosites Gothlandica*, and an undetermined species of *Stromatopora*, ...	5 0	
Reddish-grey limestone in thin beds, holding on the top the characteristic species *Cyrtodonta sigmoidea*, ...	20 0	
Reddish-grey limestone beds, with thin greenish shale partings ; interstratified, at intervals of from three to ten feet, with beds of from three to six inches, consisting of a conglomerate, the pebbles of which are composed of grey limestone, and are of various sizes, up to three inches in diameter, lying flat in a matrix of grey limestone. Many fragments of trilobites are met with in the deposit, with other fossils, among which are *Cyrtodonta sigmoidea* and the same undescribed *Metoptoma* as before, ...	25 0	
Reddish-grey limestones, conglomerates, and shale partings as before, ...	88 0	
Reddish-grey limestones in beds of from six to ten inches, interstratified with conglomerates as before. The fossils which these beds contain are *Stenopora fibrosa*, *S. mammillata*, *Favosites Gothlandica*, *Halysites catenulata*, *Leptæna sericea*, *Strophomena Ceres*, *Orthis subquadrata*, *Rhynchonella recurvirostra*, *R. capax*, *Lingula quadrata*, *Obolus Canadensis?* *Pleurotomaria Helena*, *Murchisonia rugosa*, *Subulites Richardsoni*, *Orthoceras balteatum*, *Asaphus platycephalus*, and an undescribed *Harpes*. Towards the top *Beatricea undulata* occurs in abundance, ..	102 0	

	Ft. in.	
Grey limestones, conglomerates, and shale partings, with similar fossils. A bed at the top contains an undescribed species of *Dendrocrinus*,...	82 0	
Grey limestones, conglomerates, and shale partings, with fossils as before,.	33 0	
Grey limestones, conglomerates, and shale partings as before; in addition to *Beatricea undulata* and other fossils similar to those already mentioned, a considerable number of orthoceratites are present,.........	64 0	
Grey limestones, conglomerates, and shale partings; in addition to fossils previously named, there is a greater abundance of spiral univalves, chiefly *Murchisonia gracilis*? than in any of the beds lower down, ...	165 0	
Measures concealed; supposed from fragments observed on the beach to be a greenish-grey argillo-arenaceous shale, or, from the character of beds occupying an equivalent place in another part, a greenish-grey fine grained slightly calcareous sandstone, ...	96 0	
		730 0
		959 0

These beds occupy nearly the whole length of Anticosti on the north side, extending from the west-end light-house to Fox Point, within about fourteen miles of the eastern extremity of the island, the distance being 130 miles. They dip inland, with a slope of about ninety feet in a mile, and present to the sea an escarpment divided into a set of transverse ridge-like elevations of from 200 to 500 feet above high-water mark, separated by depressions, which gradually rise to the general surface of the country behind. From English Head, three miles east from the west end, to West Cliff, a distance of fifty-three miles in a straight line, each successive ridge, from valley to valley, occupies a base of from four to six miles. The ridges present somewhat rounded ends, facing the sea. Their rise is first well marked at from a quarter of a mile to a mile from the shore; and about a mile farther inland they attain their greatest elevation. Among these, Macasty Mountain, eleven miles east from the west end, rises upwards of 400 feet at about a mile inland. High Cliff, eighteen miles farther, attains probably 500 feet, at a quarter of a mile from the shore. These are the most conspicuous ridges. High Cliff is a bold headland, while Macasty Mountain is separated by a broader valley than usual from its neighbor to the east, and is higher than any other to the west.

West Cliff rises immediately over the sea to an elevation of between 200 and 400 feet. Charleston Point has an elevation of 100 feet over the sea, and a quarter of a mile inland rises to between 300 and 400 feet. Observation Cliff, which is twenty miles beyond, rises rapidly to 350 feet; and from this cliff to Fox Point, a distance of about fifty miles, the cliffs become more prominent on the coast, rising almost perpendicularly at the points, to heights of from 100 to 300 feet, while the indentations are more numerous, producing more sharply defined valleys. The breadth which the formation occupies, for about two thirds of the whole distance from the west end, is between four and five miles, but it gradually diminishes towards the east end. The summit of the formation to the westward is at Junction Cliff, which is on the south side of the island, about four miles from the extremity.

The peculiarly marked track-bed, 229 feet from the base of the section, enters upon the land near the west end, at Otter or Indian Cove, and finally comes out again upon the coast at Observation Cliff, the distance being eighty-two miles, establishing a general strike of S. 81° E. Near West Cliff, two trap dykes occur on the beach. One of them, about half a mile west of the cliff, with a breadth of about twenty yards, is visible for 120 yards in a bearing N. 62° W.; the other, close by the base of the cliff, with a breadth of fifty yards, is seen for about twenty yards in the bearing N. 47° W. Both dykes are composed of fine-grained greenstone, with white feldspar and black hornblende, and neither appear to produce any disturbance of the strata.

West Cliff; Trap dykes.

Proceeding eastward along the escarpment, from English Head, the fossils which characterize the strata do not vary much from those given in the section. In addition to most of these, there are met with at Charleston Point, *Caryocrinus tuberculatus*, *Dendrocrinus latibrachiatus*, *Pleurocystites Anticostensis*, *Palasterina rugosa*, *Ptilodictya lanceolata*, *Strophomena Ceres*, *Murchisonia turritiformis*, *M. ramosa*, *Pleurotomaria Progne*, *Orthoceras Anticostense*, *O. magnisulcatum*, *Nautilus Hercules*, and *Proetus Alaricus*. No specimens of *Beatricea undulata*, which occurs 188 feet over the track-bed at the west end, are met with until reaching Cape Henry, where their vertical height above the track-bed is twice as great as in the section. The position at the base of the escarpment equivalent to that bed in the section which holds *Beatricea*, would be about the third of a mile eastward of Bear Head; but as the coast line here takes a turn more transverse to the strike than elsewhere, a bed holding that fossil may have been passed over without observation. East of Salmon River, a cliff of about sixty feet in height presents itself, in which the prostrate forms of this tree-like fossil protrude from the cliff in tiers, each fossil presenting a circular extremity, with an orifice in the centre, giving the cliff the aspect of a battery of guns, which has led to the name of Battery Point.

Battery Point.

On the south side of the St. Lawrence, black graptolitic shales belonging to the Hudson River formation, occur in several places in Gaspé, between Cape Rosier and the Marsouin River. These will be farther alluded to, in describing the rocks which are in contact with them to the south.

Gaspé.

CHAPTER XI.

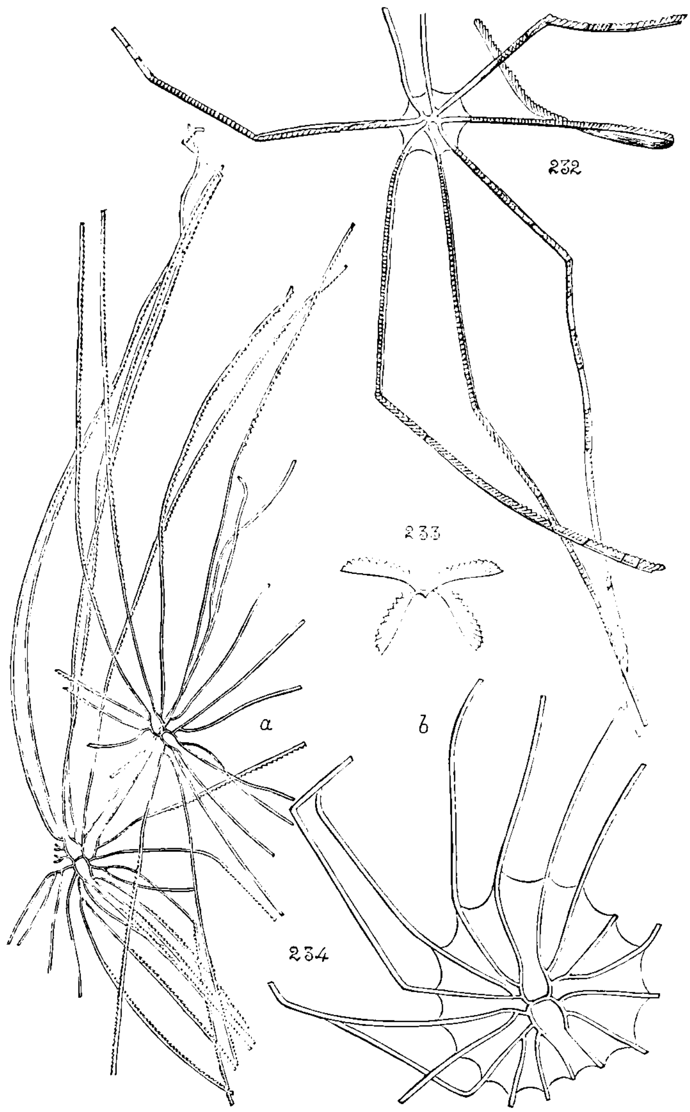
THE QUEBEC GROUP.

LEVIS FORMATION.—SECTION AT ORLEANS ISLAND; MAGNESIAN SHALES AND LIMESTONES; CONGLOMERATES; GLAUCONITE BEDS; GRAPTOLITIC SHALES; SILLERY SANDSTONES AND RED SHALES.—POINT LEVIS; FOSSILS.—AGE OF THE GROUP; DISLOCATION AND OVERLAP.—LOWER BLACK SHALES AND LIMESTONES; THEIR DISTRIBUTION.—FARNHAM; FOSSILS.—RICHMOND.—DISTRIBUTION OF THE QUEBEC GROUP; ANTICLINALS AND SYNCLINALS; ST. FLAVIEN; SOMERSET; DRUMMONDVILLE.—ACTON; COPPER ORES; MILTON; GRANBY.—METAMORPHIC ROCKS; EPIDOTIC, CHLORITIC, SPECULAR AND COPPER-BEARING SCHISTS; SERPENTINE; ANORTHOSITES.—ORFORD AND SUTTON MOUNTAINS.—LAKE MEMPHRAMAGOG; STOKE MOUNTAINS.—CHAUDIERE RIVER; L'ISLET; RIVIERE OUELLE; KAMOURASKA; RIMOUSKI; RIVER CHATTE; SHICKSHOCK MOUNTAINS; MARSOUIN, STE. ANNE, AND MAGDALEN RIVERS; CAPE ROSIER; BAY CHALEUR; CAPE MAQUEREAU; METAMORPHIC ROCKS.—MISSISQUOI BAY; PHILLIPSBURG; HIGHGATE; BELLEISLE; NEWFOUNDLAND.

In the western portions of Canada, the Hudson River formation is succeeded by the Medina sandstone of the New York geologists; and to the south of Three Rivers, on the St. Francis and the Nicolet, red slates, described in the previous chapter, occupy a similar position, and probably correspond to the red slates of the Medina formation. In the immediate vicinity of Quebec however, the graptolitic shales which belong to the Utica and Hudson River formations, are followed by a series of rocks, which are not met with to the west in the same relations. Although from their geographical position apparently superior to the Hudson River formation, these rocks belong in reality to an older group, which is developed to a great extent in eastern Canada, and presents somewhat different characters in the various parts of its distribution. The rocks of this series are still under examination, and the descriptions now given may hereafter require to be somewhat modified. As these strata have been more particularly studied in the neighborhood of Quebec, they have been designated by the name of the Quebec group, which is divided into the Lévis and Sillery formations.

At the upper end of the island of Orleans, on the north-west side, between high and low water marks, there are exposed about 500 feet of black graptolitic shales, such as belong to the Utica and Hudson River formations, dipping S. E. $< 50°$; resting upon which, is a series of different strata, dipping in the same direction, and at the same angle with them; the contact between the two being visible. After a short distance across the *Orleans Island.*

232-234.—BRYOZOA.

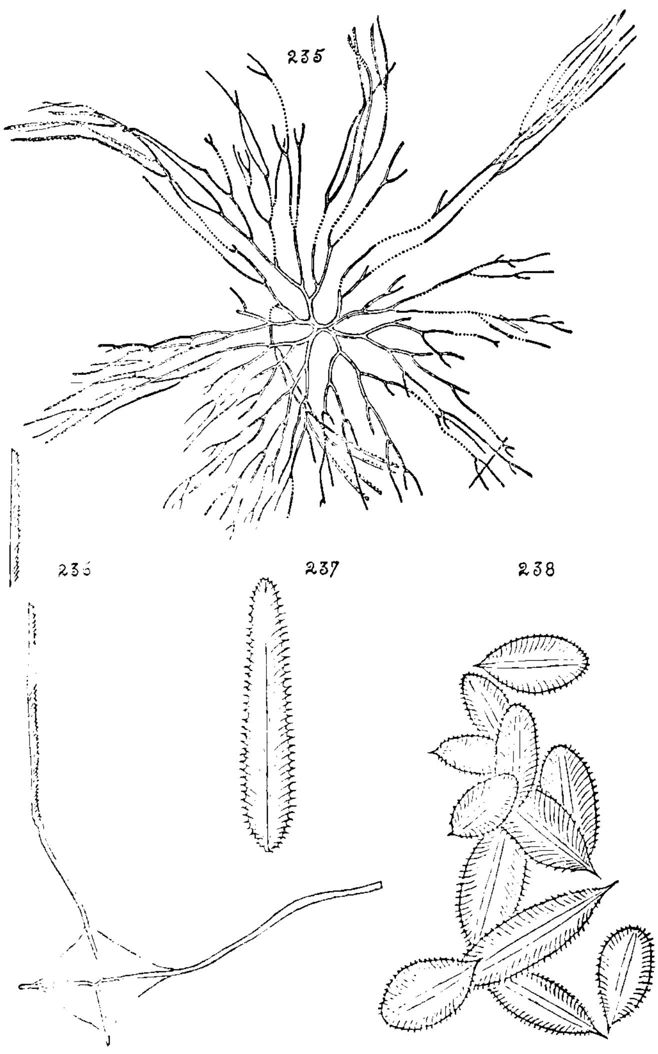


232.—*Graptolithus octobrachiatus* (Hall) ; scale one half.
233.—*G.* ——— *bryonoides* (Hall) ; natural size.
234.—*G.* ——— *Logani* (Hall) ; *a*, scale one half ; *b*, natural size.

measures, undulations occur. The effect of these on the distribution of the beds has been partially ascertained, round the upper end, to the south-east front of the island, and for several miles along it. The following is the sequence of the strata: the beds are, however, in some places so corrugated and broken that the measurements here given can only be taken as rude approximations to the truth:—

	Feet.	
1. Green calcareo-magnesian shale, weathering to a yellowish or reddish-brown, interstratified with thin bands of purplish-grey argillaceous shale. Some of the magnesian shales are nearly grass-green, and the surfaces of most of the green beds are marked with fucoid-like forms of purplish-grey; the green shales hold about twenty per cent. of dolomite. The mass is strong, and offers considerable resistance to wearing influences,....................	100	Lévis formation. Magnesian shales.
2. Grey argillaceous shale, much softer than the magnesian shale,...	100	
3. Grey limestone conglomerate; the rounded masses are chiefly of grey limestone; the matrix in many parts weathers to a brownish color, and is probably dolomitic. Fossils occur, some of them replaced by silica, but those as yet obtained in this locality are too obscure to be determined; the band in some parts appears to break into lenticular patches,..............................	10	Dolomitic conglomerates.
4. Green yellow-weathering calcareo-magnesian shale, with grey argillaceous bands of the same character as 1,................	100	
5. Grey soft argillaceous shale,...............	200	
6. Yellowish-grey dolomite, weathering orange-brown. It holds occasional masses of ash-grey limestone, and in some parts of its thickness a multitude of pebbles of quartz as large as peas, and becomes towards the top a dolomitic sandstone,............	70	
7. Grey fine soft argillaceous shale, with compound graptolites (*Phyllograptus typus*) about thirty feet from the summit,............	170	Graptolitic shales.
8. Grey limestone conglomerate; the matrix in some parts weathers to a reddish-brown, being dolomitic, and contains large concretions of carbonate of lime in concentric fibrous layers like travertine. The band holds fossils in some places,.................	35	
9. Grey fine soft shale, with occasional bands of sandstone weathering brownish, none of them over six inches; the bands of sandstone increase in number towards the top,.........................	500	
10. Olive-green argillaceous shale, striped with purplish-grey bands,..	700	
11. Olive-green arenaceous shale, with disseminated soft grains of a green mineral, resembling glauconite, and approaching it in composition. In the upper part of the deposit, the shale contains so much grit as to become almost a sandstone; and within about 100 feet of the top, it assumes a red color, in one or two bands,	400	Glauconite beds.
12. Yellowish-white limestone conglomerate; the matrix assumes a dolomitic aspect in some parts; the rounded masses or boulders are occasionally one or two feet in diameter, and some parts of the bed hold fossils,......................................	10	
13. Grey, drab-weathering sandstones, in general slightly calcareous, interstratified with grey argillaceous shales; some of the sandstone beds towards the bottom are three or four feet thick, and hold occasional calcareous pebbles. The sandstones become thinner ascending, and then the shales prevail; but these become by		Grey sandstones.

235-238.—BRYOZOA.



235.—*Graptolithus flexilis* (Hall); scale one half.
236.—*G.* ——— *Headi* (Hall); scale one half.
237.—*Phyllograptus angustifolius* (Hall); natural size.
238.—*P.* ——— *typus* (Hall); a group of twelve, natural size.

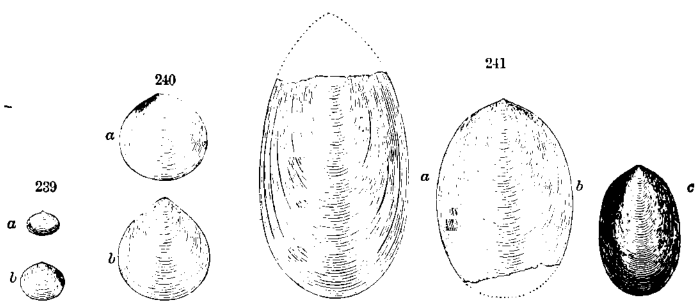
	Feet.
degrees, more and more arenaceous, and a band or two, about 200 feet from the top, assumes a red color,........................	400
14. Grey limestone conglomerate ; the matrix, weathering to a brown in some parts, is probably dolomitic,..........................	30
15. Grey drab-weathering sandstones and shales, the sandstones slightly calcareous,...	300
16. Dark grey and green shales, with thin bands of grey quartzite, and occasional thicker beds of drab-weathering sandstone, some of them being lenticular masses; the dark shales appear in some parts to pass into black,.................................... (Dark shales and quartzites.)	900
17. Red and green shales, the red prevailing, interstratified with occasional thin layers of grey hard sandstone or quartzite, and a few of grey hard limestone ; some of the bands of shale are of a deeper red than the general mass, approaching a maroon color. Towards the top of the equivalents of these shales, at Cape Rouge, there occur a small *Lingula* and *Obolella pretiosa ;* the thickness of the deposit is from 1500 feet to .... (Red and green shales.)	1000
	5025

The strata from 1 to 17 are in ascending order, provided they are not inverted, of which we have no evidence, unless it be the occurrence of an *Obolella* in the red shales. Several species of this genus occur in the Potsdam group, and one in what is considered the equivalent of the Calciferous portion of the Quebec group, at Troy in New York. The genus being only recently established, it is not yet certain of what value it may be in determining the horizon. For the purposes of generalization, in describing the Quebec group, the series will be considered an ascending one; not so much, however, with the view of asserting the order of the strata, as to render more intelligible the facts connected with their geographical distribution.

These strata occupy the whole of the island of Orleans; the magnesian shales at the base running along the north-western side, flanked, to the N. W., by the apparently underlying black bituminous beds of the Hudson River or the Utica formation, as far as the neighborhood of Ste. Famille. These black beds sometimes appear in the cliff which runs on that side of the island, but their usual position is on the beach beneath. Below Ste. Famille, the black shales are no longer seen on the beach, or in the cliff, which is occupied by the magnesian shales, and occasionally by the lowest band of limestone conglomerates, to within a couple of miles of the lower extremity of the island; while at the extremity, and for a mile above, the grey sandstones, 13, appear. The red and green shales at the summit of the series, make their appearance on the south side of the island, about two miles and a half from the upper end, and leave it about four miles from the lower end. Some of the sandstones beneath them, are brought to the shore, in the intermediate space, by undulations.

Point Lévis. From the upper end of the island of Orleans, the lower part of the series passes to Point Lévis; but in so doing, the strata are supposed to meet with a transverse upthrow dislocation; which comes upon the margin of the river in the upper part of Indian Cove, and brings the magnesian shales and their accompanying conglomerates, 1 to 4, on the west, against the glauconite shales, 11, on the east. On the west side of the fault, some of these conglomerates are carried about a mile and a half southward of Indian Point; and they can be traced sufficiently to show, that, through the effect of three nearly parallel anticlinal folds, of which the axes run about south-west and north-east, they are brought northward again to Indian Point; whence they are exposed almost continuously, along the south margin of the river, for two and a half miles up. A feature occurring at Point Lévis,

239-241.—BRACHIOPODA.



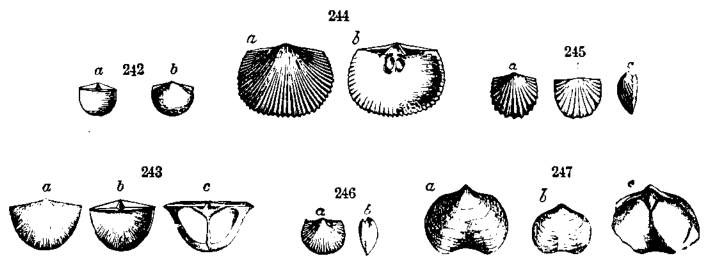
239.—*Obolella pretiosa* (Billings); *a*, ventral, and *c*, dorsal view.
240.—*Lingula Irene* (Billings); *a*, specimen from Point Lévis; *b*, specimen from a boulder of the Calciferous formation, island of Montreal.
241.—*L.*—— *Quebecensis* (Billings); *a*, *b*, *c*, three different specimens.

and not observed on the island of Orleans, is the occasional interstratification of red layers in the masses of shale which separate the lower conglomerate bands.

Quebec. From the south-east side of the St. Lawrence above Point Lévis, some of these strata cross the river, folding, as is supposed, over an anticlinal axis in its bed, and make their appearance on the opposite side, in Quebec. Two of the conglomerate bands are there met with, and, though the strata are much disturbed, one of these bands can be traced from Mountain Street, round the extremity of Cape Diamond, and for nearly a mile on the north side of the cape; shewing that the measures are here arranged in a synclinal form. There occurs here a series of black shales, with bands of limestone and occasional sandstones, the precise place of which in the Orleans section is yet uncertain, though they appear to occupy the position of the grey and green shales, 16, below the red and green shales, 17.

The red and green shales which occupy the south-east side of the island of Orleans, after folding under a supposed synclinal in the river, are seen on the south-east side of the St. Lawrence near the village of Beaumont. Thence, affected by various undulations and dislocations which render their outcrop difficult to trace, they sweep round at a considerable distance inland, and come upon the St. Lawrence again, above Point Lévis, in the neighborhood of the Grand Trunk Railway station. From this point, after folding, in the bed of the river, over the same anticlinal which affects the magnesian conglomerates, they reach the upper part of Wolfe's Cove, and **Beaumont.**

242–247.—BRACHIOPODA.



242.—*Leptæna sordida* (Billings); *a*, dorsal, and *b*, ventral aspect.
243.—*L.*—— *decipiens* (Billings); *a*, ventral, and *b*, dorsal aspect; *c*, interior of dorsal valve.
244.—*Orthis Tritonia* (Billings); *a*, exterior of dorsal valve; *b*, interior of the same.
245.—*O.*—— *orthambonites* (Pander); *a*, ventral valve; *b*, dorsal valve; *c*, side view.
246.—*O.*—— *Electra* (Billings); *a*, ventral valve; *b*, side view.
247.—*Camerella calcifera* (Billings); *a*, ventral valve; *b*, dorsal; *c*, interior of ventral valve, showing the small chamber beneath the beak.

running inland behind Sillery Cove, re-appear at Cape Rouge, where they are seen forming the cliff, for some distance below the cape. **Cape Rouge.**

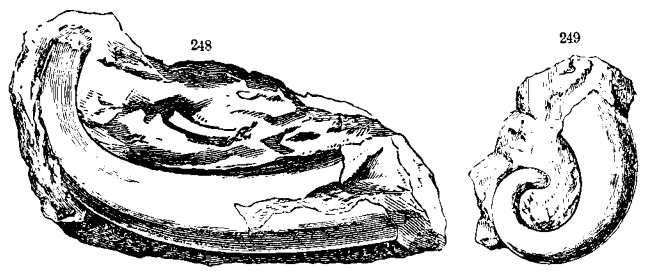
At its summit, this great mass of red and green shales is interstratified with greenish drab-weathering sandstones, the shales prevailing. Higher up, the sandstones exceed the shales, and appear as a well-marked series of fine and coarse grained rocks, frequently assuming the character of fine conglomerates, with white quartz pebbles as large as peas. The sandstones are sometimes slightly micaceous, and occasionally hold small scales of green and black shale, and a few spangles of graphite. They **Sillery sandstones.**

are often slightly calcareous. They usually present massive beds; and at Sillery, many of the layers are quarried for building purposes, for which the stone is used at Quebec. The breadth of the formation at Sillery, including the interstratified masses of red shale, is upwards of half a mile. The average inclination of the strata, which is towards the south-east, is about fifty degrees, and the total thickness may be about 2000 feet.

Thickness of the group.

The whole volume of the Quebec group, including the Sillery rocks, would thus appear to be about 7000 feet. Its attitude, and its geographical position in relation to the Hudson River formation, are such, that, without the aid of fossils, it would be difficult to arrive at any other conclusion in

248, 249.—GASTEROPODA.



248.—*Ecculiomphalus Canadensis* (Billings).
249.—*E.* ———— *intortus* (Billings).

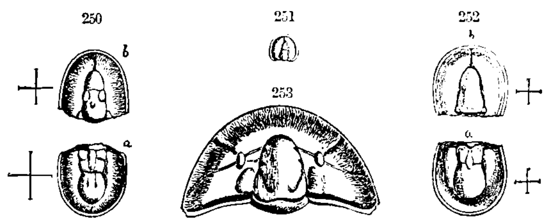
regard to its age than that it is a newer rock. It was in fact so considered until 1860, when the discovery of a considerable number of fossils in the group, at Point Lévis, furnished the means of comparing it with the Hudson River and other Silurian formations. These fossils have been obtained from the limestone conglomerates of the Lévis formation, and from the interstratified slates; but from the corrugated condition of the strata, it is not yet quite certain from how many distinct bands the fossils are derived. The fauna from this locality, as far as yet known, consists of one hundred and thirty-seven species, of which forty-two are graptolites, fifty-five mollusks, thirty-six articulates, and four radiates.

Fossils of Point Lévis.

The graptolites include the genera *Graptolithus*, *Phyllograptus*, *Thamnograptus*, *Dendrograptus*, *Retiolites*, and *Dictyonema*. The other genera are *Orthis*, *Lingula*, *Strophomena*, *Camerella*, *Murchisonia*, *Pleurotomaria*, *Holopea*, *Helicotoma*, *Straparollus*, *Ophileta*, *Maclurea*, *Ecculiomphalus*, *Orthoceras*, *Cyrtoceras*, *Nautilus*, *Asaphus*, *Cheirurus*, *Bathyurus*, *Agnostus*, *Amphion*, *Menocephalus*, *Arionellus*, *Conocephalites*, *Shumardia*, *Holematopus*, *Endymion*, *Ampyx*, and *Dikelocephalus*. The described species are *Orthis Euryone*, *O. Tritonia*, *O. orthambonites*, *O.*

Electra, Lingula Mantelli, L. Irene, Leptæna decipiens, L. sordida, Camerella calcifera, Pleurotomaria calcifera, P. vagrans, P. Postumia, Heliotoma uniangulata, H. perstriata, Holopea dilucula, Maclurea Atlantica, Metoptoma Melissa, M. Orphyne. M. Hyrie, M. Augusta, Straparollus Quebecensis, Ecculiomphalus Canadensis, E. intortus, Orthoceras Autolyeus, Cyrtoceras Metellus, C. Dictys, C. Alethes, Asaphus Illænoides, A. goniurus, Cheirurus Apollo, C. Eryx, Bathyurus Saffordi, B. capax, B. dubius, B. bituberculatus, B. armatus, B. oblongus, B. Cordai, B. quadratus, Agnostus Americanus, A. Orion, A. Canadensis, Amphion Cayleyi, Menocephalus Sedgwicki, M. globosus, Arionellus cylindricus, A. subclavatus, Conocephalites Zenkeri, Dikelocephalus magnificus, D. Belli, D. Oweni, D. megalops, D. cristatus, Shumardia granulosa, Endymion Meeki, and *Holematopus Angelini.* Of these, one species, *Maclurea Atlantica*, belongs to the Chazy, and the fol-

250–253.—CRUSTACEA.



250.—*Agnostus Americanus* (Billings); *a*, the tail; *b*, the head? a little magnified.
251.—*A.*—— *Orion* (Billings); natural size.
252.—*A.*—— *Canadensis* (Billings); *a*, the tail; *b*, the head; magnified. The crosses show the natural dimensions.
253.—*Conocephalites Zenkeri* (Billings); the head.

lowing nine to the Calciferous: *Lingula Mantelli, L. Irene, Camerella calcifera, Heliotoma uniangulata, H. perstriata, Pleurotomaria calcifera, P. Postumia, Holopea dilucula,* and *Ecculiomphalus Canadensis.* Besides these, which are identical with Chazy and Calciferous forms, there are many others closely allied to fossils found in the Calciferous in Canada. The aspect of the trilobites is like those figured by Dr. D. Dale Owen, from the oldest rocks of the Mississippi valley. Descriptions of the graptolites will be found in Decade II. of the Survey.

The Quebec group would thus appear to be a great development of strata about the horizon of the Chazy and Calciferous formations, which are brought to the surface by an overturn anticlinal fold, with a crack and great dislocation running along its summit, by which the group is made to overlap the Hudson River formation. The supposed structure is illustrated

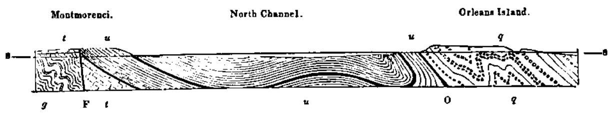
Age of the group.

Structure and section.

in the accompanying transverse section from the falls of Montmorenci to the island of Orleans; in which it will be observed, that, without the aid of fossils, the break on the island would never have been suspected from the attitude of the strata.

A series of such dislocations traverses eastern North America, from Alabama to Canada. They have been described by the Professors Rogers, in

254.—SECTION FROM MONTMORENCI TO ORLEANS ISLAND.



Horizontal and vertical scale, one inch to a mile.

g, Laurentian gneiss.	*q*, Quebec group.
t, Trenton limestone.	F, Fault.
u, Utica and Hudson River formations.	O, Overlap.
	S, Level of the sea.

Great fault.

Pennsylvania and Virginia, and by Mr. Safford, in Tennessee. The dislocation in question comes upon the boundary of the province, in the neighborhood of Lake Champlain. From this, it proceeds in a gently curving line to Quebec, running nearly parallel with the Phillipsburgh and Deschambault anticlinal, and keeping just north of the fortress. It thence skirts the north side of the island of Orleans, leaving a narrow margin on the island for the Hudson River shales. From near the end of the island, it keeps under the waters of the St. Lawrence, to within about eighty miles of the extremity of Gaspé, where it again comes upon the land, and appears to leave a narrow strip of the Hudson River or the Utica formation on the coast.

On the south-east side of this line, the Quebec group seems to be arranged in long narrow synclinal forms, with many overturn dips. These synclinal forms are separated from one another, on the main anticlinals, by

Lower black shales.

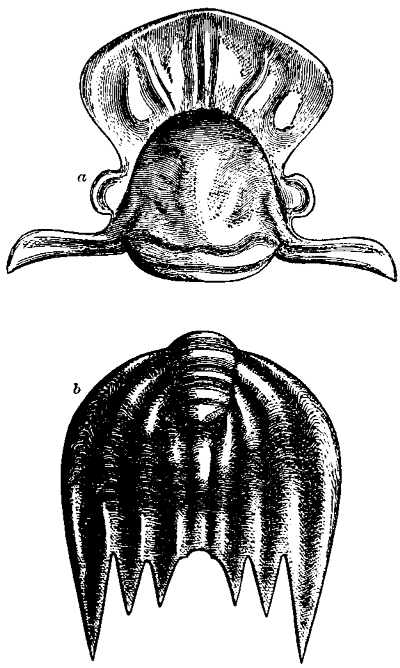
dark grey and black shales, with occasional limestones, which resemble the shales of the Hudson River formation, and, previous to the discoveries at Point Lévis, were supposed to be equivalent to them. As they separate the supposed synclinals of the Quebec group, their stratigraphical place is inferred to be beneath them, and they would thus appear to have some relation

Potsdam formation.

with the Potsdam formation; but it will require farther investigation to determine what that precise relation may be. No great body of rock which can be taken for the Potsdam formation, in its typical form of a sandstone, has been observed immediately above these shales, where they occur in greatest force. In some other localities however, masses of granular quartzite occur, not far removed from the magnesian rocks of the

Quebec group, and it will be necessary to re-examine these quartzites before the absence of the Potsdam formation from above the shales can be asserted. From the occurrence of wind and ripple marks on closely succeeding layers of the Potsdam sandstone, where this rests immediately upon the Laurentian series, we know that this arenaceous portion of the formation must have been deposited in shallow water, along the coast of the ancient Silurian sea. Out in deep water, the deposit may have been a black partially calcareous mud, such as would give rise to the shales and

255.—CRUSTACEA.



255.—*Dikelocephalus magnificus* (Billings) ; *a*, glabella ; *b*, pygidium.

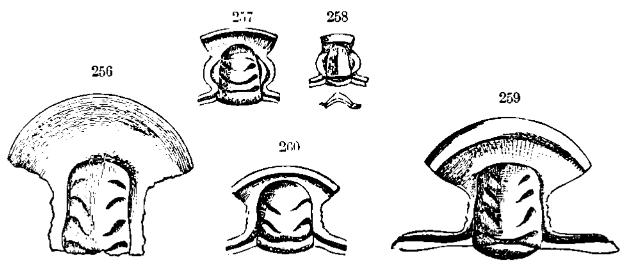
limestones which come from beneath the Quebec group. The worn fragments of black shale, which, as has already been stated, are enclosed in the sandstones of Hemmingford Mountain (p. 88), appear to indicate that such an argillaceous rock must have preceded the arenaceous deposits of the Potsdam, and that it may be a subordinate deep-sea member of the formation.

In different parts of their distribution, the rocks of the Quebec group seem to vary considerably in the character of the sediments composing them. They present moreover, over areas of considerable extent, two very different lithological aspects, being in the one much more crystalline than in the other. The subject of their metamorphism will be treated of hereafter, in a separate chapter. The lower division of the group appears to be supplied, in a greater or less degree, with ores of iron, lead, zinc, copper, nickel, cobalt, chromium and titanium, as well as with silver and gold. Some of these are already known to exist in quantities economically available, and others will probably be hereafter found to be so. This portion of the group abounds also, in its more altered portions, in roofing slates, serpentine, soapstone, potstone, whetstone, magnesite, and dolomite ; the latter

Metamorphism.

Metals of the group.

256-260.—CRUSTACEA.



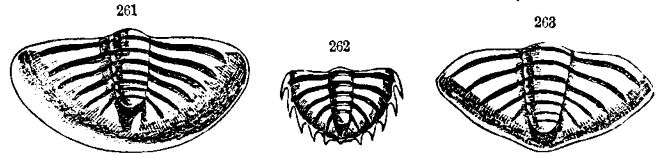
Glabellæ of the following species :

256.—*Dikelocephalus planifrons* (Billings).
257.—*D.* ——— *megalops* (Billings).
258.—*D.* ——— *cristatus* (Billings).
259.—*D.* ——— *Oweni* (Billings).
260.—*D.* ——— *Belli* (Billings).

existing also in the unaltered area. The country over which the group is distributed, is a mineral region of great importance. What is considered the upper part of the group, composed of the Sillery sandstones, does not appear to be in any remarkable degree metalliferous, nor is it yet certain whether the more valuable metals abound in the dark shales which are at the base of the group. This whole series of rocks however occupies a stratigraphical place which brings it to the horizon of the upper copper-bearing series of Lake Superior, in which the Kaministiquia slates may perhaps represent the dark colored shales underlying the Quebec group. As the Kaministiquia strata are not wanting in those metals which give value to the Lake Superior series, it is reasonable to expect that their supposed equivalents at the base of the Quebec group, may also be metalliferous.

With the exception of the ridge between Cape Diamond and the vicinity of Cape Rouge, and of various islands between Cape Diamond and Father Point, the Quebec group and the subjacent dark shales are wholly on the south-east side of the St. Lawrence, where they occupy a breadth varying from seven to forty miles, before becoming covered up by the uncon- Undulations.

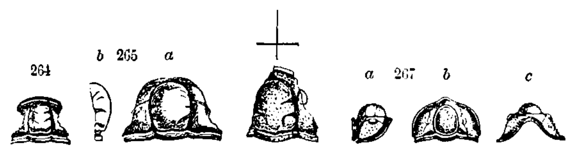
261-263.—CRUSTACEA.



261-263.—Pygidia, supposed to belong to different species of *Dikelocephalus.*

formable Middle Silurian, Upper Silurian, and Devonian deposits. The axes of the undulations of these lower rocks run rudely parallel with those which have been mentioned as affecting the Trenton and Hudson River formations to the north-west, and with the dislocation which brings the Quebec group to the surface; the whole being subordinate to the Appalachian system of mountains. Guided by the bearings of these undulations, the strata come out somewhat obliquely upon the river, having a north-easterly strike, with many minor modifications, as far as Cape Chatte; they then

264-267.—CRUSTACEA.



264.—*Arionellus cylindricus* (Billings); the head.
265.—*A.*——— *subclavatus* (Billings); *a*, glabella; *b*, side view.
266.—*Menocephalus Sedgwicki* (Billings); glabella enlarged.
267.—*M.*———— *globosus* (Billings); *a*, side view of the head; *b*, upper surface; *c*, front view.

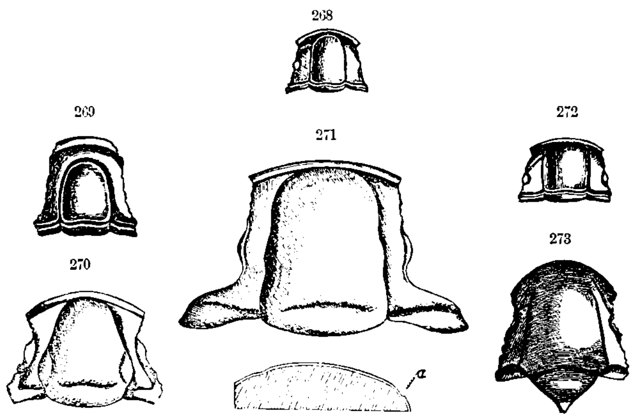
turn eastward, and finally southward of east, before quitting the continent in Gaspé.

The corrugations of these strata are so numerous, and so frequently connected with overturn dips and dislocations, that it is almost impossible to follow them out in detail; and for the present, it is only by the geographical distribution of the larger masses that the position of some of the main anticlinals can be determined, and a notion of the general structure arrived Overturn dips.

at. The overturns appear to be more frequently on the north-west than on the south-east side of the anticlinals, producing a predominating south-eastwardly dip in the strata, and giving to the anticlinals a more precipitous slope on the north-west than on the south-east. In this, they differ from the anticlinals on the north-west side of the main overlap, which, as has already been stated, have the down-throw, or more precipitous dip, on the south-east.

Bayer and Stanbridge anticlinal. What appears to be one of the main anticlinal axes of the Quebec group, entering on the south-east side of the St. Lawrence, at the mouth of the river

268–273.—CRUSTACEA.



Glabellæ of the following species:

268.—*Bathyurus oblongus* (Billings).
269.—*B.*——— *Cordai* (Billings).
270.—*B.*——— *bituberculatus* (Billings).
271.—*B.*——— *capax* (Billings); *a*, longitudinal section.
272.—*B.*——— *quadratus* (Billings).
273.—*B.*——— *armatus* (Billings).

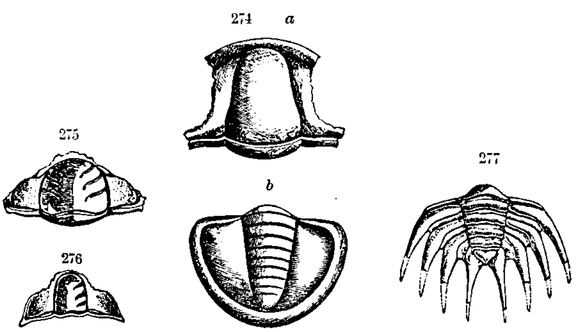
Bayer, passes by St. Henry, between thirteen and fourteen miles from Quebec. Proceeding thence by the north part of Inverness and the south part of Somerset, through Arthabaska, it maintains a south-westwardly course to the south-east part of Stanbridge, and crosses St. Armand into Vermont. Between Inverness and Vermont, this anticlinal brings to the surface the lower black shales; but in consequence of three or four undulations, subordinate to the main geological ridge, the distribution of these shales presents an irregular perimeter, giving place to long parallel stretches of the superior rocks, which occupy some of the intermediate synclinals in Acton, Roxton, and Shefford. The greatest breadth of the shales is on the St.

Francis, where they extend nearly across Simpson and Kingsey, and occupy about fourteen miles; displaying on the banks of the river, in the latter township, a very broken and corrugated condition. To the north-east from this, the shales gradually grow narrower, and appear to come to a point somewhere beyond Inverness, probably in the seigniory of St. Croix, where however they are covered with drift. To the south-west, the continuity of the distribution is very nearly interrupted by the effect of the subordinate undulations which have been mentioned: the narrowest part is near the line between Roxton and Shefford. South-west of this, there is intruded among the shales, a mass of granitoid trachyte, forming Shefford Mountain; beyond which, the ridge of the anticlinal appears to be somewhat removed to the westward, and a large mass of the same trachyte, occupying an area of twenty square miles, and forming the Brome Mountains, bounds the shales to the eastward. Opposite to these

Lower shales.

Intrusive trachytes.

274-277.—CRUSTACEA.



274.—*Bathyurus Saffordi* (Billings); *a*, glabella; *b*, pygidium.
275.—*Cheirurus Apollo* (Billings); glabella.
276.—*C.* ——— *Eryx* (Billings); glabella.
277.—*Amphion Cayleyi* (Billings); pygidium.

trachytic hills, the shales have a breadth of about five miles, which is maintained with considerable uniformity to the province line.

Throughout their distribution on this anticlinal, these lower rocks consist of dark grey and black clay slates, often carbonaceous, with some bands of a lighter color. The slates are interstratified in some parts with thin grey sandstones, and in others with thin black and dark grey limestones, which are occasionally in sufficient quantity to be wrought for lime-burning. A mass of this description is quarried for the purpose on the twenty-sixth lot of the first range of Farnham, near the western limit of the area which has been described. The rock contains very small, almost microscopic trilobites, and fragments of small brachiopods. The genera are *Ptilodictya*, *Graptoli-*

Farnham.

thus, *Orthis*, *Leptæna*, *Ampyx*, *Dalmanites*, *Lichas*, *Triarthrus*, and *Agnostus*. The *Ptilodictya* strongly resembles *P. acuta*, and may be the same; while one *Leptæna* cannot be distinguished from *L. sericea*. These fossils have a less ancient aspect than might be expected in the Potsdam formation; so that the Farnham slates, with similar ones in other localities, may be brought into position by some of the many complicated dislocations which affect the strata. Except, however, where such fossiliferous strata are known to occur, the black slates and limestones will be provisionally described as older than the Quebec group. At Cook's Corner in St. Armand, near their eastern limit, these lower slates are cut by a vein of white quartz, marked with spots of copper pyrites, galena, and blende. The vein runs north-east and south-west, coinciding with the strike, and presents a breadth of between five and six inches.

Fossils.

The anticlinal form which these slates are supposed to possess between the province line and St. Croix, can scarcely be proved from a comparison of the dips. These are in general at high angles, and, though sometimes to the one side and sometimes to the other of the strike, they do not always coincide in direction with the results deducible from the geographical distribution of the strata, several of them being no doubt overturn dips. Such as are considered to be of this character generally point to the south-east, but this is not the case in every instance. The anticlinal form is rather to be inferred from the arrangement of the superior rocks on each side, and from the fact that the black slates and limestones are traceable nearly round the extremity of a trough of those rocks, through a transverse gap on the west branch of the Nicolet, into a long narrow valley; which they occupy for the distance of about fifty miles along an anticlinal, which runs from Danville to Sutton, in a direction nearly parallel with the one already described.

Danville and Sutton anticlinal.

In this valley, the slates, which are often plumbaginous, run under Danville and Richmond, in Shipton and Cleveland, and across Melbourne and Ely, the southern line of which last township they intersect about the middle; proceeding thence across Stukely to the north-east corner of Brome, where they point to Brome Lake, and to the valley of Sutton beyond. The breadth of the slates varies from one to three miles; at Melbourne it is two miles, and in this breadth there would appear to be two folds, which gradually separate from one another. One of these proceeds towards Sutton valley, as already stated, and the other turns up a tributary of the Salmon River, in which it is traceable for between eight and nine miles, to the twelfth lot of the eighth range of Brompton, where it points to the north-east corner of Stukely, and to Potton valley beyond. On the line between Stukely and Ely, these two anticlinal branches are about five miles apart, and there are facts in Ely which indicate that another bifurcation probably occurs in the geographical distribution of the slates, about the third lot of the third and fourth ranges of the township. This would shew an anticlinal intermediate between the other two, the axis of which, in its course southward, would apparently run through the highest part of Sutton Mountain.

North-east of Danville, the slates have been traced about half way across Tingwick; and in their farther course, they would probably run through the north corner of Ham, into Wolfestown. In the continuation of the anticlinal, which there brings them to the surface, they are seen again in a narrow strip, running along the north-west side of Broughton, and crossing the Chaudière in the seigniory of St. Joseph; but they have not yet been observed on the same axis farther on.

Where the strata of the Quebec group come upon the St. Lawrence above Cape Rouge, a considerable portion of the beds seen on the island of Orleans, including the magnesian shales and their conglomerates, is wanting, and it appears to be the second mass of sandstones, 15 of the section, that is in contact with the Hudson River shales. A still farther portion is deficient where the dislocation reaches the opposite side of the river, a little above St. Nicholas church; and here the red and green shales, 17, underlying the Sillery sandstones, constitute the strata which lean against the Hudson River beds. It is not improbable, however, that in other places the lower black slates may occasionally present themselves in a narrow strip between the overlap and the margin of the Quebec group. In such cases, the strong resemblance of these slates to those of the Hudson River, would render it difficult to distinguish the one from the other, and to determine the exact position of the dislocation, unless through the presence of fossils. The difference in age between the two sets of slates having been only recently ascertained, it will require farther investigation to trace out in detail the line that divides them.

St. Nicholas.

In the general synclinal form that lies between the overlap and the Bayer and Stanbridge anticlinal, the Quebec group is either completely or very nearly divided into two areas, by the underlying black slates on or near the St. Francis. The deepest part of the north-eastern area, which may comprehend a superficies of about 800 square miles, appears to be in Lauzon, where it is crossed by the Chaudière; on the banks and in the bed of which, the Sillery sandstones, with their interstratified red shales, display a breadth of nearly ten miles, while longitudinally they extend about the same distance on each side. They present a complicated series of undulations, which give to the perimeter of the space occupied by these sandstones, an irregular longitudinally indented figure, the details of which have not yet been completely made out.

Lauzon and Farnham synclinal.

North-east basin.

Within this north-eastern area, at St. Flavien, about five leagues above the Chaudière, and two leagues from the St. Lawrence, red shales occur, underlaid by a band of amygdaloidal diorite, which appears to occupy the

St. Flavien.

place of the magnesian conglomerates. It is between a quarter and half a mile wide, and limestones occur both at the summit and at the base of the band, which in those parts appears to be of a concretionary or conglomerate and brecciated character, being composed, particularly at the base, of rounded and angular masses of amygdaloidal diorite, varying in diameter from two inches to two feet. Many of these appear to be calcareous, and much of the rock is red. The interstices among the masses are filled with calcspar, which is transversely fibrous towards the walls, and incloses crystallized quartz in the centre. This band is highly cupriferous, and ores of copper occur both in the beds, and in veins or lodes which cut them; the bearing of the veins, however, being with the strike. The ore in the beds is copper pyrites, large masses of which have been met with associated with the limestones at the top. The veins, in addition to copper pyrites, hold the variegated and vitreous sulphurets. In one spot, native copper occurs in small masses in the conglomerate at the base of the diorite, and the whole band has a striking resemblance to some of the rocks of the upper copper-bearing series of Lake Superior.

Diorite with copper.

To the south-west of this, the country is very much covered by drift; but upon the Bécancour and the Nicolet, there are many exposures of red shales and of grey sandstones, which are supposed to be lower than the Sillery division. No great exhibitions of the magnesian slates and conglomerates of the Lévis formation have been observed near to the margin in this part of the north-eastern area. Along its southern border, through Nelson, Somerset, and Stanfold, red slates approach to within a short distance of the lower black slates and limestones; but they are separated by intervening grey calcareous sandstones and green slates, which may possibly represent the magnesian strata. On the fourteenth and fifteenth lots of the eighth range of Somerset, there are interposed about 150 feet of grey coarse grained calcareous sandstone, resting on ten feet of limestone conglomerate, followed by a twelve-feet band of diorite, in which are disseminated small masses of calcspar, giving it an amygdaloidal aspect. The conglomerate is marked by the presence of copper pyrites, running in patches with the stratification. Nearer to the St. Francis, grey calcareous sandstones occur on both margins of the area, with red slates not far above them; but they are not associated with any observed limestone conglomerate. The only beds of Quebec rocks belonging to this north-eastern area, which are exposed on the St. Francis, consist of coarse grained greenish sandstones associated with red shales, which occur at the rapid above Drummondville. The sandstone has more of the character of the Sillery beds than of those lower in the series, and it appears to form a portion of the south-western extremity of the trough to which it belongs. It is underlaid by blackish

Somerset.

shales, and a band of good black limestone, which occurs about half a mile farther up the river, and it is not improbable that the grey calcareous sandstone may be concealed both above and below these exposures on the stream.

These greenish sandstones on the St. Francis are intersected by several dykes of diorite, the courses of which, in the short distance seen, are in a general way down the stream. The rock of the fall at Drummondville, which is about two miles lower on the St. Francis, appears also to be a diorite, and is of a grey or greenish color; it probably belongs to the stratification, and is not known to have any connection with the dykes. It has a breadth of about half a mile, and some parts are porphyritic from the presence of small crystals of light greenish feldspar, while others are amygdaloidal, holding small portions of white and pinkish calcspar, and occasional nodules of agate. Much of it bears the aspect of a breccia, in which fragments of the diorite are held together by a close grained but highly crystalline calcareous cement, approaching in color to the general mass of the rock. This rock bears a resemblance to that of St. Flavien, of which it may be a continuation, and like it is highly cupriferous. On the first lot of the first range of Wendover, it holds vitreous, variegated, and pyritous sulphurets of copper, which run in six or seven thin veins or courses, formed by breaks and slips in the diorite, within a breadth of about 350 yards.

Drummondville.

Diorite

The south-western portion of the above described synclinal of the Quebec group, has a length of about fifty miles, extending from Wickham to Farnham. How near it may approach, on the north-west, to the band of Trenton limestone running from St. Dominique towards Phillipsburgh, is not quite certain. Between St. Pie and Farnham, the distance appears to be not over a mile. The nearest observed strata of the Quebec group, apparently belonging to the Sillery division, are on the Barbue, on the road of the Seraphine range in the seigniory of St. Hyacinthe; and other exposures occur at the base of the Yamaska Mountain. The greatest breadth of the area may be about fifteen or eighteen miles, across Milton and Roxton. It appears to be divided into at least two subordinate synclinals, running parallel with one another, and including many minor undulations. The deepest part of the area seems to be in Roxton, Milton, and Granby, in which the Sillery sandstones are largely displayed, with their accompanying red shales. Along the margin of the area there is exposed, in a great many places, a band of greyish-white and reddish-grey compact sub-crystalline yellowish-weathering dolomite, from 200 to 300 feet thick. It is in massive beds, associated with a good deal of chert, and often incloses mammillated concretionary forms, resembling those of travertine. At the summit, this rock often terminates in a breccia or conglomerate, holding angular and rounded masses of limestone, intermingled with ragged

South-west basin.

Dolomites

irregular masses of chert. In some places, the conglomerate is separated from the main body of the dolomite by dark grey or black shales, intermixed with diorite. In these, the conglomerate lies in large isolated masses, running parallel with the summit of the main body of the dolomite. On the thirty-eighth lot of the seventh range of Acton, the junction of the shale and the dolomite is characterized by numerous well preserved branching fucoids, resembling *Buthotrephis flexuosa* of Emmons. This magnesian limestone is marked in a multitude of places by the occurrence of the vitreous, variegated, and pyritous sulphurets of copper, which are found in irregular masses running with the stratification. In the neighborhood of these, many veins of quartz and calcspar intersect the rock in various directions, and hold small portions of the sulphurets of copper. The copper ores, which are often slightly argentiferous, appear to be most abundant in the upper part of the limestone, and in many places the quantity found has been sufficient to give reasonable expectations of profitable mining. The largest masses of ore which have been met with in this region, are at the Acton mine, on the thirty-second lot of the third range of that township. Here the conglomerate presents a number of isolated masses at irregular distances from one another, separated from the main band of limestone by between eighty and ninety feet of dark grey shale and olive-green yellowish-weathering amygdaloidal diorite. These isolated masses are overlaid by a considerable amount of the same dark grey or black shale. On the opening of the mine, the sulphurets, where most abundant, appeared to occupy a position immediately near some of the isolated masses of conglomerate, and partially to surround them, in certain parts constituting the paste of the conglomerate. A description of this mine will be given in a subsequent chapter.

Acton: copper ores.

The Acton mine is situated on the south-east side of the more north-western of the synclinals. The measures there dip north-west, at an angle of between thirty and forty degrees, and the copper-bearing limestone finally re-appears in Upton, seven miles to the north-west, where it is associated, in some parts, with red shale. Intermediate undulations cause its appearance about half way between the two points; and in the north-eastern part of the synclinal there are many exposures of the rock in Acton, Upton, and Wickham, always more or less accompanied with the sulphurets of copper. Towards the north-west side of this synclinal, in Milton, where the band of magnesian limestone has not yet been observed, indications of these sulphurets occur in red slates, which can be readily traced, on the strike, across Milton and Granby, for a distance of twenty-five miles, and probably represent the slates underlying the Sillery sandstones. On the south-east side of the synclinal, from Milton to Farnham, these red slates, and the underlying magnesian limestones, appear to be absent, as there is no room for them, between what are considered the Sillery strata, and the lower black shales to the east of them, by which they may possibly be overlapped.

Milton.

The most eastern exposure of these sandstones, with the interstratified red slates, is at the village of Granby, and presents an overturn dip of S. 50° E. < 70°. Within a hundred feet of the base of these are included two beds of green unctuous chloritic limestone, holding iron, manganese, nickel, and chromium. In the more south-eastern synclinal of the south-western area, the Quebec rocks appear to extend either uninterruptedly, or in separate patches, from the fourth range of Durham to the neighborhood of Shefford Mountain. The magnesian limestone crops out in several places, and in Durham and Roxton is strongly marked with sulphurets of copper. Granby.

In the synclinal lying between the two anticlinal ranges of black shales and limestones, which have been described, the one running from Inverness to Stanbridge, and the other from Broughton to Sutton, the rocks of the Quebec group present themselves with a somewhat altered aspect. The magnesian limestones, of which several bands, in two groups, occupy a place on each side of the synclinal, are more crystalline than before, and are studded with crystals of magnetic iron and chromic iron, the former in one place so abundant as to render the rock an iron ore, available for economic purposes. Chlorite and greenish-white foliated talc occur in the limestones, and red dodecahedral garnets are occasionally met with. The colors of these magnesian limestones, which are often true dolomites, are light grey and yellowish-white, and they usually weather to some decided tint of yellowish-brown or reddish-brown. They sometimes exhibit an obscurely brecciated or conglomerate aspect, and occasionally present, in the direction of the stratification, short patches of peroxyd of iron, passing into a blood-red jasper. They are almost always marked by a net-work of white quartz veins one or two inches thick, cutting them in various directions, and often by similarly reticulating veins of peroxyd of iron, which is occasionally titaniferous. Shipton and St. Armand synclinal. Altered rocks.

These limestones are separated from one another by quartzo-chloritic strata, made up of grains of quartz and scales of chlorite in various proportions; constituting in some places light greenish chloritic quartzites, occasionally resembling coarse sandstones, and in others dark green chloritic slates. Towards the province line, the quartzites appear more conspicuous on the west side of the synclinal; but towards the St. Francis, they are well displayed on both sides, and in many places, losing all their chlorite, they become nearly pure white. On the east side of the synclinal, towards the province line, the dark green chloritic slates are sometimes interstratified with light grey micaceous slates with a nacreous lustre, and thin beds of dark grey clay slates with a plumbaginous gloss. Associated with these, are other beds of a schistose rock, made up of specular iron mixed with grains of quartz, and often with chlorite, forming varieties of what has been named siderocrist and itabirite by some authors, and by others has been called specular schist. In some of these beds, the oxyd of iron Chloritic slates. Specular schists.

predominates, constituting a rich iron ore; but in others, the earthy minerals are in excess, and the rock passes into the ordinary slates of the country. These iron ores often contain a portion of titanium. Thin leaves of talc and chlorite lie in the divisions between the layers of the specular schists, and their surfaces are sometimes stained with green carbonate of copper: which is also met with in small veins with quartz, orthoclase, and chlorite, running with the stratification. These veins sometimes contain sphene and rutile. In some parts, the nacreous slates abound in chloritoid; and occasionally the sulphurets of copper are so disseminated in them, in grains, and in thin interlocking lenticular patches, as to constitute what appear to be workable beds, traceable for considerable distances with much regularity. Near to the St. Francis, in one or two places, bands of red shale are associated with the magnesian limestones.

Copper ores.

These magnesian limestones, on the opposite sides of the synclinal, are traceable from the province line to the river St. Francis, and beyond it nearly as far as the Nicolet, where they turn towards one another, and probably join. The only difficulty in following them arises from the intrusion of the granitoid trachyte of the Brome Mountains, which disturbs them on the west side, and between which and Brome Lake they have not yet been observed. The interval between these belts is occupied by chloritic, micaceous, and epidotic rocks. Towards the province line, these are of a slaty character, and of various shades of color, from very dark bluish-green or blackish-green, to ash-grey. The green bands are more abundant than the grey, and both have occasionally a talcoid lustre. The grey bands appear to derive their color from a large amount of very fine grains of white quartz, which are uniformly mixed with chlorite. These beds often contain nodules of white granular quartz and crystalline pistachio-green epidote, sometimes several inches in diameter, and frequently elongated in parallel directions. The two minerals are often in separate nodules, but as often intermixed: in the latter case, the epidote is generally within the quartz. In the grey bands, fine blackish-green lines of chlorite often run parallel to one another; but these are contorted by the nodules of quartz and epidote, with which orthoclase feldspar is sometimes associated. Radiated actynolite often occurs in these rocks, together with asbestus in short parallel veins, which are found cutting the epidote in the direction in which the nodules are elongated, and occasionally between the layers of slate. Crystals of specular and magnetic oxyd of iron are abundant in the chloritic and epidotic bands, the magnetic species being more frequent where the chlorite prevails.

Epidotic rocks.

Near to the St. Francis, nodules of an epidotic character are thickly disseminated through the chief part of these chloritic strata; some of the nodules being six, eight, and even ten inches in diameter. Some of the bands hold small patches of finely granular white quartz, which occasionally swell into beds of white quartzite, of some importance, while many of the strata assume the aspect of fine quartzose conglomerates or coarse sandstones with a chloritic base. Except where intersected by transverse valleys, these chloritic and epidotic rocks constitute a ridge in the middle of the synclinal running from the Pinnacle Mountain in St. Armand, to Brooker's Hill in Shipton.

The workable beds of the specular schists in this synclinal, appear, so far as yet known, to be confined to St. Armand, Sutton, and Brome. They may represent the red slates of other parts, which, being very ferruginous, and often containing titanium, may give rise to these slaty iron ores by their alteration. The number of localities in which the ores are met with in these townships is no doubt in a great measure due to repetitions of the same beds through undulations. These iron ores will be described more at length in a subsequent chapter.

Copper-bearing slates.

In the limestone on each side of the synclinal, and in two or three different stratigraphical positions among the chloritic slates which occupy its centre, there occur beds or fahlbands, impregnated with the sulphurets of copper. These beds, at intervals on the strike, appear to contain such quantities of copper ores as may be economically available. Copper-bearing beds are found in Shefford, Stukely, Ely, Melbourne, Cleveland, and Shipton, and trial pits have been sunk on the outcrops of some of them to depths varying from twenty to thirty feet.

Danville and Sutton anticlinal.

The axis of the Danville and Sutton anticlinal would cross the boundary between Canada and Vermont, near to the line dividing St. Armand from Sutton. On the east side of this axis, the magnesian rocks are repeated. Here the dolomites inclose crystals of chromic and magnetic iron ore, foliated talc, and chromiferous mica. They are associated with beds of soapstone, often containing bitter spar, and with others of magnesite and serpentine. Almost all of these rocks contain chromium in some form, generally with traces of nickel. In these magnesian bands, the dolomites prevail; and they are separated from one another, as on the west side of the axis, by chloritic slates, chiefly of a coarse quartzose character, and often thickly studded with crystals of the magnetic and specular oxyds of iron. Workable beds of these ores, however, have not been observed among the strata on this side of the anticlinal.

Sutton Mountain.

This belt of magnesian strata runs nearly parallel to its equivalent on the west side of the anticlinal axis, and passes through Sutton, Brome, and Bolton, along the western base of Sutton Mountain. This mountain stands on an area, which, near the province line, has a breadth of about ten miles; it appears to be composed of coarse chloritic and micaceous slates. In many parts, the slates become very quartzose; and they frequently contain a portion of feldspar, giving to them the characters of gneiss; while in some parts, they lose their schistose structure, and break into large solid blocks.

Potton; serpentine.

On the east side of the area which includes Sutton Mountain, the belt of magnesian rocks is repeated in Potton. It here consists of serpentine, soapstone, and other magnesian minerals. The serpentine, usually in a band of from 150 to 300 feet broad, is of a blackish-green; it has a very uneven exterior, and weathers to a decided reddish-brown, or to a marked opaque-white. Thin veins of a pea-green serpentine, which is softer than the blackish-green, and reticulating veins of asbestus, intersect the rock in various directions. Considerable masses of the rock are sometimes of a light greyish-green, chequered by thin veins or seams of a darker color, cutting and sometimes slightly dislocating one another in rudely parallel directions, which, not being at right angles, divide the masses into irregular rhombic prisms. Picrolite is very frequently met with in irregular seams or veins, some of which are two or three inches in breadth; and as the fibres of the mineral run slightly oblique to the veins, specimens may be obtained two or three feet long in the direction of the fibres. Octahedral crystals of magnetic iron ore are often disseminated in the rock, and the mineral frequently runs in small beds in the direction of the strike. Chromic iron also occurs in the same manner, and workable quantities of it have been found. Iron pyrites is disseminated in small cubes, and the sulphurets of copper are found running in patches with the stratification.

Soapstone.

Soapstone or steatite is often associated with the band of serpentine, and occurs in considerable quantity in some parts on the west side of it. It seems also in some places to be present in the run of the serpentine, where this is not observed, and it occurs in workable beds of several feet thick: its color is light grey, occasionally banded with greyish-green. The soapstone sometimes contains veins of delicate greenish-white amianthus two or three inches thick; and it occasionally passes into an asbestiform talcose slate, which breaks into long fibrous masses in the direction of the dip. In some parts, the place of the serpentine is apparently occupied by dolomite. On the west side of the serpentine band is a rock which appears to be quartzose, strongly chloritic, and slightly calcareous, and beyond this occurs a green translucent compact feldspathic rock, holding magnetic iron ore and veins of asbestus. Both rocks together occupy a breadth of about a hundred yards.

Melbourne and Potton anticlinal.

This belt of magnesian strata runs nearly north and south, on the west side of the Missisquoi River, in Potton. A similar belt runs parallel with it on the east side of the river, the one being a repetition of the other on the opposite side of an anticlinal axis. The distance between them is upwards of a mile; and with the exception of a part concealed, in immediate succession to the western band of serpentine, it appears to be occupied chiefly with beds of a hard grey white-weathering feldspathic rock, and grey clay slates with talcoid surfaces. Some parts of the feldspar rock assume a granular texture, giving them the aspect of coarse-grained sandstones, and solid massive beds are separated by thinner bands of a more schistose structure, holding mica. Interstratified with the grey clay slates are thin black, and apparently carbonaceous bands, with glossy surfaces. It is difficult to say what proportion the feldspar rocks may bear to the clay slates in this section, but it appears probable that the latter predominate. Anorthosite rocks.

Before reaching the eastern band of serpentine, there are interposed about 270 yards of green chloritic and epidotic slaty rocks. A portion of these appears as if made up of large reniform or ovoid masses, pressed on one another irregularly; the epidote occupying the interstices, and giving a marbled aspect to the surface. The colors are various shades of light green, and the rock has in general a waxy lustre, and a jaspery fracture. Thin fragments are imperfectly translucent on the edges, and their texture is something like that of porcelain. In some parts, there occur brecciated or conglomerate beds, enclosing slaty fragments, weathering whiter than the matrix: this, under atmospheric influences, becomes pale greenish-yellow, passing into white. This rock appears, like that just described as occurring with the grey clay slates, to be composed of an anorthic feldspar, and occasionally, by the presence of hornblende, passes into a diorite.

The breadth of the eastern band of serpentine is about the same as the western, but perhaps may occasionally exceed it. It seems in some parts to be interstratified with a band or two of what appears to be an intimate mixture of feldspar and diallage. Crystals of the latter mineral are often imbedded in the serpentine; and in the north-eastern extension of the band, layers of it frequently pass into diallage rock. Beds of soapstone are common, and appear in general to be towards the east side. Magnetic oxyd of iron and chromic iron often occur in imbedded crystals and small seams. Interstratified workable masses of both are occasionally met with; and in one case, a large mass of ore consists of a granular mixture of ilmenite and magnetic oxyd of iron. A limestone, generally magnesian, is frequently met with either in contact with or very near to the serpentine. It is generally grey; and in a large number of cases, it presents such an aspect, both externally and internally, as to leave little doubt that it is of a brecciated or conglomerate character; it is often spotted with bright green stains, generally due to a chromiferous mica or garnet. On the east side of Brompton Lake, associated with the serpentine, is a pale greenish pyroxene rock, in which occur druses lined with large twin crystals of white pyroxene and cinnamon-colored garnets. Large masses of calcareous spar, probably filling a vein, are here met with; sometimes nearly pure, white and cleavable, at others penetrated and filled with small emerald- Diallage; chromic iron; ilmenite. Pyroxene and garnet.

green crystals of a chrome garnet. This mineral also forms granular masses, mixed with a little calcareous spar and pyroxene, and containing disseminated, small quantities of the sulphuret of nickel, millerite.

Feldspathic rocks.

In Potton, a bed of rock, supposed to be a dolomite, with disseminated iron pyrites, bounds the serpentine on the east side; and after about 400 yards (in nearly a fourth part of which distance, grey clay slates with glossy talcoid surfaces are exposed), appears a series of feldspathic strata. Some of these consist almost wholly of a white compact anorthic feldspar, with a scaly fracture and a waxy lustre. In other cases, the rock has an admixture of hornblende, constituting a variety of diorite. This is sometimes fine grained; and the two elements not being readily distinguishable, the rock has a uniform greenish color and a compact texture. It weathers to an opaque white, and in some degree resembles serpentine in its aspect, although much harder. In some beds of this character, small rounded or angular grains of quartz are imbedded; and in others, occasional fragments of indurated jaspery shale. Small veins of asbestus, and occasional patches of serpentine, also occur in these rocks. In some parts, the hornblende is replaced by pyroxene, or passes into diallage; the crystals of hornblende are sometimes dark green in color, and of large size, giving rise to a coarse grained diorite. This, in one locality, is intermixed with a white compact garnet, which in other localities forms distinct beds, associated with the diorite or with the serpentine.

Diorite.

Large masses of these feldspathic rocks, sometimes equalling 400 yards in breadth, and subdivided into layers, which present various modifications of the varieties just mentioned, are separated by bands of dark grey pyritiferous clay slate, sometimes 300 yards wide, and with very smooth talcoid surfaces. Some parts of the slate appear to hold fragments and nodules, differing slightly in color from the general mass, and weathering to a much lighter color, while other parts of it are of a decided red. These alternating rocks occupy about a mile beyond the last mentioned serpentine, and the strength of the feldspathic portions causes them to form a range of hills, which accompany the serpentine as far as it has been traced, and constitute some of the highest peaks of the district; Orford or Victoria Mountain being one. Beyond these feldspathic rocks, to the eastward, there are additional bands of dolomite, some of them passing into magnesite. Both of these rocks contain a good deal of carbonate of iron.

Orford Mountain.

The eastern band of serpentine of the Missisquoi valley, in its northern prolongation, is traceable across Potton, Bolton, and a part of Stukely, into Orford, where it presents a complicated distribution, through the effect of undulations. Farther on, it can be followed through Brompton and Melbourne, to the St. Francis, on the south-east side of the eastern branch of the lower black shales and limestones. It has already been stated that where these black shales cross the St. Francis, they have a breadth of about two miles; and it will be observed, that while they are flanked on the one side by the magnesian rocks which run to the east side of the anticlinal in Potton, they are bounded on the other by those which are traceable to the west side of the anticlinal in Sutton: the distance between the two anticlinals increasing from two to about fourteen miles.

Sutton Mountain, standing between these two anticlinals, with a height said to be about 4000 feet, and gradually dying down before reaching the St. Francis, might be expected to present a synclinal structure. In three transverse sections, however, the strata have been observed to maintain dips, generally at high angles, in opposite directions from the axis of the mountain, with much constancy, for upwards of twenty-five miles. This accords with the apparent distribution of the underlying black shales and limestones in the spur intermediate between the projections on the Sutton and Potton anticlinals. Sutton Mountain would thus appear to be composed of strata which overlie the magnesian portion of the Quebec group. It may probably include the whole or a portion of the Sillery sandstones, which, standing in an anticlinal attitude, would seem to have resisted or escaped the denuding forces that have worn out the valleys on the anticlinals of Sutton and Potton. The belts of magnesian rock, which are at the base of the mountain, on its opposite sides, should by this structure be carried to a junction on the central anticlinal axis, after turning on the synclinals which must occupy the two flanks of the mountain; but though these belts have been traced northward for upward of twenty-five miles, their point of union has not yet been observed. None of the rocks of the mountain have been observed to be of a red color; but if any part be the equivalent of the red shales of the Orleans section, the iron which forms the coloring matter of these may be represented in the magnetic and specular oxyds, which, in the form of crystals, abundantly characterize the strata in many parts. It may be remarked also, that if this mountain were composed of strata lower than the Quebec group, the argillaceous rocks, which are the next in succession, instead of diminishing to points in their southward course, should rather be spread over a considerable part of the mountain, or constitute a broad zone of clay slates on each side.

Sutton Mountain.

Its structure.

To the east of the main band of feldspathic rock in Potton, there is met with a farther amount of a similar rock, with dolomite and magnesite, associated with clay slates. On approaching Memphramagog Lake, a different series of rocks is met with, consisting of clay slates, followed by fossiliferous limestones. These strata, which appear to be of the Upper Silurian and Devonian ages, belong to a synclinal area, which terminates in a point at the base of the Owl's Head, a mountain on Memphramagog Lake. The west shore of this lake, from the Owl's Head, inclusive, to the

Memphramagog Lake.

Upper Silurian and Devonian rocks.

province line, is however composed of strata which appear to belong to the Quebec group.

Stoke Mountains. The rocks of this group, here branching off from a range of hills which comes up from Vermont into Canada, take a north-easterly direction, and, crossing Memphramagog Lake, run from the township of Stanstead through Stoke, to Weedon, and constitute the Stoke Mountains, which are bounded on each side by the more recent strata just mentioned. The average breadth occupied by the Quebec group in these hills, seldom exceeds two or three miles, except in Ascott and Stoke. On the St. Francis, in the former township, through the influence of three undulations, the Quebec rocks have a transverse measure of seven miles, extending from the vicinity of Lennoxville to the north-west corner of the township: and in Stoke, they present two parallel ranges, included in a breadth of about five miles.

In this range of hills, the strata consist chiefly of chloritic rocks in harder and softer bands, the softer and more schistose constituting chlorite slates, while the harder may be termed chloritic sandstones. With these are associated micaceous and nacreous slates, often presenting a very quartzose character; and thin layers of agalmatolite of a somewhat fibrous texture, are sometimes met with. Some of the micaceous and nacreous slates are very fine grained, and on the south side of the range afford excellent whetstones and hones. Many of the whetstone beds appear to be micaceous slates, passing into argillite. Some bands of the slates are studded with chloritoid; and in Sherbrooke, they inclose a bed of blood-red jasper, passing into silicious red hematite, and another of a somewhat coarse silicious conglomerate. In the same neighborhood, the nacreous slates are marked by the occurrence of copper pyrites, containing a little gold and silver, in a gangue of white quartz, running with the stratification. The chlorite slates are often marked by iron and copper pyrites: and on Haskell Hill, on the eighth lot of the eighth range of Ascott, a band of the slate, five feet wide, holds such a quantity of the copper ore as to give promise of a profitable mine. A considerable portion of the Owl's Head Mountain appears to be composed of petrosilex, or an intimate mixture of quartz and orthoclase feldspar.

Sherbrooke.

On the St. Francis, the breadth of the rocks of the Quebec group on the south side of the lower black shales and limestones, is between four and five miles. The lowest beds in the neighborhood consist of a grey soft very argillaceous sandstone, yielding whetstones; while some beds not far removed from these, in Shipton, are composed of micaceous rock, somewhat resembling potstone, cracks in which are frequently invested with thin films of carbonate of copper. In Pine Hill, on the south-west side of the St. Francis, the serpentine has a breadth of nearly one third of a mile; and above the serpentine on both sides of the stream, there occurs a band of very beautiful roofing slate, in which quarries have been opened. Between the slate and the serpentine, on the west side of the stream, a thin band of anorthic feldspar rock occurs; and on the east side, white dolomite, penetrated with asbestus, forms reticulating veins in the upper part of the serpentine, some of the veins being five or six inches thick. In the serpentine band, near to the roofing slates, is a layer of serpentine about a foot in breadth, containing masses of chromic iron in nodules.

Richmond and Cleveland. Roofing slates.

The serpentine enters Cleveland on the sixth lot of the fifteenth range; and crossing the lines of the lots at a small angle, it attains the north-west side of Shipton Pinnacle Mountain. This hill, which is a narrow ridge, is composed of a coarse conglomerate, in which the pebbles, many of them of two or three inches in diameter, are of various descriptions, some of them consisting of anorthic feldspar, and others of a mixture of this mineral with crystals of diallage. In the matrix, there is much chlorite and epidote in spots and patches. Pebbles of red jasper are met with, and patches of it run in the rock. There is also a regular band of red jasper on the south-eastward side of the hill, and a band of anorthic feldspar on the north-west, between the conglomerate and the serpentine.

Shipton Mountain.

The conglomerate ridge is continued in a narrow chain of hills north-east from the Pinnacle, and the band of serpentine is about 400 yards to the north-west of the chain. From this, the serpentine gains West Nicolet or Richmond Lake in Tingwick, where it is represented by an almost unmixed diallage rock, and its course, nearly due east, points for the vicinity of Ham Mountain. It is met with about half way to the mountain; and again on the south side of East Nicolet Lake, where it is associated with workable masses of chromic iron. Ham Mountain, which is about three miles south-west of the lake, has here the same relation to the serpentine as Victoria Mountain in Orford; of which it is a repetition in almost every respect, with perhaps a small addition in height.

Ham Mountain.

Ham Mountain is not far removed from the extremity of the Stoke Mountain range, and its position in regard to the range is somewhat analogous to that of the Owl's Head. These two hills, standing at the opposite extremes of a rudely elliptical area, which is nearly surrounded by rocks of the Quebec group, are about sixty-five miles asunder; while the greatest transverse measure of the area, from the Gosford Road, on the line between Dudswell and Westbury, to the Danville anticlinal near Shipton Pinnacle, rather exceeds twenty-five miles. The interior of this area, for a breadth of about fifteen miles, is filled with clay slates and fossiliferous limestones of the same age as those of Lake Memphramagog, which indeed belong to this basin.

From East Nicolet Lake, the serpentine turns northward, and runs along several small lakes, on the line between Wolfestown and Garthby, to the line between Ireland and Coleraine. In these two townships, there

Ireland: serpentine.

is a great display of the rock. It lies on both sides of Black Lake, extending four miles to the south-west in Ireland, constituting Cariboo Hill, and probably two miles to the north-east in Coleraine, with an average breadth of about two miles and a half, thus spreading over an area of about fifteen square miles. On the twenty-first lot of the first and second ranges of Ireland, about a mile from this area, there is another exposure of serpentine, without any observed rock between the two. What relation these may bear to one another geologically, or what may be the course of the larger mass beyond Coleraine, has not yet been ascertained.

Wolfestown.

On the twenty-eighth lot of the fourth range of Ham, there occurs a band of dolomite, running into Wolfestown, and marked by copper ore disseminated in a breadth of thirty feet. The relation of this dolomite to the serpentine is uncertain. In the south corner of Wolfestown, and about six miles from the dolomite, red slates, occurring at intervals on the Gosford Road, appear to occupy a place on the north-west side of the band of serpentine. On the south and south-east sides, the serpentine is accompanied by a broad band of diorite, associated with coarse conglomerates, all the way through Wotton, Ham, and Garthby, composing Ham Mountain in their course. Associated occasionally with chloritic and epidotic rocks, it is traceable still farther across Coleraine, Adstock, Thetford, and Broughton, rising into the White Mountain in Adstock and into Broughton Mountain in the township of that name. On the south-east side of this zone, another band of serpentine makes its appearance to the south of Ham Mountain, where it is partially calcareous. Accompanied occasionally with a band of conglomerate, it can be traced across Garthby and Coleraine, where it approaches to within a mile of Lake St. Francis. Associated with it, in the twenty-first lot of the fourth range of Garthby, there is a considerable mass of mingled yellow sulphurets of copper and iron, subordinate to the stratification. An exposure of serpentine occurs on the twenty-fourth lot of the fourth range of Tring. Its precise relation to the previous masses is uncertain, but its strike would carry it to a junction with other exposures on the Bras and the Guillaume, in the seigniory of Vaudreuil Beauce. On the Guillaume, there is a six-feet band of massive white garnet rock in the middle of the serpentine, and a thicker one in contact with it on the south side; while farther south, there occurs a considerable band of diorite, limited by clay slates which are supposed to be Upper Silurian. Disseminated in the white garnet rock of the Guillaume, small grains of gold have been met with.

Vaudreuil Beauce.

Between the serpentine, where it crosses the Chaudière and attains the Guillaume, and the lower black slates and limestones of the St. Joseph anticlinal, exposures of red slate, and red and green sandstones, are frequent, for a breadth of between four and five miles. They have been traced to the north-eastward, across Cranbourne into Standon, a distance of twenty miles; and south-westward into Tring, about ten miles. In many parts of this area, there are red colored rocks holding much epidote; but accompanying these, are also large masses of epidotic rock with a greenish tinge. On the right bank of the Chaudière, proceeding north-westward across the measures from the serpentine, after a concealed interval of a quarter of a mile, there is a breadth of nearly half a mile of massive green sandstone, often conglomerate, which, dipping to the north-westward, becomes interstratified with red slate, and is terminated by a red sandstone bed of twenty-five feet. This is followed by five feet of highly crystalline red limestone, with patches of red slate, to which succeeds a peculiar rock, which is well seen on the Rivière des Plantes in the seigniory of St. Joseph, near the Chaudière. It has a general grey color without: but when examined, is seen in many parts to consist of flattened spheroidal or reniform masses, sometimes a foot in diameter, standing on edge in the direction of the strike. They are made up of an indurated purplish red argillaceous rock, which is jaspery in its texture, and sometimes spotted with grains of a soft greenish mineral. When sections of these spheroids have been exposed to the weather, they present a concentric arrangement of various shades of color, becoming lighter and greyer toward the exterior; the whole however being included in a band of deeper red. These masses, which often have a nucleus of calcareous spar, show a tendency to divide in concentric layers with the bands of color. Many of the larger spheroids are traversed by a multitude of cracks, such as are seen in septaria; and in weathered sections, these cracks are bordered by a dark colored ridge, raised above the rest of the surface.

St. Joseph.

Concretionary epidotic rock.

The interstices between the spheroids, in some parts of the rock, are filled with a mixture of dark green serpentine, chlorite, pistachio-green epidote, white calcite, and occasionally colorless translucent quartz: the latter four minerals being highly crystalline. The epidote frequently surrounds nodules of calcite. Interstratified between two masses made up of these spheroids, there occurs a reddish schistose rock, which often includes fragments of slate and small brownish jasper pebbles, and weathers with a rough discolored surface. This conglomerate runs in bands with the strike of the rock, which has a breadth of nearly 300 yards; and towards the middle, it includes a portion approaching in its characters to the ordinary red slate of the region. We can scarcely doubt that the peculiar characters of this rock are due to the alteration of layers of concretionary masses like septaria, which were originally included in the red slates. Some parts of this rock resemble the *gabbro rossi* of the Italian geologists; and the concretionary portions recall, by their arrangement, the green feldspathic rock, already described as occurring near the eastern band of serpentine in Bolton, in the Missisquoi valley. The general bearing of this epidotic rock is to the north-east, with the strata. It has been traced up the Rivière des Plantes for a short distance, and about three miles in continuation, on the road to Cranbourne, where it appears to be wholly green, still retaining its reniform structure. Red and green epidotic rocks, without the reniform masses, occur in different parts of the area which includes the red and green sandstones and shales.

Sillery formation.

Many of the beds of these red and green rocks very strongly resemble the strata of the Sillery sandstones, and it is highly probable that this portion of the Quebec group is here represented. The area should therefore have a synclinal form; and in conformity with this, the dips on the opposite sides are towards the centre; while between the red and green sandstones, and the black slates of the St. Joseph anticlinal, masses of serpentine and dolomite make their appearance in the seigniory of St. Joseph. Similar masses, associated with soapstone, occur in the same relation, farther to the west, in Broughton. On the north side of the synclinal, at the base of the red and green strata in St. Joseph, patches of red limestone are associated with the sandstone and slate. Vitreous sulphuret of copper here occurs, disseminated with talc, chlorite, and ferruginous oxyd of manganese in a bed of quartz running with the strike.

Shipton and Leeds synclinal.

On the Chaudière, the distance between the anticlinal of Sutton and St. Joseph, and that of Stanbridge and the river Bayer, is about fifteen miles. The synclinal between these, from the Nicolet River to the north-eastward, is occupied by strata similar to those described in the same synclinal between this river and the province line; except that in the vicinity of the Chaudière, and farther to the north-eastward, there is a more frequent exhibition of red slates. The undulations subordinate to the synclinal are too numerous to permit the distribution of the strata to be followed out in detail. The general course of the magnesian rocks on the south side of the synclinal, is, however, pretty well determined by a band of dolomite, occasionally passing into serpentine, which has been traced from the thirteenth lot on the line between Chester and Halifax, to the Chaudière, near the line between St. Mary and St. Joseph seigniories,—a distance of about forty-five miles. Chloritic and epidotic rocks occur on the north-west side of the band nearly the whole way; while dolomites and limestone conglomerates similar to those of Point Lévis appear in many places along the north-west side of the synclinal, and become very frequent in Inverness, Nelson, Leeds, and the seigniories of St. Giles and St. Mary. Nacreous and chloritic slates, the former often studded with chloritoid, accompany the magnesian belt, and, as well as the dolomites, often contain sulphurets of copper in Chester, Halifax, Inverness, Leeds, and the seigniories beyond; giving promise, in many places, of quantities economically available.

At Harvey Hill, in Leeds, about two miles south of the stratigraphical place of the main band of dolomite, and immediately near a bed of soapstone, nacreous and chloritoid slates occur, on the seventeenth lot of the fifteenth range. In a vertical thickness of about thirty fathoms, they include three beds of from three to thirty inches thick, marked by vitreous, variegated, and pyritous sulphurets of copper. The strata are here intersected by several veins of quartz and bitter spar, running slightly oblique to the strike. Some of these contain available quantities of the same ores; and in the workings of the English and Canadian Copper Mining Company, they have been found to hold ore to a depth of more than thirty fathoms. These veins are continued to the north-eastward, and similar ones are met with in the Ste. Marguerite range of the seigniory of St. Giles, the distance being about six miles, where they are characterized by the same ores of copper. On the fourteenth lot of the same range of Leeds, a vein occurs, cutting a bed of steatite, and containing, in a gangue of coarsely crystalline bitter spar mixed with talc, copper glance, with specular iron and small portions of native gold. Leeds; copper ore.

From St. Sylvester church in St. Giles seigniory, which is four miles north-westward, across the measures, from the band of dolomite that has been mentioned, there occur, in a transverse breadth of about five miles farther, to the forks of the Beaurivage River, four bands of calcareo-magnesian conglomerate. Some of these are probably repetitions of one another; but their outcrop appears to be due to an anticlinal, which divides the general synclinal basin into two subordinate troughs. The most south-eastward of these conglomerate bands appears to maintain a course about a mile to the north-west of the road from St. Sylvester to St. Mary; striking the Chaudière about the same distance below St. Mary church, and proceeding thence to a position on the Etchemin about half a mile below St. Anselm church. St. Giles.

A short distance south-eastward of this band, there occurs an area occupied by red and green rocks which, probably representing the Sillery series, show the deepest part of the synclinal, and in some places present the same chloritic and epidotic characters as those of Cranbourne and St. Joseph farther south. The area over which these strata occur, commences in a point near the Chaudière; it has been traced about twenty miles to the north-eastward, across the seigniories of St. Mary and Jolliet, into St. Gervaise, and it probably extends much farther. In St. Gervaise, it lies between the church of St. Lazare and the north line of Frampton, where it has a breadth of about five miles. In the seigniory of St. Mary, it is characterized, on its south side, by the occurrence of variegated sulphuret of copper in red slate, in close proximity to a bed of ferruginous magnesian limestone. The distance between this area and its equivalent to the south, across the eastern part of Frampton, is about ten miles. In this township, the axis of the St. Joseph anticlinal appears to bear for the highest peak of the mountains in Buckland, about ten miles to the eastward. The strata Frampton.

of these, although they have not yet been examined, are conjectured to belong to the same part of the Quebec group as the peaks in Orford, Ham, and Adstock, and to be composed of feldspathic rocks.

Rivière du Sud. Before reaching the axis of the Bayer River anticlinal, two additional areas of red and green rocks, considered to be equivalent to the Sillery sandstones, are met with in the synclinal of which that axis is the north-westward limit. These lie on the opposite sides of the Rivière du Sud, in the lower part of its course. The southern area extends from the Government road, opposite St. Pierre church in Lepinay, about twelve miles to the south-west, and probably as far to the north-east. It has been examined for a breadth of four miles south-eastwardly, along the road; and it appears probable that to the north-east of St. Lazare, overlying the small anticlinal indicated by the magnesian conglomerates of St. Mary, it may join the St. Gervaise area of Sillery rocks, in their extension into Armagh and Ashburton. The Sillery formation, on the north side of the Rivière du Sud, occupies the chief part of the space between this stream and the St. Lawrence. Its northern limit runs up the valley of the Bayer, and the area extends longitudinally about twenty-three miles, from St. Thomas to the vicinity of St. Charles, in Livaudière.

The sandstones, in these two areas on the opposite sides of the Rivière du Sud, are massive; on the northern side, they are often very coarse grained, and in general of a green color, while the shales which separate the masses are usually red. Very coarse beds are not so frequent on the south side; and there the red color is not confined to the shales, but characterizes the sandstones also, which are as often red as green. Along the valley between the two areas, thick beds of white and grey granular quartzite, coming from beneath the Sillery strata, are extensively exposed, and frequently enclose bands of a limestone conglomerate with an arenaceous matrix, varying in thickness from one to six feet.

L'Islet. Quartzites similar to these, are somewhat extensively developed to the north-eastward. About six or seven miles from the margin of the St. Lawrence, at L'Islet, they rise into a considerable ridge, which occupies a breadth of about two miles and a half in the seigniories of L'Islet and Lessard. The quartzites are flanked on both sides by green sandstones, interstratified with occasional red shales. On the south side, these appear to continue for between six and seven miles across the measures, and occur again near the province line, about fourteen miles farther on. The interval between these positions has not yet been examined. On the north side of the quartzites, the green sandstones incline somewhat to grey; and near the St. Lawrence, they display interstratified bands of conglomerate, with calcareous and silicious pebbles.

The quartzite ridge of L'Islet and Lessard appears to constitute an anticlinal corresponding with that of St. Joseph. Proceeding north-eastward, the ridge gradually approaches the coast; and at Ste. Anne de la Pocatière, about twenty miles below L'Islet, the north side of the quartzites is scarcely more than half a mile removed from the St. Lawrence, where the dip is northward at an angle of about thirty degrees. The quartzites are there interstratified with a band of coarse conglomerate not far from a hundred feet thick. Its included masses are calcareous and silicious, and some of them, composed of light grey limestone, are two and three feet in diameter. Near the mouth of the river Ouelle, there are beds of grey calcareous sandstone, interstratified with a few layers of grey arenaceous limestone from two to six feet in thickness, associated with occasional red shales. These are supposed to be somewhat above the quartzites; and they are interesting from the fact, that in lenticular layers of limestone conglomerate, enclosed in the grey limestones and red shales, black phosphatic nodules, resembling coprolites, are abundantly disseminated in scattered patches. With these, was found a curious hollow cylindrical fossil, an inch and a half long, and one fourth of an inch in diameter. The smaller extremity is thin, but gradually enlarges from the thickening of the substance, and the other extremity becomes externally somewhat triangular, while the cavity remains nearly cylindrical. The specimen very much resembles a fragment of bone, and is composed of phosphate of lime; but having no bony structure, it may be part of a *Serpulites*. As already stated, *Serpulites*, with similar phosphatic nodules, occurs in the lower part of the Chazy formation, which probably would not be far above the horizon of this locality at the river Ouelle. River Ouelle.

The quartzites come upon the coast between Kamouraska and St. Andrew; and in this vicinity there are several hills, which rise parallel with one another, and appear to be composed of granular quartzite. Just below Kamouraska, the exposures are comprised within the breadth of about two miles and a half; but they are narrower at St. Andrew, near which, at a place designated, from the abrupt rocky eminences, by the name of Les Caps, the width is only a mile. Here the sides and summits of three hills appear to be cased over, in succession, by the same granular quartzites; the thickness of which, as displayed in one locality, appears to be about 200 feet. These hills correspond to three folds in the stratification; and a fourth one, less prominently shown, is found a little farther from the coast. The Pilgrim Islands, lying off St. Andrew, are also composed of the same rock; and including them, the breadth of the quartzites would here be about three and a half miles. Kamouraska.

Beds subordinate to the same strata continue to Rivière du Loup, many of them being of a conglomerate character: and between the coast at this point and Temiscouata Lake, a distance of about thirty miles, which is the whole breadth occupied by the Quebec group in this part, no rocks lower than these quartzites make their appearance. At the distances of six and eight miles from the coast, there are indications of repetitions of the Temiscouata.

quartzite, very probably brought to the surface on two anticlinals; but none of the limestone conglomerates which are associated with them on the coast, have here been observed. The highest strata of the series observed on this line, occurs at twelve miles from the coast, across the measures, between the Ruisseau des Roches, a branch of Green Island River, which is tributary to the St. Lawrence, and the Little St. Francis, a tributary to the St. John. The distance between these streams, which is four miles, is occupied by the Sillery sandstones, here constituting a very rugged ridge.

Cacouna Island.

On the immediate margin of the St. Lawrence, about two miles below Rivière du Loup, there is a narrow strip of green sandstones of the Sillery series, extending for about two miles along the shore. Another presents itself a little lower down, including the island of Cacouna, and extending thence to the mouth of Green Island River. It is altogether about twelve miles in length; and although only half a mile wide, it presents several folds subordinate to a synclinal form. Inside of these positions about a mile, the quartzites, with thin grey calcareous sandstones, grey arenaceous limestones, and limestone conglomerates, appear at intervals all the way, with red, green, and black shales both among and above them. Between Green Island River and Metis, a distance of seventy-five miles farther, the coast is occupied by the lower strata only.

Trois Pistoles.

At Trois Pistoles, in a section of 700 feet of strata, 150 feet at the base consist of grey calcareous sandstones and coarse limestone conglomerates, the latter comprising one third of the amount, in nine separate layers of from two to sixteen feet thick. The matrix of the conglomerates is a grey calcareous sandstone; and the rounded masses imbedded in it, in addition to limestone, consist of quartz, and occasionally of amygdaloidal diorite. Of the limestone and the diorite, there are masses weighing from a pound to a ton, while the quartz pebbles seldom exceed an ounce. The remainder of the strata consists chiefly of red and green shale, with greenish-white compact limestone in thin beds, and an occasional band of black shale.

Bic Harbor.

In the vicinity of Bic Harbor, there is a great display of the limestone conglomerates and their associated grey calcareous sandstones; and it is to the resistance which these have offered to the destroying agencies that have worn away the other rocks of the coast, that the formation of Bic Harbor is due. A great deal of beautiful structural detail might be obtained in the neighborhood of Bic; but a very minute investigation of it has not yet been attempted, for want of time. Many of the facts necessary for the complete understanding of the arrangement of the rocks in this district, are still wanting. One point ascertained, however, is the occurrence of a small synclinal area of green sandstones of the Sillery series, which furnishes the means of determining the summit of the subjacent rocks around. Bic Point is about two miles below Bic Harbor, and the sandstones in question are met with, about three quarters of a mile inland from the bight of the bay, below the point. The bearing of the synclinal axis is N. 65° E., and the area of the sandstone is three quarters of a mile in length by 250 yards in width. The sandstones appear to be surrounded by red and green shales, and the limestone conglomerates come into their proper place on the outside of the shales. The relations of the strata are here better shewn than in many other parts, as the sandstones are comparatively flat, and none of the dips are overturned.

In the neighborhood of Metis, in a conglomerate band which may be a continuation of the one at Trois Pistoles, enclosed masses occur, still larger than those already mentioned. The band is altogether about 200 feet in thickness, and consists of various alternations of white granular quartzite and limestone conglomerate, the proportions being about one half of each. Among the boulders, one of dark grey limestone was measured and computed to weigh twelve tons. Another, which had for a considerable time been quarried for lime-burning, was, when measured, eleven feet long by six feet broad, and was supposed still to contain twenty-five tons of limestone. The boulders occur in separate but parallel exposures of the rock, on the opposite sides of an anticlinal, one of them being at the outlet of the Metis River, and the other about half a mile to the south. Both exposures dip to the southward at an angle of between thirty and forty degrees; and the northern dip would thus appear to be an overturn. Metis.

Less than half a mile beyond the southern exposure of conglomerate, there occurs an escarpment of green sandstones of the Sillery series, belonging to a synclinal area which extends in a pretty straight course, for thirty-five miles, from the south side of Little Metis Bay to the Rimouski River in the rear of Rimouski seigniory, where its extremity is upwards of five miles from the coast. Its greatest breadth is about two miles; but on the east side of the Rimouski seigniory it diminishes to a few yards, and farther west increases to about half a mile, while it is probably cut into two parts by the Great Metis River. At the mouth of the Little Metis River, the green sandstones fold over the axis of the anticlinal, which, as has just been mentioned, affects the band of coarse conglomerate a little to the south-westward, and spread over the peninsula of Metis Point. On the south-east side, they fold over another and parallel anticlinal axis, and extend into a synclinal area, which runs along the valley of the Neigette on the north-west side, crossing the Great Metis River about three miles below the mouth of the Neigette. On the south-east side of the valley of the Neigette, there extends still another parallel synclinal area of the sandstones, composing Mont Commis, which has a length of about twelve miles, with a breadth of about two, and is bounded at the north-eastern extremity by the Great Metis River. Rimouski.

On the Rimouski River, the breadth of the Quebec group does not exceed seven miles; but on the Great Metis, it augments to about

Little Metis River. sixteen; while on the Matanne, it is nineteen miles. Between Little Metis Bay and Long Point, a distance of thirty-one miles, terminating seven miles below the Matanne, the coast is occupied by the shales intermediate between the conglomerates and the Sillery sandstones; with the exception of a point about seven miles below Little Metis Bay, and a short interval about a mile below Little White River, where strata of the Sillery series, belonging to areas that lie under the St. Lawrence, just touch upon the coast. Although there appear to be several small folds in the strata, the coast-line and the strike seem nearly to coincide the whole way, and most of the exposures consist of red, green, and black shales, which are not far below the base of the Sillery formation. In one or two places, however, the summit of the limestone conglomerates and calcareous sandstones of the Lévis formation is exposed. Black shales near the Tartigo River, display fragments of encrinites and broken shells, which are too obscure to be determined.

Basins of Sillery formation. Between Long Point and the river Marsouin, there is a distance of about sixty-three miles. In this, the coast-line intersects longitudinally four synclinal areas, occupied by green sandstones of the Sillery series, with occasional interstratified red shales. The first extends nearly twenty miles, from Long Point to the vicinity of Les Crapauds, with an additional mile inland at the eastern extremity, and has a breadth of between one and two miles. The second, with a length of four miles between the Little Michaud and Great Capucin Rivers, is a mere strip, with a breadth scarcely exceeding a quarter of a mile. The third, between Cape Chatte and the mouth of the Chatte River, with a length of four miles on the coast-line, is extended in the interior, across and beyond the Chatte, about two miles more. The fourth, with a length of eight miles on the coast-line, extends in the interior about a mile farther each way, and has a breadth of perhaps three miles, forming a mountain of about 1000 feet in height. The whole of these areas are probably in the run of one synclinal; subordinate to which, in the first and last basins, there is an undulation dividing them each into two troughs. The dips on the south sides of the whole appear in general to be overturned.

Long Point. The sandstones in these four areas are usually green, weathering to a drab, and are in general massive. The beds exposed about a mile below Long Point are from six inches to six feet thick, and very even. The rock composing them is fine grained; and while the main body of it appears to be free from carbonate of lime, there are included portions of various shapes and sizes, from one to several inches in diameter, which are calcareous. The sandstones, at irregular intervals, are interstratified with red and green shales, which include greyish-green layers of from one to six inches thick, weathering whitish-yellow, and probably magnesian. The red shales are spotted and striped with green, and the green with red.

The coast along this mass of Sillery rocks is bold and rugged, and for the most part inaccessible. At Whale Point, it rises into a bold headland, which presents a vertical face of about 150 feet to the St. Lawrence, and immediately inland attains a height of probably 800 feet.

As seen in the lowest area, the sandstones are a mixture of grains of quartz and feldspar, with sometimes a little mica. They are in general moderately fine grained, but occasionally rather coarse, and sometimes approach the character of a fine conglomerate; containing small pebbles of white quartz, a few of calcspar resembling worn crystals, and sometimes a larger number of small flat pebbles of black slate, with a few soft opaque white flakes like kaolin. The rock frequently encloses arenaceous spheres of various sizes, up to six inches in diameter, which are harder and lighter colored than the mass. Under the influence of the weather, it becomes pitted with deep holes of various shapes and sizes, having thin, but well marked divisions between them, arising probably from an unequal distribution of calcareous matter. The stone is rather soft, and appears to wear away rapidly. When the strata are vertical or nearly so, the action of the sea between high and low water marks divides them into pillars, sometimes thirty feet in height and four or five across, which are usually smaller at the base than at the summit, producing occasionally a very picturesque effect in the landscape. Two of these pillars stand Cape
near a small fishing station below Ste. Anne des Monts, called from Tourelle.
them, Cape Tourelle, and the remains of many more are visible in the vicinity. One of a similar description occurs at the lower end of the second area of sandstones, near the mouth of the Capucin River.

The intervals on the coast between these four areas are for the most part occupied by the red, green, and black shales which immediately underlie the Sillery strata, and occasionally, as at the mouth of the Great Capucin River, contain yellow sulphuret of copper. In some parts, the still lower limestone conglomerates are very conspicuously displayed. The Les Crapauds
chief of these exposures are at Les Crapauds and Les Islets, which are both between the first and second areas, and at a prominent point east of the Chatte River, between the third and fourth. The exposure at Les Crapauds displays a thickness of nearly 700 feet; the whole of which, with the exception of twenty feet of black shale at the bottom, consists of light-grey slightly calcareous sandstones, resembling quartzite, and of limestone conglomerates, interstratified with one another in masses varying in thickness from six to one hundred and fifty feet. A mass of conglomerate towards the top presents pebbles and boulders of compact grey limestone, weighing from an ounce to several tons, with smaller masses of black limestone, and occasionally masses of amygdaloidal diorite, weighing from one to thirty pounds. One layer of the grey sandstone, towards the bottom, is 137 feet thick, without any observed subdivisions into beds.

Les Islets. The exposures at Les Islets consist of the same grey calcareous sandstones, composed of translucent colorless quartz grains of the size of pinheads, cemented together by calcareous matter. The beds are from one to two feet thick. The sandstones are interstratified with an equal and perhaps greater amount of beds of conglomerate, from one to three feet thick; consisting of rounded and flattened masses of compact grey and black limestone, in a matrix of calcareous sandstone similar to that of the beds. Cracks in these strata are often filled with a black carbonaceous mineral resembling coal, which is identical with the altered bitumen of the island of Orleans. Among these rocks are interstratified deep brownish-black shales, with obscure graptolites, resembling some of those of Point Lévis. The coast composed of these sandstones and limestone conglomerates, is, in these localities, very rough and broken; but though a somewhat bold cliff rises from the beach, the country inland is moderately smooth.

Chatte River. The rocks at the point east of the Chatte River, though considered to be immediately or proximately equivalent to the preceding masses, are somewhat different in character. They consist of a bed of grey oolitic limestone of about twelve feet thick, followed by a thinner one of limestone conglomerate, and a mass of thin bedded, dark grey, yellow-weathering and probably magnesian limestone, interstratified with thin bands of black bituminous shale, and occasionally with thicker beds, holding large calcareo-arenaceous nodules. These are very conspicuous in a bed of bituminous argillaceous shale at the top, where the nodules resemble septaria, and are occasionally composed of dark olive-grey chert, weathering to a dingy red; in which cracks or veins hold the black carbonaceous mineral mentioned above. These beds are altogether about 240 feet thick; and some of the black shales hold *Phyllograptus*, one of the genera of graptolites found at Point Lévis. They are followed by a series of argillaceous shales, which are green for about fifty feet at the bottom; red, striped and partially spotted with green, for 230 feet in the middle; and green, striped with red for 120 feet, at the top. Upon these shales rests an unequal grey oolitic conglomerate limestone bed, sometimes twenty feet thick; followed by alternating beds of black shale and light and dark grey sandstones, in some of which specks of blende appear. To these succeed green shales striped with black; then very pyritiferous black shales, and alternating with them at the top, thin grey calcareous sandstones and arenaceous limestones, terminated by another band of grey oolitic limestone conglomerate, and one of grey coarse grained calcareous sandstone. The thickness of this part may be 500 feet, and of the whole mass about 1140 feet. Red, green, and black shales and limestone conglomerates occur for several miles up from the coast on the Matanne, the Chatte, and the Ste. Anne, in places which would indicate the continuance of such strata along the south side of the general synclinal holding the four areas of the Sillery series. None of the exposures however show such important masses of conglomerate as those on the coast.

The Shickshock mountains, between the Matanne and Ste. Anne Rivers, have a length of about sixty miles, with a breadth at the south-west end of about five miles; and opposite Ste. Anne des Monts, of about nine miles. The axis of the range is nearly parallel with the coast of the St. Lawrence, from which the north-westward flank is about sixteen miles distant, opposite Long Point, and eleven miles on the Ste. Anne. As already stated, their main peaks rise to heights ranging from 3000 to nearly 4000 feet above the St. Lawrence, and more than 2000 feet above the country on each side. The whole range appears to possess a synclinal structure, with an undulation along the middle, dividing the basin into two subordinate troughs. The rocks of the range are composed in great part of epidosite, which is an intimate mixture of epidote and quartz. Their general color is yellowish-green, passing occasionally to olive-green, with a hardness and texture like that of jasper. They sometimes present the appearance of a close grained green sandstone, in which the beds would be obliterated were it not for fine lines of discoloration. In some parts, the green rock is mottled with red. The existence of fragments of jaspery red slate, which have been found in this vicinity, makes it probable that there are strata of this character. Some of the beds are chloritic as well as epidotic, and portions display a fibrous structure, breaking into hard long splinters; while others have the character of mica schist, and split into plates, whose surfaces are covered by scales of mica. Beds of black highly crystalline hornblende rock, of a slaty structure, and holding red garnets, are occasionally met with; and large fragments composed of white quartz and red feldspar, indicate the existence of such a rock in the vicinity, but whether in beds or veins, is uncertain.

Shickshock mountains.

Epidosites.

Close along the southern base of the Shickshock range, rocks appear which belong to the unconformable Middle Silurian series; but along the northern base, the limestone conglomerates and their associated strata seem to prevail. These are seen on the Matanne River, between its tributaries the Little Matanne and the Trout; and the general strike of the measures would bring them out in front of the mountains, two or three miles from their base. A mile and a half below the Trout River, slaty epidosites occur, similar to those of the mountains, and most probably a continuation of them. Along that part of the Ste. Anne River, whose upward course turns east and runs close along the foot of the mountain range, exposures of limestone conglomerates occur at moderate intervals, for a distance of about thirteen miles. Although none of these have been met with on the Chatte River, where it approaches the range and runs parallel with it, sandstones are met with in the lower part of the mountain flank, which may be equivalent to those so often associated with the conglomerates on the coast.

Stratified serpentines.

At the eastern extremity of the Shickshocks, there is a great display of serpentine, which appears to come in above the limestone conglomerates, with a thin band of black slate between, and to sweep round to the south-eastern shoulder of the range, composing Mount Albert, one of the main peaks. It continues south-westward for a considerable distance, along a tributary of the Great Cascapedia River, there constituting the southern flank of the range; and it finally disappears beneath the Middle Silurian series farther on. The thickness of this great mass of serpentine is estimated to be about 1000 feet. The whole of it presents evidences of stratification, in some parts remarkably clear and distinct, in others more obscure. Much of the lower 600 feet is bottle-green in color, with beds towards the top, of a streaked and mottled reddish and greenish brown, much studded with small crystals of diallage. The upper 400 feet display the bedding very beautifully, by differences of color on the weathered exterior, as well as in freshly exposed surfaces. The weathered surfaces are marked by a set of red and opaque white bands, the white broader than the red; varying from the eighth of an inch to an inch, and becoming often interstratified with layers of a brownish-fawn color, which vary in breadth in the same way. When cut and polished, this serpentine displays dark brown parallel bands, with thin blood-red vein-like lines, running through those which are red on the weathered surface. These red lines are sometimes disposed after the manner of false bedding. Very thin parallel bands of asbestus are found separating the red layers, together with occasional crystals of diallage: both of these, in certain lights, give golden-red reflections. With the red bands, chromic iron ore is associated, which is sometimes diffused in grains along the layers. Occasionally minute faults displace the layers; and where they cross those which contain chromic iron, the fissures connected with the fault are filled with the ore, for some distance on each side. Beds of chromic iron, of two and three inches in thickness, are met with in several parts; and somewhat above the well stratified serpentine, the ore occurs on the surface in considerable quantity, in large loose angular blocks; which are traceable on the strike for some distance, showing that workable masses are probably imbedded in the rock.

Lower black slates.

Between the conglomerates south of the sandstones of the Sillery series, near the St. Lawrence, and those nearer the Shickshock range, there is an interval, seen alike on the Matanne, the Chatte, and the Ste. Anne Rivers, in which the prevailing strata are black and dark grey slates, with bands of dark colored limestone. To the eastward of the Ste. Anne, the breadth occupied by these, increases towards the Marsouin River, the south boundary of them gradually sweeping round parallel with the base of the Shickshock range, until they come up against the northern part of a great mass of trachytic granite, at a distance of fifteen miles from the St. Lawrence. Here they are overlaid by nacreous slates, holding chloritoid; while their northern limit, on reaching the Marsouin, turns down towards the coast, and comes to within a couple of miles of it. These black and dark grey slates and limestones are supposed to be those which underlie the Quebec group, and to be here brought to the surface on an anticlinal between two synclinals, each of which has overturn dips on the south side. The metamorphic strata of the Shickshock range may represent some of the finer grained masses which overlie the limestone conglomerates of the Lévis formation, but it is uncertain whether they include any part of the Sillery division.

On the Marsouin, about a mile and a quarter from the coast, there is a set of grey calcareous sandstones, which, running along the strike to the east, come out upon the St. Lawrence, and run along the coast for several miles. The beds are from two to three feet thick, and some of them are coarse grained, holding little pebbles of black and grey schist, small translucent fragments of blackish quartz, with others of black shale and brownish-weathering magnesian limestone. These sandstones are fossiliferous; but the fossils, which consist of fragments of brachiopods, are too obscure to be easily determined, though some of them resemble *Leptæna sericea* and *Orthis testudinaria*. The sandstones are interstratified with black shales holding graptolites, one of which appears to be *G. pristis*. On a small island at the mouth of the Marsouin, beds of black and green compact jaspery rock are met with, very similar to those previously mentioned as occurring on the St. Lawrence, about a couple of miles above Cape Rouge. They are there associated with the black graptolitic shales of the Hudson River or Utica formation, and the fossils would seem to indicate that these strata at the mouth of the Marsouin belong to one of these formations. Black shales holding abundance of graptolites, and among them *G. pristis*, are exposed on the beach a little way above the Marsouin, while in the cliff near by, red and olive-green shales, accompanied by brownish-black dolomites, are supposed to belong to the Lévis formation. The strata are very much twisted; and it appears probable that we have here a continuation of the fault, and of the contact between the Hudson River formation and the Quebec group. As the Hudson River strata on the eastern side of the Marsouin appear to range farther south than those on the west, it is probable that a dislocation runs up the valley of this tributary, and may have some connection with the intrusion of trachytic granite, against which the lower black shales partially abut, farther to the south.

Marsouin River.

Hudson River formation.

This mass of trachytic granite extends probably eighteen miles to the southward, with a general breadth of about four miles. About midway, a spur appears to project for ten miles to the westward, crossing the Ste. Anne, and coming against the serpentine at the southern base of

Intrusive granite. the Shickshock range. The granite forms a table-topped mountain, which is equal in height to some of the main summits of the Shickshocks; and thus, although its axis is at right angles to the bearing of those mountains, it appears to terminate the range, by falling about 1000 feet on the east side, to the general level of the country beyond. This table-topped mountain gives rise to the northern and middle branches of the Magdalen River, and perhaps also to the south branch, the source of which has not yet been ascertained. It appears probable that this mountain will be found to come against Upper Silurian limestones at its south end; but on the east side, which is nearly straight, it is flanked by the black shales and limestones which are supposed to underlie the Quebec group. These extend at least as far south as the middle branch, with a breadth that does not quite reach the junction of this with the north and south branches, being about three miles.

Magdalen River. From the union of these three branches, to within about ten miles of its mouth, the Magdalen runs altogether upon the conglomerates and other associated rocks of the Quebec group. Of the last ten miles of its course, the upper five miles present no exposures; but in the lower five, there appears a series of strata, consisting of black shales, interstratified with thin bands of black dolomite, which yield an excellent hydraulic cement, and are accompanied by hard grey calcareous sandstones. The sandstones, where a part of them come out upon the coast somewhat below the mouth of the river, present two coarse grained beds about ninety feet apart, and each fifty feet thick, which hold fossils. Among these can be recognized *Stromatopora fibrosa*, *Leptæna sericea*, *Orthis testudinaria*, and fragments of what is probably *O. plicatella*, while *Graptolithus pristis* occurs in the accompanying black shale, leaving little doubt that these strata belong to the Hudson River formation. We have seen that between these, and the rocks of the Quebec group, upon the Magdalen, there is an interval of five miles, in which the strata are concealed. It is not improbable that a portion of this space may be occupied by an eastward continuation of the lower black shales. Through this interval, too, runs a continuation of the great break between the upper and lower parts of the Lower Silurian series.

Sandstones and shales, holding the fossils of the Hudson River formation, already mentioned, occur on the coast ten miles above the mouth of the Magdalen; and as the coast section all the way to the Marsouin presents no great variety in its lithological aspect, it is reasonable to suppose that the rocks are all of one age. The area between the coast and the Magdalen has not yet been sufficiently examined to enable us to determine the precise limits between the lower black shales and the Hudson River formation, on the one hand, and between these same shales and the Quebec group, on the other.

From the Magdalen, almost to the extremity of Cape Rosier, a distance of about fifty-five miles, the rocks of the coast possess the same lithological character as those of the thirty-five miles to the Marsouin. They consist of black bituminous argillaceous graptolitic shales, interstratified with grey calcareous sandstones, and thin dark grey and black yellow-weathering dolomites, with thicker black limestones in some parts. These rocks probably belong to the Hudson River formation. Undulations in the strata appear to be frequent the whole way from the Marsouin; and instances of them are visible along the shore, wherever points or indentations afford transverse sections. At the mouths of a few of the chief valleys, such sections are laid bare in the sides of mountains, which come close upon the water, and rise to heights of 800 and 1000 feet. An instance of this kind is seen on the east side of the river Pierre (called the Claude on Bayfield's chart), where the summit of the hill shows an overturn dip; and the strata in the whole section, as viewed from the opposite side of the cove, appear to be arranged in the form of a very flat Z. There is one of less importance at Pointe Corbeau, on the upper side of Mont Louis Cove; and a third, of a striking character, in the mountain east of the Grand Matte River. Minor undulations may be seen at each of the two points next above Great Pond River; and again at the points above and below Little Fox River, and at that above Great Fox River. It is probable that the last three examples, occupying a distance of six miles, are all on the run of the same flexure, which in some parts exhibits an inversion of the beds. Hudson River rocks.

Many transverse cracks occur in the strata, accompanied by dislocations, usually of small amount. One, however, which is seen near a point a short distance below a brook called the Grande Coupe, four miles and a half below Great Pond River, runs S. 20° W., obliquely across a thick vertical bed of arenaceous limestone, and throws the measures 120 yards northward, on the east side. On account of these undulations and dislocations, it is not easy to arrive with certainty at the thickness of the Hudson River strata along this coast; but from some of the exposures, it appears probable that it may equal about 1500 feet. Dislocations.

Below the Magdalen, the breadth of the formation has been ascertained by transverse sections in two places only; one of them being at the Great Pond River, where it is about two miles, and the other at Griffin Cove, where it is less. Approaching Cape Rosier, the breadth gradually diminishes: and the Hudson River strata finally disappear under the waters of the Gulf, at Anse à la Tierce. The remainder of the distance to Cape Rosier is occupied by the grey calcareous sandstones, red shales, and limestone conglomerates of the Quebec group.

In the Great Pond section also, the rocks which succeed to the Hudson River strata, belong to the Quebec group, and they prevail for a breadth of

Great Pond section.

about eleven miles, before becoming covered up by the Upper Silurian limestones. Two miles in the middle of this section are occupied by sandstones of the Sillery series, with the red shales which usually accompany them. The dips on both sides of the area occupied by these sandstones, are to the southward; the inclination on the north side being fifty-one degrees, and that on the south side, sixty-four degrees. It is probable, however, that the strata are arranged in a synclinal form, and that those on the south side are inverted: the general synclinal probably contains several subordinate undulations of a similar character. The rocks on each side of the sandstone appear to belong to the Lévis formation: some of the masses on the south side resemble the magnesian conglomerate bands of Point Lévis. Towards the end of the section, on the south side, chloritic and nacreous slates appear, and in the last mile rise into a considerable hill, and are associated with a band of blackish-green serpentine, weathering to brownish-red, and supposed to be about 120 feet thick. Like all the serpentines of the Eastern Townships, and of the Shickshock mountains, this rock contains chromium and nickel.

Griffin Cove section.

On the section from Griffin Cove, at the distance of two miles south-westward from the coast, about one eighth of a mile is covered with large angular fragments of greenish sandstone, some of which are fine conglomerates, with quartz pebbles as large as peas. None of this rock has been seen in place; but the abundance and angularity of the fragments leave little doubt that the beds cannot be far removed. The position of the fragments may therefore be assumed as that of the Sillery sandstones, particularly as they occur in what would be a continuation of the axis of the Sillery synclinal on the Great Pond section. Between the position of these sandstones and the Hudson River strata on the coast, there would be room for the rocks of the Lévis formation; but none of them have been there observed. Half a mile from the south-west side of the sandstones, however, loose fragments of black slate and grey slightly calcareous sandstone, resembling those associated with the limestone conglomerates, cover the bed of a brook in great abundance; while half a mile farther southward, at about five miles from Griffin Cove, large masses of conglomerate are traceable for 200 yards each way on the strike. The conglomerate consists of white quartz pebbles, some of them an inch in diameter, with others of grey arenaceous limestone and yellowish-white feldspar, imbedded in a greenish and strongly calcareous sandy base. A quarter of a mile beyond these masses, the Quebec group becomes covered up by strata belonging to the Gaspé limestones, of Upper Silurian age.

Between Cape Rosier and the base of the Gaspé limestones, a sudden turn in the coast gives a natural section, nearly at right angles to the strike, of two miles and a quarter in length. The coast is low and shelving, and the violence of south-eastern storms has heaped upon it a great mass of grey limestone shingle, which covers nearly the whole of it, with the exception of three points. One of these is Cape Rosier itself, where a breadth of 450 yards of the strata, including what are seen between high and low water-marks, is exposed. The strata consist of grey limestones, in beds varying from six inches to a foot in thickness, with two thicker conglomerate beds, made up of grey limestone pebbles in a calcareous matrix, very much resembling the conglomerates of Ste. Anne des Monts; the whole interstratified with black and grey shales. Separated from the strata of the cape by an interval of 1000 yards, covered by limestone shingle, there occur, at the next point exposed, grey yellow-weathering limestones, probably magnesian, interstratified with jet-black and gray shales, with a band of conglomerate or brecciated limestone on the north-east side. The distance across the strata is about 800 yards; but there are intervals of concealment in it, making up 300 yards of the amount, and, though the dip is pretty uniform in direction to the south-west, there are variations in the inclination, which ranges from forty-four to sixty degrees. Another interval of concealment occurs, of about 1000 yards across the measures; but a partial exposure at the end of the distance shews a continuation of the same alternation of shales, limestones, and sandstones. Red, purple, black, and olive-green shales succeed, associated with grey sandstones; some beds fine-grained and close in texture, and others coarse with transparent quartz, silvery mica, white feldspar, and very minute bright green grains, probably of glauconite. A few thin layers of black bituminous limestone are interstratified among the shales. Several corrugations are visible in a low cliff, in which these beds are exposed; but the measurement across the shales is about 350 yards, and the dip, which is south-westward, varies in inclination from twenty-six to ninety degrees. Cape Rosi

Between these beds and the base of the Gaspé limestones, there is a distance of about 800 yards, across the shales; but the strata are only obscurely seen at intervals at the beginning and end of the measurement. The strike appears to be uniform, being N. 62° W.; but only the extreme edges of the beds are anywhere seen, and the dip is sometimes to the one side and sometimes to the other, at inclinations varying from fifty to ninety degrees. The strata consist of black shales and thin limestones, which become somewhat arenaceous towards the south side: and the last beds, seen immediately in contact with the overlying Gaspé limestones, are of jet-black shale, yielding a black powder. This has induced some of the fishermen of the place erroneously to suppose that coal cannot be far removed. The rocks occupying these 800 yards most probably represent the black shales and limestones which underlie the Quebec group.

Between Memphramagog Lake and the Chaudière, portions of the Quebec group appear through the Upper Silurian or Devonian strata in two or three places, which will hereafter be mentioned in describing these newer rocks. The only other place in the eastern part of the province in which any part of this group is at present known, is on the Bay of Chaleurs. Thirteen miles of the coast, extending from the lagoon of Grand Pabos to the south side of Cape Maquereau (with the exception of a small patch belonging to the Carboniferous series, at a point called Jardin à Naveau), are occupied by a great mass of sandstones. Most of these are grey or greyish-green, while some parts towards the Pabos side have a light red or rusty-brown tinge. The sandstone has often a glazed or vitreous aspect, and many of the beds contain white translucent quartz pebbles, of the size of swan and partridge shot. There are no coarse conglomerates. The whole mass is more or less associated with bands of slate, which often split with glossy surfaces, in the direction of the beds. They are occasionally somewhat micaceous, and sometimes of a talcoid or nacreous aspect, and present various shades of grey passing to black.

Cape Maquereau.

Altered rocks.

Approaching Cape Maquereau, the proportion of sandstones augments, and the crystalline condition of the rock gradually increases, until, in the immediate vicinity of the cape, it assumes a highly metamorphic character. Layers of reddish crystalline feldspar, occasionally with white quartz, occur in some beds; while others, of a slaty character, split into glossy talcoid laminæ. A considerable portion of the rock is of a dark green color, with the aspect of an imperfect greenstone or diorite. The breadth of the belt composed of these rocks, is about seven miles, in a straight line across the strike. The stratification is in general well defined in the whole breadth; and the courses of the streams from the interior, show that a uniform strike is maintained for some distance. The direction is, with little variation, a few degrees south of west; but the dip, which ranges from forty-five to ninety degrees, is sometimes to the one side and sometimes to the other. In a large proportion of the distance, however, it seldom varies more than from ten to twenty degrees from the perpendicular. That there are undulations in these strata, is very probable; but if they exist, they are very sharp, and the rock is so uniform in its character, that it would be difficult to determine their position, notwithstanding that there are very few intervals of concealment in the whole distance. The more highly altered strata of the cape are as near as possible vertical; and in that attitude they run along the shore, which is nearly in the strike, from the extremity of the point, towards Anse à la Vieille. Here they are seen to be unconformably overlaid by an Upper Silurian limestone, which in its turn supports an unconformable Carboniferous conglomerate. These sandstones of Cape Maquereau strongly resemble, in many parts, those of the Sillery series, to which they are probably equivalent.

Deschambault anticlinal.

It has been stated in a previous chapter, that what has been called the Deschambault anticlinal, brings to the surface, between St. Dominique and

Farnham, strata of the Trenton, the Birdseye and Black River, and the Chazy formations; the exposures being almost wholly confined to a comparatively narrow strip on the east side of the anticlinal axis. The distance between the two extreme exposures is about twenty-five miles, and the bearing of the axis, in this distance, is about S. 15° W. If continued in the same direction for eighteen miles farther, it would reach Missisquoi Bay on Lake Champlain, and run under the waters of this bay about three quarters of a mile west of Phillipsburgh. From this, a gentle turn a little more southward, would carry it, in four miles farther, to the shore of the same bay, near the Franklin House, at Highgate Springs in Vermont. At this spot, strata similar to those of St. Dominique, are brought to the surface by an anticlinal, which may not improbably be a continuation of that of St. Dominique and Farnham. Trenton and Chazy.

As already mentioned, the band of Trenton limestone running between these two places, is only about a mile from an exposure of the Sillery division of the Quebec group, on the Barbue. The dip of the limestone is to the eastward: and between it and the Sillery rocks, there would be room for portions of Utica and Hudson River strata. Deposits lithologically resembling some of those of the Hudson River, do occur in the interval, but no fossils have been found in them to aid in determining their horizon. The exposures of the Trenton band in this part, reach farther south than those of the Chazy: and approaching Farnham, their breadth gradually diminishes, until they terminate in a point, not far from the Yamaska River. This arrangement would seem to indicate a gentle slope on the crown of the anticlinal: this would probably bring in higher strata farther south, from beneath which the Trenton limestone would rise again in Missisquoi Bay, to join the exposures near Highgate Springs. The natural inference, unless fossils were found to contradict it, would be, that on the axis of the anticlinal, between Farnham and Highgate Springs, we should find the Utica and Hudson River formations.

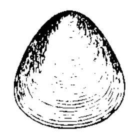
The lowest rock brought to the surface on the anticlinal at Highgate Springs, is a dove-grey limestone, similar to that of St. Dominique. It occurs on what is considered the axis of the anticlinal, near a wharf and an old lime-kiln, on the shore of the bay, less than half a mile northward from the Franklin House. It is associated with bands of brownish-grey, buff-weathering dolomite, from one to three feet thick, and is flanked on both sides by greenish-grey calcareous fine grained sandstones. These on the west side of the axis have a thickness of probably between fifty and a hundred feet, becoming at the top interstratified with greenish shale. No fossils have been found in the dove-grey limestone; but in the upper part of the sandstone there occur one or two undetermined species of trilobites, probably of the genus *Asaphus*. These sandstones are followed, on each side, by blackish thin bedded shaly nodular limestones, partially magnesian. Highgate Springs.

Chazy formation.

They are fossiliferous, but the species do not appear to be numerous. Among the fossils met with on the east side are *Ptilodictya fenestrata*, *Orthis platys*, and *Ampyx Halli*, all Chazy species; the last, already mentioned as occurring in the Chazy limestone at St. Dominique. The thickness of these shaly beds is not certain, but they probably exceed sixty feet.

The shaly nodular beds are followed, on each side, by about thirty feet of massive black limestone. Southward from the lime-kiln, these bands,

278.—BRACHIOPODA (CHAZY?)

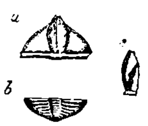


278.—*Lingula Perryi* (Billings); dorsal valve.

Black River formation.

which are about 300 paces apart, run parallel with one another for some distance inland; and then gradually curve round so near one another, as to make it probable that they may join not far beyond the spot where they become concealed. Both bands hold masses of black chert; that on the west contains *Orthoceras recticameratum*, *O. anellum*, and *O. Allumettense;* while that on the east has *Columnaria alveolata*, *Stromatopora rugosa*, *Petraia profunda*, *Helicotoma planulata*, *Murchisonia perangulata*, and *Orthoceras Bigsbyi;* leaving little doubt that these beds

279.—CRUSTACEA (CHAZY).



279.—*Ampyx Halli* (Billings); *a*, head; *b*, pygidium; *c*, side view.

Trenton formation.

represent the Birdseye and Black River formation. These black calcareous bands are succeeded, on each side, by a series consisting chiefly of black thin bedded shaly nodular limestones, interstratified occasionally with thicker beds of the same color. These strata, on the west side, appear to have a thickness of between 300 and 400 feet, and contain, towards the middle, about thirty feet of massive black limestone. They are highly fossiliferous on both sides, and contain, among other species, *Stenopora fibrosa*, *S. petropolitana*, *Ptilodictya acuta*, *Orthis lynx*, *Rhynchonella increbescens*, *Orthoceras strigatum*, *Calymene Blumen-*

bachii, and *Trinucleus concentricus*. On the west side of the axis, these strata are followed by black brittle slates, which occupy a breadth of about seventy yards, and reach to the margin of the bay. They are fossiliferous, but, having a cleavage independent of the bedding, it is difficult to obtain specimens. *Orthis testudinaria*, however, occurs in them in some abundance; and as there is no doubt that the limestones to the east of them belong to the Trenton, these black slates would appear to come into the place of the Utica formation. Utica formation.

On the west side of the anticlinal, the strata have a more precipitous dip than on the east. The inclination on the former side appears to range from about seventy to ninety degrees, and it occasionally shows an inversion of the strata. Plunging under Lake Champlain in this attitude, the Trenton formation is not known to emerge again before approaching the opposite side of the lake in New York. It is probable that the shales which fill a great part of the interval between these two outcrops, may belong to the Utica and Hudson River formations, as these are known to occupy a considerable part of the promontory separating Missisquoi Bay from the Richelieu River. On the east side of the anticlinal, the inclination of the strata does not appear to exceed forty-five degrees; and to the west of the Franklin House, a subordinate undulation repeats the Birdseye and Black River limestone, and carries the Trenton farther east. After a short interval of concealment to the east of the house, the latter formation rises again, near the mineral spring, with an attitude not far removed from vertical. This is very probably a final outcrop, as some magnesian strata, which seem to belong to the Quebec group, appear not much more than a quarter of a mile beyond.

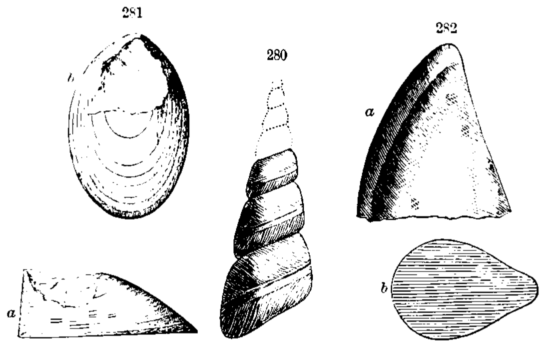
The eastern outcrop of the Birdseye and Black River limestone, connected with the subordinate undulation which has been mentioned to the west of the Franklin House, is traceable northward to the margin of the bay, about a quarter of a mile from the axis of the main anticlinal; where its dip becomes S. 30° E. $<$ 39°. The corresponding north-eastward strike would carry the band towards the mouth of the Rock River; and about a quarter of a mile in this direction, we meet with the subjacent grey calcareous sandstone, inside of a promontory which shows a considerable mass of the dove-grey limestone. Less than a quarter of a mile farther in the same direction would bring us to the probable position of the Quebec group, as inferred from the run of the rocks of this group from the Barbue southward.

In this direction, the most western edge of the group comes upon Missisquoi Bay, at Phillipsburgh, preserving a well marked escarpment for four miles before reaching the bay, and continuing along the shore of the bay in a pretty straight line, for upwards of three miles more, to within about half a mile of Rock River. Instead, however, of the Sillery portion Phillipsburgh.

Lévis formation. of the group, as on the Barbue, the strata here displayed appear to belong to the Lévis formation. On the province line, and a mile north of it, they occupy a breadth of two miles, extending from the shore of Missisquoi Bay to the valley of Rock River; and in Canada, they are traceable from the province line to the village of Bedford on the Yamaska, a distance of eight miles. They have a general dip to the eastward; but it appears not improbable that they are affected by longitudinal dislocations, which may be upthrows on the east side, arranging partial repetitions of the strata in long parallel belts. The strata are also disturbed by transverse faults, throwing them eastward and westward, at right angles to the strike; the whole producing a complicated structure, the details of which will require farther investigation.

On the province line, and on a parallel line about a mile north of it, running east from Phillipsburgh, longitudinal dislocations are suspected to occur

280-282.—GASTEROPODA.



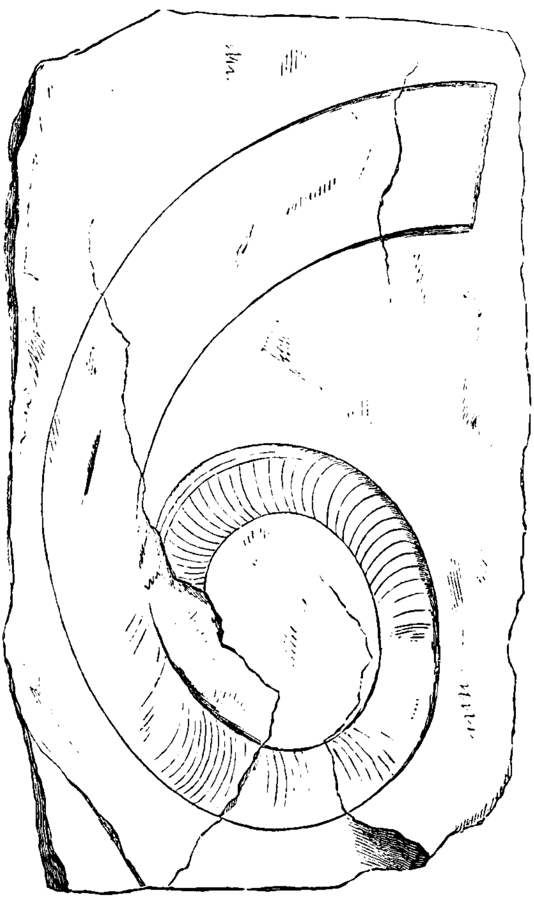
280.—*Murchisonia Vesta* (Billings).
281.—*Metoptoma Niobe* (Billings); *a*, side view; *b*, view of upper side.
282.—*M.* ——— *Orithyia* (Billings); *a*, side view; *b*, outline of the base.

in the west half of the two miles; while in the east half, the measures appear to be arranged in the form of a trough, with a moderate dip on the west side, and a precipitous one on the east, which often becomes perpendicular, and sometimes presents an inversion of the strata. What appear to be the lowest strata, occur on the shore of Missisquoi Bay. They consist of dark grey and yellowish-white dolomites, weathering grey and yellowish-brown, and divided into massive beds. Some of these hold geodes of calc-spar, and others, geodes of quartz, which also occurs in patches and nodular portions; while towards the top, are beds similarly marked with black and grey chert, which sometimes occurs in angular masses. The average general dip of these beds is about E. S. E. $< 12°$, and their thickness appears to

Missisquoi Bay.

be about 400 feet. A few feet at the top become mottled with patches of ash-grey pure limestone, and these are followed by from fifty to a hundred feet of ash-grey, dove-grey or greyish-white, pure compact limestone, in massive beds. The weathered surfaces of these are marked by a multitude of

283.—CEPHALOPODA.

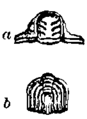


283.—*Lituites Farnsworthi* (Billings).

thin raised reticulating lines of crystalline dolomite, more numerous in the lower than in the upper beds. At the summit, the dove-grey color merges in some places into an opaque slightly yellowish-white. These beds occupy a belt, lying between the margin of the bay and a parallel valley occurring about 800 yards to the east. The only indications of fossils associated with them are confined to the dove-grey and white limestones, in which the genera *Pleurotomaria* and *Holopea* have been observed, but too indistinct to be specifically determined.

Farther eastward from Phillipsburgh, these beds are followed by reddish-grey, brown-weathering dolomites in thick beds, succeeded by black massive dolomites. In contact with these, there are, in two or three places, some thin bedded black limestones, which resemble beds much higher in the series, and may be here brought into place by some complicated

284.—CRUSTACEA.



284.—*Amphion Salteri* (Billings) ; *a*, the head ; *b*, the tail.

structure not yet understood. The thickness of these grey and black dolomites is by no means certain, but it is supposed to be about 200 feet.

Phillipsburgh section.

Beyond this ridge, these black dolomites are succeeded by a series of strata which appear to be as follows, in ascending order :—

Lévis formation.

	Feet.
1. White and dove-grey limestones, with thin raised chain-like lines of crystalline dolomite, reticulating over the surfaces of the beds. Interstratified with them, are a few beds of magnesian limestone, some light grey, weathering yellowish, and some dark grey, weathering white ; a bed of mottled red and white dolomite a foot thick occurs about the middle of the mass. The white and dove-grey limestones hold fossils, of which the genera appear to be *Pleurotomaria* and *Ophileta*, but the species are not yet determined. In what is considered the equivalent of these beds on the province line, there occurs *Bathyurus Saffordi*,.................	120
2. Dark grey and black limestone, some of the beds being highly magnesian. Some are mottled and weather light grey, and others are reticulated by thin raised lines of yellowish weathering dolomite. These beds are very fossiliferous, and contain, among other genera, *Orthis*, *Orthisina*, *Camerella*, *Maclurea*, *Ophileta*, *Ecculiomphalus*, *Pleurotomaria*, *Murchisonia*, *Holopea*, *Metoptoma*, *Orthoceras*, *Cyrtoceras*, *Nautilus*, *Amphion*, *Bathyurus*, and *Dikelocephalus*. The described species are *Orthis Electra*, *Camerella calcifera*, *Maclurea matutina*, *Ophileta sordida*, *O. levata*, *O. complanata*, *Ecculiomphalus Canadensis*, *E. intortus*, *E. spiralis*, *Lituites Farnsworthi*, *Amphion Salteri*, and *Bathyurus Saffordi*,..	120
3. Dark bluish-grey, reddish-grey, and black, thin bedded nodular limestones, interstratified with thin layers of bluish-grey slate, probably magnesian. Although thin bedded, the layers are aggregated in considerable masses, which have little tendency	

	Feet.
to separate in the planes of deposit. In the escarpments of these strata, the more calcareous parts of the rock being dissolved away by atmospheric waters, the slaty portions stand out in bands, which weather yellowish. On the surface of some of the beds, the rock weathers into a red or yellow ochery arenaceous earth, in which the moulds of fossil forms are numerous. The genera and the described species are nearly all identical with those of the previous division. Towards the top, *Lituites* appears to be very frequent,..................................	150
4. Black slaty thin bedded nodular limestone, with a cleavage independent of the bedding. The rock generally weathers to a grey, occasionally tinged with yellow; it has a somewhat scaly fracture, and breaks with the cleavage, rather than with the bedding. It holds fossils, of which the genera appear to be chiefly *Pleurotomaria*, *Orthoceras*, and *Lituites;* the only described species being *Lituites imperator*,..................................	300
5. Black limestones, some of them massive, weathering light bluish-grey, interstratified towards the bottom with occasional black and dark grey magnesian bands, some of them weathering yellowish and others white; they are much intersected by joints running in various directions. Towards the top, they are interstratified with thin bedded dark grey limestones. About 150 feet from the summit, beds of this kind rest upon a massive layer of black limestone, filling up hollows in its surface. The fossils met with in this division are chiefly of the genera *Eospongia*, *Pleurotomaria*, *Murchisonia*, *Holopea*, *Orthoceras*, *Cyrtoceras*, *Nautilus*, and *Bathyurus;* the only described species being *Bathyurus Saffordi*,..	350
	1040

The whole of these strata occur on a line east from Phillipsburgh, on which they occupy about a mile and a quarter, terminating at the road from Moore's Corners to Bedford. On the province line, the last two divisions, 4 and 5, appear to be absent. On this line, the three lower divisions, 1, 2, and 3, constitute a hill, which, immediately west of the valley of the Rock River, rises to a height of about 300 feet over Lake Champlain. The summit of this hill is composed of the thin bedded limestones, 3. The upper part of them is there arranged in the form of a trough, the axis of the synclinal being a few yards east of one of the iron posts which mark the boundary of the province. To the south, the hill slopes down to a road; and between the road and the hill, the black limestones, 2, can be traced round from the position which they occupy west of the hill on the province line, to another close by the same line, on the east side of the hill. Here they are nearly vertical, with a dip north-westward, and the outcrop of one of the bands can be traced north-eastward, without any break or concealment, for three quarters of a mile, in which distance it becomes

Province line section.

occasionally overturned. Its bearing, in the more northern half of this distance is N. 54° E., which would carry it much to the eastward of the most eastern exposures of the higher limestones, 4 and 5; but the position where these divisions turn on the synclinal axis, has not yet been observed. The white limestones, 1, have been observed on both sides of the trough, to the southward of the province line; but their turn upon the axis appears to be covered by drift. Farther south-westward, there are exposures of black limestones and dolomites, whose arrangement has not yet been investigated; it is conjectured, however, that their structure will conform to that on the north side of the province line.

Swanton

A short distance southward from Highgate Springs, the rocks connected with the anticlinal which occurs there, become covered with drift; but in the bed of the Missisquoi River at Swanton Falls, about five miles in that direction, and not far out of the course of the anticlinal, dark grey shales and thin interstratified limestones occur, which resemble those of the Hudson River formation. About three miles farther south, we again meet with a group of strata similar to those of the Springs, which are traceable, at intervals, for upwards of six miles, to St. Alban's Bay. On a recent examination of one of the exposures of these rocks, occurring near Smith's lime-kiln, under the guidance of the Reverend J. B. Perry and Dr. G. M. Hall, of Swanton, who have devoted much attention to the geology of their own neighborhood, it was ascertained that strata of the Trenton, of the Birdseye and Black River, and probably of the Chazy formation, are there presented in an inverted attitude. Between sixty and seventy feet of thin bedded black limestones, dipping eastward, and marked by *Calymene Blumenbachii* and *Trinucleus concentricus*, support from eighty to one hundred feet of thick bedded black limestones, with *Columnaria alveolata* and *Orthoceras Bigsbyi*. After a very small interval of concealment, these are followed by about sixty feet of grey calcareous sandstone, on which rest about 200 feet of dove-grey limestone; becoming interstratified towards the top with beds of yellow-weathering dolomite, and finally overlaid by 150 or 160 feet of yellow and brown weathering magnesian limestones. Except that Chazy fossils have not been observed between the thick bedded black limestone and the grey calcareous sandstone, the sequence sufficiently corresponds with that of the series at St. Dominique and at Highgate Springs, and, without much doubt, represents it.

Inverted section.

Overturn dips.

The dip, which is to the eastward, has an inclination varying from forty-five degrees on the west, to fifteen on the east; being thus in some places forty-five, and in others seventy-five degrees beyond the perpendicular. The overturn, it will be perceived, is greatest on the east side. Within 150 yards of the most eastern exposure of the magnesian rocks belonging to the section, there occurs a yellowish dolomitic sandstone, or sandy dolomite, which appears to be associated with a series of red and white mottled dolomites, largely displayed on the property of Mr. C. Bullard in the neighborhood; where they have been, to a small extent, quarried as marbles. These red and white dolomites slope in the same direction, and at about the same angle, as the strata to the west of them, their dip being about E. $< 12°$; while there is nothing in the physical attitude of the rocks to indicate that there is any considerable break between them, or that the one does not regularly and conformably pass under the other. Such may very possibly be the case; but the evidence of the fossils would seem to prove, that, whether the strata are so arranged or not, there must be a break of many thousand feet between the two series, and that the apparently overlying strata to the east are greatly the older of the two.

Dislocation.

Red sandrock.

These dolomites, with sandstones, generally red, and occasional shales, constitute what is called the Red sandrock of Vermont. From the position of their western outcrop, on the public road, at Mr. Bullard's, they are traceable southward in an almost unbroken course, not only to St. Alban's Bay, but in a line, which is in a general way parallel with the margin of Lake Champlain, to Burlington. Here they are exposed at Sharp Shins, and they are represented on the map of the State Geological Survey of Vermont, as extending still much farther to the south. To the northward, they come upon the Missisquoi River, upwards of a mile east of Swanton Falls, and, crossing the river, are traceable thence, by the residence of Mr. Church, to the neighborhood of Saxe's mill, within two miles of the province line.

Swanton section.

As far as our investigations have gone, the following appears to be the ascending sequence and the approximate thickness of the series of strata to which the red mottled dolomites belong:—

	Feet.
1. White and red dolomites with sandy layers; some of the strata are mottled rose-red and white, and a few are brick-red or indian-red. Some beds contain a considerable amount of silicious sand, and all weather to a reddish or yellowish brown. In the cliff opposite the residence of Mr. Church, some of the red beds contain *Conocephalites Adamsi* and *C. Vulcanus*, ...	370
2. Grey argillaceous limestone, partially magnesian, weathering brownish, and holding a great abundance of tangled specimens of *Palæophycus incipiens*,	110
3. Buff sandy dolomite, weathering brown, ...	40
4. Dark grey and bluish-black slate, partially magnesian, with thin bands of sandy dolomite, weathering yellowish. The slate is fossiliferous, but, having a cleavage independent of the bedding, it is somewhat difficult to obtain specimens. Towards the top there occur *Obolella cingulata*, *Orthisina festinata*, *Camerella antiquata*, *Conocephalites Teucer*, *Paradoxides Thompsoni, and P. Vermontana*, ...	130
5. Measures not well exposed, but consisting in part of bands of bluish mottled dolomite, weathering to a red ochery earth; mixed with patches of grey pure limestone and grey dolomite, weathering grey. There are also	

	Feet.
bands of light grey fine-grained and slightly micaceous flagstones, weathering reddish-yellow, with abundance of fucoids. Some bands of bluish slate are also visible, and it is supposed that the chief part of what is concealed, probably more than three fourths of the mass, may also consist of slate, ...	60
	710

Paradoxides slates.

This section occurs over a mile east of Swanton Falls, where, as well as near Mr. Church's residence, we were aided by Dr. G. M. Hall and the Reverend J. B. Perry, in the examination of the fossiliferous beds. From the neighborhood of Swanton, the Paradoxides slates, 4, have been followed southward by these gentlemen, to their junction with similar beds at Georgia, where the two species of *Paradoxides* mentioned in the section, were long ago discovered by the late Rev. Zadock Thompson. Mr. Thompson and the late Prof. C. B. Adams, then State Geologist of Vermont, also obtained *Conocephalites* from the Red sandrock in 1847; but until specimens were presented by Messrs. Hall and Perry to the officers of the Canadian Survey in 1861, which was the first announcement to us of their occurrence, the true horizon of the rock from which these fossils were derived, had never, we believe, been established on palæontological evidence. There is little doubt that they belong to the Potsdam group, and may very possibly represent its lowest member.

Conocephalites.

As has already been stated, the rocks of the foregoing section can be followed northward to the vicinity of Saxe's mill; beyond which, on the road to the province line, additional strata are met with. They appear to be as follows in ascending order :—

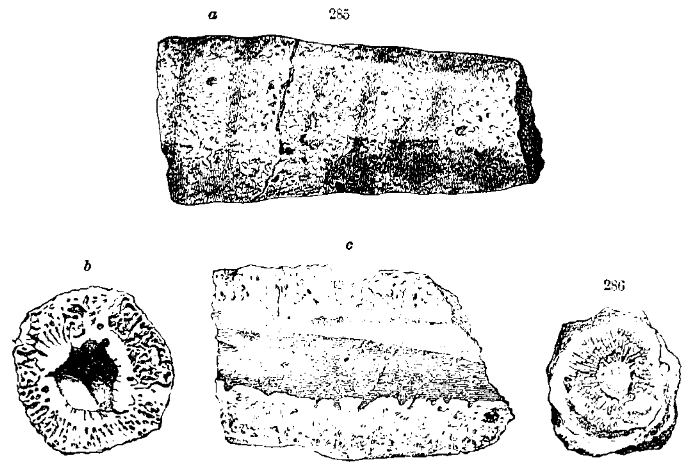
	Feet.
6. Light grey brown-weathering, more or less dolomitic sandstones, some of which are fine grained, while others are fine conglomerates, with white quartz pebbles as large as swan-shot. These are interstratified with bands of white sandstone, varying in thickness from five to fifteen feet, and making an aggregate of about one eighth of the whole mass. A band of bluish-grey dolomite near the top holds one or two species of *Orthis* and *Orthisina*, ...	630
7. Bluish thin-bedded, argillaceous, dolomitic flagstones and slates, cleaving with the bedding. These flagstones contain *Conocephalites arenosus*, together with many fucoids, ...	60
8. Bluish and yellowish mottled dolomite, with reddish and whitish mottled dolomite at the summit, ...	120
9. Yellowish and yellowish-grey brown-weathering sandy dolomite, not well exposed; about half the amount towards the lower part being concealed,	600
	1410

Across the measures, on the province line, there occurs a still farther amount of strata belonging to this series, occupying a breadth of a little more than a mile. A large portion of the measures in this part, however, is concealed; and in those exposed, it is often difficult to determine the planes of bedding. It is, in consequence, not easy to estimate the volume of strata to be added to the preceding series; they may however be described in a general way as follows:—

	Feet.
10. Buff and whitish, brown-weathering, sandy dolomite, holding a great amount of black and grey chert in angular fragments of various sizes up to a foot in length and six inches wide. The chert occasionally forms layers of a few inches, in which different shades of color coincide with the stratification. In some beds the fragments of chert make up the chief part of the rock, while in others it lies in scattered pieces. It is often associated with masses of white quartz, which occasionally appear as if filling geodes or druses. The thickness given is in a great degree conjectural,....................................	790

The whole volume of these magnesian rocks of the Potsdam group, Potsdam group.
would thus seem to be about 2200 feet. On the province line, the most western exposure belonging to them, approaches to within a quarter of a

285, 286.—ZOOPHYTA (POTSDAM GROUP).

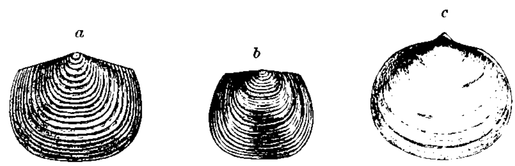


285.—*Archeocyathus Atlanticus* (Billings); *a*, exterior of a fragment; *b*, transverse section of the same; *c*, longitudinal section.
286.—*Archeocyathus* ——— ? weathered extremity of a specimen with more numerous and regular septa, probably a distinct species.

mile of the most eastern exposure of the Phillipsburgh limestones, showing the proximate position of a dislocation, that must run between the two. It would thus appear that from the neighborhood of Smith's lime-kiln, northward, there proceed two diverging lines of fault: the one running to Phillipsburgh, and thence to the Barbue; and the other, by Saxe's mill, to the Rock River at the province line, and to Moore's Corners beyond. On the western side of the one, the Trenton and its associated Black River and Chazy rocks, and, on the same side of the other, the Phillipsburgh strata, appear to stand with a nearly vertical western dip, or with an inverted eastern dip. The rocks on the east side of the two dislocations, on the contrary, present a moderate slope to the eastward;

Dislocations.

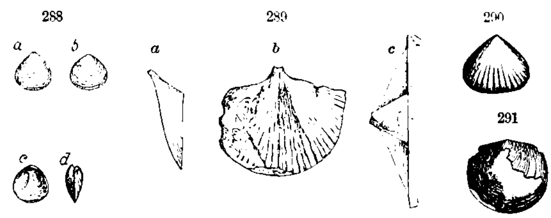
287.—BRACHIOPODA (POTSDAM GROUP).



287.—*Obolella cingulata* (Billings); *a*, ventral valve; *b*, dorsal valve; *c*, cast of interior of dorsal valve.

being at the same time, in each case, much older than those on the west. In other words, we have here two diverging anticlinal folds, often overturned, with upthrow dislocations on their eastern sides, running along the axes, and probably producing overlaps. They are thus analogous to the

288-291.—BRACHIOPODA (POTSDAM GROUP).



288.—*Obolella chromatica* (Billings); *a*, ventral valve; *b*, dorsal valve; *c*, interior of supposed ventral valve, showing the muscular impressions; *d*, outline restored from detached valves.

289.—*Orthisina festinata* (Billings); *a*, side view; *b*, ventral valve; *c*, area of the same valve enlarged.

290.—*Camerella antiquata* (Billings).

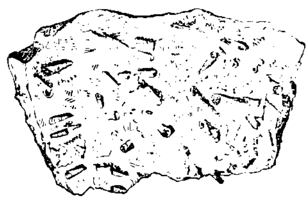
291.—*Obolus Labradoricus* (Billings); dorsal valve.

great dislocation on the north side of the island of Orleans (p. 234), of which the eastern one is probably a continuation.

While the strike of the strata on the west side of the eastern anticlinal is north-eastward, that of those on the west side is about north. The strikes on the opposite sides, thus converge northwardly, demonstrating that the crown of the anticlinal sinks in that direction. In conformity with this, the Potsdam rocks narrow in that direction, and become concealed between two and three miles north of the province line. The facts, however, which have been ascertained in connection with their disappearance, are not sufficient to authorize a detailed description. Where the two breaks nearly meet, at Smith's lime-kiln, the displacement would appear to become not much less than about 4000 feet.

To the eastward, the Potsdam strata are succeeded by dark grey or blackish calcareo-magnesian slates, weathering yellowish; interstratified with thin nodular layers of dark grey limestone, and occasional beds of six or eight inches in thickness. The rock is fossiliferous in some places; but in consequence of a cleavage independent of the bedding, it is difficult to obtain good specimens. Among the genera are *Orthis*, *Amphion*, *Asaphus*, *Illænus*, and *Bathyurus*. Of these, the only determined species

292.—ANNELIDÆ (POTSDAM GROUP).



292.—*Saltcrella rugosa* (Billings).

is *Bathyurus Saffordi*. These calcareo-magnesian slates occupy a breadth of probably not far from a mile, in the neighborhood of Herrick's mills, near the province line, in the valley of the Rock River. They have been traced southward of the province line, up the valley, about a mile and three quarters to Stimet's mills. They probably reach Highgate Falls on the Missisquoi, upwards of four miles farther south, and may continue in the same direction beyond. A mile north of the province line, on the road from Moore's Corners to Frelighsburg, they appear to be covered up by drift; but their breadth must here be less than three quarters of a mile, as at that distance eastward from the chert-bearing Potsdam dolomites, there occurs an argillaceous slate, without ascertained fossils, which seems to belong to the series of black slates that have been mentioned as separating the main synclinals of the Quebec group. Herrick's mills.

The lithological character of the calcareo-magnesian slates at Herrick's mills, as well as the general aspect of their fossils, would very well accord with the view that they occur in ascending succession to the highest strata of the Phillipsburgh series, although they have only one species (*Bathyurus Saffordi*) in common. But the fact that they follow directly the Potsdam chert-bearing strata, without the intervention of the great mass of the Phillipsburgh rocks, and without any apparent disturbance, is one that will require farther investigation to explain. On the province line, the Potsdam strata terminate less than half a mile to the east of Rock River. Rock River, the highest beds dipping S. 76° E. < 24°. The concealed interval between them and the slates, is only about fourteen paces; and although the slates present several small undulations, their general dip appears to be in the same direction, and at about the same angle as that

293-297.—CRUSTACEA (POTSDAM GROUP).

293 294 295 296 297

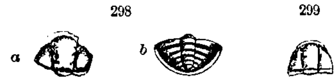
Glabellæ of the following species:

293.—*Conocephalites miser* (Billings).
294.—*C.* ——— *Adamsi* (Billings).
295.—*C.* ——— *Teucer* (Billings).
296.—*C.* ——— *Vulcanus* (Billings).
297.—*C.* ——— *arenosus* (Billings).

of the older rock, which would thus seem to pass conformably under the slates. On the Rock River, about 150 paces below the bridge near Herrick's mills, the slates and dolomite are seen together in the same bank, the slates about fifteen feet above the dolomite. They both appear to dip S. 80° E. < 33°. If notwithstanding this appearance of conformity in the two rocks, there should be a dislocation between them, it would in this instance, probably be a downthrow to the east.

298, 299.—CRUSTACEA (POTSDAM GROUP).

298 299



298.—*Bathyurus senectus* (Billings); *a*, head; *b*, pygidium, supposed to be of the same species.
299.—*B.* ——— *parvulus* (Billings); the head.

The calcareo-magnesian slates have not been as yet traced continuously, much farther northward than Herrick's mills; but it may be here remarked, that they resemble lithologically, the slates which have been mentioned as occurring on the twenty-sixth lot of the first range of Farnham. The distance between the exposures is about sixteen miles, but they apparently strike for one another; and as they have both, palæontologically, an aspect somewhat newer than that of the Phillipsburgh series, it might be supposed that they belong to one and the same band. They have not however been found to contain any species in common; and a larger number of facts connected with these exposures must be accumulated, before any decided opinion can be formed regarding their true horizon. On the twenty-fifth lot of the sixth range of Dunham, which is about four miles south-eastward of the Farnham exposure, there occurs a band of limestone of about thirty feet thick, traceable for about a hundred yards, and probably having a lenticular form, in which the *Leptæna* and the *Orthis* of Farnham are present, but without any of the other fossils. Its strike appears to be parallel with that of the Farnham band; and it would seem to occupy about the same place on the east side of the general mass of shales, that the Farnham rock does on the west. Dunham.

No strata with the combined palæontological and lithological characteristics presented by those of the Potsdam group, which come from Vermont into St. Armand, are yet known to crop out from beneath the Quebec group, in its extension on the south side of the St. Lawrence. On the north side of the Gulf of St. Lawrence, however, at the Straits of Belle Isle, about 900 miles from St. Armand, the rocks alluded to in Chapter VI. as occurring at Anse aux Blanc Sablons, have been found, on an examination made since that chapter was written, to be characterized by fossils which appear to show that they belong to the same horizon as the Red sandrock of Vermont. Straits of Belle Isle.

At the east horn of Pillage Bay, on the main coast, opposite to Hunter's Island of the Mingan group, a white sandstone about eight feet thick has been met with, resting on Laurentian gneiss. The position of this sandstone, and the moderate dip of the palæozoic strata in that neighborhood, would bring it to within two feet of the nearest strata of the Calciferous formation. It is probable that it may belong to the Potsdam group, and represent its summit. Between this exposure and Bradore Bay, the distance is about 300 miles. The shore, which is very much indented by bays and inlets, and fringed with a multitude of islands, presents an almost continuous line of bare rocks; but in no part of it have there been observed any strata, but such as belong to the Laurentian series. On the east side of Bradore Bay, which is situated near to the entrance to the Straits of Belle Isle from the Gulf of St. Lawrence, the palæozoic rocks again present themselves. Resting on the Laurentian gneiss, they run along the north coast for nearly eighty miles, with a breadth of probably ten or twelve miles, and a slope, towards the water, of about sixty feet in a mile. In this stretch along the coast, they are divided into five or six tabular masses, separated from one another by narrow denuded portions of the gneiss, which in every case terminates in a deep bay. These areas of nearly horizontal strata, in most cases present abrupt escarpments on all sides; and on the water-line in Anse aux Blanc Sablons, the gneiss shows itself at the base. These tabular masses consist, in ascending order, of the following strata:— Mingan Islands. Bradore Bay.

	Feet.
1. Red and grey sandstones, sometimes of a reddish-grey; consisting, in the lower part, of a conglomerate composed of rounded pebbles of white quartz from an eighth of an inch to three inches in diameter, in a matrix of fine-grained sandstone, made up of whitish and reddish quartz, and white and red feldspar. A similar fine-grained mixture constitutes the great mass of the rock in the upper part. The beds vary in thickness from three inches to three feet, and many of them are penetrated vertically by *Scolithus linearis*, about a quarter of an inch in diameter, and always of a lighter color than the surrounding mass. Four feet below the summit, there is a bed three and a half feet thick, of a mammillated or concretionary character; the concretions, which are from one to ten feet in horizontal diameter, being composed of concentric layers from a quarter to half an inch thick,........	231
2. Grey, reddish, and greenish limestones, presenting on the strike great diversities of character. They sometimes consist of yellow-weathering, massive, nodular, argillaceous limestones, probably magnesian, holding lenticular patches of pure limestone, as well as of red and green shale from three to six feet in horizontal diameter. On the strike, these yellow-weathering limestones pass in some parts into grey, compact, pure limestone, in thick, massive beds, while in others they are evenly divided into layers of only two or three inches thick. In Forteau Bay, the whole mass appears to be more or less fossiliferous, and among the species are *Palæophycus incipiens*, *Archeocyathus Atlanticus*, *A. Minganensis*, *Obolus Labradoricus*, *Obolella chromatica*, *O. cingulata*, two new species of *Orthis*, one new species of *Orthisina*, *Paradoxides Thompsoni*, *P. Vermontana*, *Conocephalites miser*, *Bathyurus senectus*, *B. parvulus*, *Salterella rugosa*, *S. pulchella*, and *S. obtusa*, ...	143
	374

The general aspect of the fossils, with the fact that *Obolella cingulata*, *Paradoxides Thompsoni*, and *P. Vermontana* are common to these strata and to the Red sandrock of Vermont, appears quite sufficient to establish the equivalency of the two deposits. In front of these rocks, the strait has a width of between ten and fifteen miles; and on the opposite side, the shore of Newfoundland is occupied by a series of limestones, apparently of Calciferous age, which rise from the water at so small an angle that it is nearly impossible to determine it by the eye. From Anchor Point, and perhaps from Cape Norman, which is the most northern point of Newfoundland, they stretch along the coast for upwards of a hundred miles, to Hawke's Bay, in the bight of which they are underlaid by a white sandstone. The attitude of the rocks on the opposite sides of the strait, would appear to indicate that they lie in the form of a shallow trough; and it is therefore to be inferred that the limestones of the south side, and the white sandstones which underlie them, must be concealed by the water on the north side of the trough. In ascending succession to the rocks that have been given, 1 and 2, we should therefore have—

Newfoundland.

Ascending section.

Feet.

3. White fine-grained silicious sandstone; the beds vary in thickness from one to three feet, and, while some are a little coarser than others, a few hold scattered pebbles of white quartz of an inch in diameter, and several enclose flat worn pieces of black slightly micaceous shale. Many of the beds are streaked with a reddish color, running with the stratification. This sandstone is identical in character with that which underlies the Calciferous formation of the Mingan Islands, and specimens of it cannot be distinguished from the white sandstone associated with the track-beds of Beauharnois. The small worn patches of shale enclosed in some of the strata, strongly resemble those which are imbedded in the sandstone of Hemmingford Mountain. Though only twenty feet of the rock were seen in place in Hawke's Bay, the occurrence of large flat angular fragments of it, over a transverse breadth of several miles, in the rear of the overlying limestones, makes it probable that it is a formation of some importance. The small slope of the lower rocks on the north side of the strait, and the narrowness of the channel, will however scarcely allow a greater thickness than about,............................ 250 White sandstone.

4. Grey and reddish magnesian limestones in massive beds, weathering grey and yellow; interstratified with thin beds of light greenish magnesian limestone, weathering buff, and with occasional thin layers of a yellow and light greenish limestone not magnesian. In grey magnesian limestones, supposed to be near the top of the mass, *Lingula acuminata* occurs, ... 150

5. Dark grey limestones, occasionally argillaceous, and often magnesian, weathering yellowish, and then holding geodes of white quartz and calcspar, in some abundance; the beds appear to be from three inches to four feet thick. The only fossils observed are undetermined species of *Lingula* and fragments of undetermined trilobites,................................. 400

6. Dark grey limestone, associated with dark bluish and yellowish calcareo-argillaceous layers; the beds are from one inch to five feet thick, and the thicker ones, which are probably magnesian, hold in abundance, geodes of white quartz and calcspar. At about one third from the bottom, a bed of three feet thick contains, in some abundance, geodes holding white, pink, and red fluor spar. Fossils are abundant in some of the beds, and occasionally occur in a silicified condition; in the great mass of the rock, however, they have not been met with. The genera observed are *Orthis*, *Strophomena*, *Ophileta*, *Ecculiomphalus*, *Orthoceras*, *Bathyurus*, and *Leperditia*; the only species determined being *Bathyurus Cordai*,............................ 400 Geodiferous dolomites.

7. Dark grey limestones similar to the previous, more geodiferous and probably more magnesian; they are at the same time more fossiliferous. The genera which they contain are *Strophomena*, *Orthis*, *Ophileta*, *Maclurea*, *Ecculiomphalus*, *Pleurotomaria*, *Murchisonia*, *Orthoceras*, *Asaphus*, *Bathyurus*, and *Leperditia*; the only determined species appears to be *Murchisonia Anna*,. ... 130

8. Greyish-blue even bedded limestones, purer than before; the thickness of the beds ranges from one inch to one foot. These limestones are very fossiliferous, but the fossils are often obscure. Among the genera are *Orthis*, *Strophomena*, *Ophileta*, *Maclurea*, *Ecculiomphalus*, *Pleurotomaria*, *Murchisonia*, *Orthoceras*, *Pilo-*

		Feet.	
	ceras, Asaphus, Bathyurus, Leperditia, and trilobites of two or three undetermined genera; *Murchisonia Anna* and *Piloceras Canadense* are the only determined species,.................	340	
	9. Light yellowish-grey mottled yellow-weathering magnesian limestone; some of the beds hold in great abundance geodes of white crystallized quartz and yellowish-white calcspar. The fossils in these strata are few and obscure; the only genera met with are *Ophileta* and *Orthoceras*,......................	150	
		——	1570
Point Rich limestones.	10. Light-grey and yellowish-white mottled magnesian limestone, of the same general character as the previous mass, but in some parts suddenly changing on the strike, for a thickness of from ten to thirty feet, into a bluish-grey pure limestone, in which the fossils are better preserved than in the magnesian parts. It might be supposed that the two limestones, in these cases, are thus brought into juxtaposition by dislocations, were it not that the thicknesses of the beds on the opposite sides of the junction precisely agree, and that there occasionally runs evenly through both of them, an unbroken interstratified band of dark grey or black compact limestone. The fossils are *Strophomena, Orthis, Ophileta, Maclurea, Ecculiomphalus, Pleurotomaria, Murchisonia, Holopea, Orthoceras, Nautilus, Asaphus, Illænus, Bathyurus, Amphion, Leperditia*, and several undetermined genera of trilobites. In the upper ten feet, the yellowish-white magnesian limestone is replaced by a similar rock of dark grey. This portion becomes black on the strike, and then contains no observed fossils, ...	130	
	11. Light bluish-grey tough limestones of a uniform texture; in beds varying from an inch to two feet in thickness, which hold a greater abundance of fossils than any of the strata lower down. Among the genera met with are *Eospongia, Stromatopora* (like *S. compacta*, but larger), *Strophomena, Orthis, Ophileta, Maclurea, Ecculiomphalus, Pleurotomaria, Murchisonia, Holopea, Bathyurus, Amphion, Leperditia*, and several trilobites of undetermined genera,...	130	
	12. Light bluish-grey limestones of the same description as the previous mass; they are however thicker bedded, but their fossils are more obscure. The upper third is rather darker in color than the rest, and contains trilobites in abundance, and a few orthoceratites, which are often badly preserved,.................	550	
	13. Black bituminous limestone, in beds of from one to three inches thick, interstratified with fine brittle black shale, in layers varying from a quarter of an inch to three inches; the limestones hold fossils, but not in abundance,............................	200	
		——	1010

[Fossils were collected from the last two divisions; but it became necessary to abandon them on the coast, the surf being too heavy to permit the approach of the boat to take them on board.]

Grey sandstones. 14. Grey calcareous sandstones, generally fine grained; in beds of from six inches to two feet, interstratified with black and greenish shales, which predominate towards the top. The sandstones are sometimes of a conglomerate character, and include pebbles of white quartz, and black limestone, varying in diameter from the eighth of an inch to two inches; with small fragments of red and black jasper, and flat pieces

Feet.

of black and green shale. The sandstones and the shales are aggregated in masses varying from six up to sixty feet in thickness. No fossils have been met with in this rock,........................... 700

15. Grey, drab, and whitish limestone conglomerates, interstratified in the lower part, with bands of black and greenish shale from forty to a hundred feet thick; and associated with black limestone holding layers of black chert from one to three inches thick. Graptolites occur in the black limestones, and fragments of trilobites in the chert. In the upper part, the conglomerate is more massive, great thicknesses showing no trace of bedding. The enclosed pebbles, boulders, and fragments of limestone, range in weight from one ounce to a ton, and in color from white, through various shades of drab and grey, to black. Associated with the masses of limestone, are occasionally others of grey calcareous sandstone, specimens of which cannot be distinguished from those of the sandstone, 14, which is beneath. Some masses, which are of the same character as smaller inclosed blocks, are 200 feet long by thirty feet thick. It is difficult to decide whether these are sediments deposited in the bed, or enclosed transported masses, notwithstanding that they are divided into beds with partings of black shale. Some of the conglomerate beds are filled with pebbles of black chert. Near to the top, patches of several hundred yards, in the supposed direction of the strike, but without observed bedding, consist of light reddish-grey pure limestone, in part highly crystalline, abounding with convoluted shells and other fossils. The genera found in these conglomerates and their interstratified masses, are *Graptolithus*, *Orthis*, *Rhynchonella*, *Camerella*, *Ophileta*, *Maclurea*, *Orthoceras*, *Asaphus*, *Illænus*, *Amphion*, *Bathyurus*, *Holematopus*, *Nileus*, *Ampyx*, *Agnostus*, *Endymion*, and several trilobites of undetermined genera. The determined species are *Graptolithus Headi*, *Camerella Calcifera*, *Maclurea ponderosa*, *Bathyurus Saffordi*, *Holematopus Angelini*, *Endymion Meeki*, and *Nileus scrutator*,.............. 700 — Limestone conglomerates.

16. Greenish sandstones of a chloritic aspect, made up apparently of fine grains of quartz and feldspar, with a few scales of mica, mixed with greenish argillaceous matter. Some beds are of a conglomerate character, the pebbles consisting of white quartz and reddish feldspar, varying from the sixteenth of an inch to an inch in diameter; the quartz pebbles are somewhat larger and much more numerous than those of feldspar. They are accompanied by occasional pebbles of red jasper, and by flat pieces of green shale. In some beds, the masses enclosed consist of grey limestone. The finer beds are aggregated in thicknesses of several hundred feet, and the conglomerates are from ten to twenty feet. These fine and coarse sandstones are interstratified with several bands of red shale, from ten to twenty feet thick; and one of sixty feet, consists of red shale interstratified with green layers. The thickness of the whole was not measured, but it is supposed to be not much under,... 2000 — Green sandstones. Red and green shales.

6230

The limestones, 4 to 9, succeeding to the white sandstones, 3, were examined along the coast of Newfoundland at intervals, for fifty miles, extending from Anchor Point to Hawke's Bay. In a large part of this distance, the beds come obliquely upon the coast, with a S. S. W. slope of between ten and thirty feet in a mile; and along the water line, they are apparently turning from the extremity to the side of the shallow trough to which they belong. With the small slope just mentioned, they run under the limestones of St. John's Island and Point Rich, 10 to 13; the contact being visible at Port au Choix, near the latter place In Hawke's Bay there is probably a transverse dislocation, again bringing the lower limestones, 4 to 9, forward to the coast, along which they run for about twenty-five miles to Table Point. Here, with a south-west slope of about five degrees, they pass under the Point Rich limestones, the dip gradually increasing, between the base and summit of these, to eighteen degrees. With this increased dip, the Point Rich limestones sink beneath the grey sandstones, 14; the nearest approach of the two rocks across the measures being about twenty feet.

Point Rich.

Dislocation.

South-eastward from Table Point, another transverse break occurs, which brings the base of the Point Rich limestones opposite to the base of the grey sandstones. On the south-east side of the dislocation, the dip, which is still to the S. W., becomes thirty degrees. With this slope, the limestones and the sandstones, 10 to 14, again come in succession; and the conglomerate limestones, 15, follow at a distance of about a mile across the measures. The exposures showing this succession are at Daniel's Harbor; and at Portland Creek, three miles beyond, there is a great display of the conglomerate limestones; but in their south-eastward course, these are cut off by another transverse dislocation, and on the south side of the creek the grey sandstones are brought forward to the coast. They here present a dip about S. $< 4° - 8°$; and the conglomerate limestones are again seen about four miles, in the direction of the dip, from Portland Creek.

Portland Creek.

Seventeen miles farther on, the grey sandstones again appear; being this time arranged in the form of an anticlinal, the axis of which runs about N. 37° E. and S. 37° W. The slope on the north-westward side ranges from seventy to ninety degrees, while that on the south-eastward gradually diminishes to fifty-eight degrees. Here the sandstones sink under the conglomerate limestones, the contact being visible. The bearing of the axis of the anticlinal would carry the sandstones between Steering Island and Cow Head, both of which are composed of the conglomerate limestones. The rocks of these two localities thus appear to be equivalent masses on opposite sides of the fold.

Bonne Bay.

Bonne Bay is situated about twenty-five miles still farther along the coast, from Cow Head. It is a deep indentation, running south-eastward into the land; and at the distance of about six miles from the entrance, it splits into two parts, the East Arm and the South Arm. The portion of land separating these two arms is from three to five miles wide, and, although the strata which compose it are somewhat broken by small dislocations, the whole succession of deposits, from 4 to 15, can be partially seen, the one in contact with another. They stand at a high angle, with a general slope to the south-west; and on the South Arm, in addition to the rocks already given, we have the greenish sandstones, 16, in immediate succession to the conglomerate limestones.

These greenish sandstones have so striking a lithological resemblance to the Sillery series, both in the aspect of the arenaceous beds and in their interstratification with red shales, that there can scarcely be much doubt of the equivalency of the two. The whole succession of the Belle Isle rocks, attaining a thickness of about 6000 feet, would appear to bear a remarkable general analogy to the Potsdam and Quebec groups. As already stated, the Scolithus sandstones and the Paradoxides limestones, 1 and 2, of the north shore, are the equivalents of the Red sandrock of Vermont and its associated strata; while the white sandstones, 3, of Hawke's Bay, are the representatives of the Beauharnois strata, at the summit of the Potsdam group. The magnesian limestones, 4 to 9, of Anchor Point and Port au Choix, appear to occupy the position of the Calciferous formation. Four species, *Lingula acuminata*, *Murchisonia Anna*, *Piloceras Canadense*, and *Bathyurus Cordai*, are common to the two, and there is a striking resemblance in the aspect of the whole faunas of both series. The Point Rich limestones, 10 to 13, appear to be a higher part of the same series, possibly not represented to the westward, in Canada; while the grey sandstones and conglomerate limestones, 14 and 15, seem to be equivalent to a part at least of the rocks of Point Lévis, and to the higher portion of those of Phillipsburgh. In addition to the great general resemblance of the faunas, these strata have, in common with the two western localities, *Graptolithus Headi*, *Camerella calcifera*, *Maclurea ponderosa*, and *Bathyurus Saffordi*. But while some of their fossils strongly resemble in general aspect those of the Farnham limestones, the Newfoundland rocks have none of the trilobites, such as *Conocephalites*, *Dikelocephalus*, *Menocephalus*, and others, which give to a small portion of the Point Lévis series a primordial aspect.

Sillery formation.

Potsdam group.

Lévis formation.

The apparent physical structure, both at Quebec and at Bonne Bay, would seem to place the Sillery sandstones above the conglomerate limestones of the Quebec group; but it is to be kept in mind, that, although the greenish sandstones at Bonne Bay appear upon the east side of the South Arm, in conformable sequence to the conglomerate limestones, both are tilted up to a high angle, the dip being W. S. W. $< 45° - 80°$. It is to be farther noted, that on the west side of the South Arm, the rocks become highly metamorphosed. After exposures of other conglomerates and succeeding sandstones, which are associated with white talcose slates, there rises, to a height of between 2000 and 3000 feet, a mountain of serpentine, similar in character to that of the Eastern Townships.

Altered rocks. Serpentine.

It has been shown, that, with the exception of a small area of the Potsdam sandstone at St. Ambroise (p. 96), we have no evidence of a marginal outcrop of this formation between the St. Maurice River and the Mingan Islands. No marginal outcrops of the Calciferous and Chazy formations have been observed from the longitude of Lake St. Peter to the same group of islands; and between the vicinity of Kingston and the north shore of Lake Huron, all three of these formations appear to be wanting. From the Mingan Islands to the Mohawk River in New York, the marginal outcrops of the Potsdam, Calciferous, and Chazy united, do not in any part much exceed 1000 feet in thickness; while the thickness of the Quebec group alone, is about 7000 feet. This, constituting the great metalliferous formation of the continent, is traceable, under various designations, from Gaspé to Alabama; thence sweeping round on the west side of the Mississippi, through Kanzas, to Lake Superior, where it appears without any diminution in its volume.

Marginal outcrops.

Extent of the Quebec group.

From these facts, it would appear probable, that, during the Potsdam period, the older rocks, which formed the coast of the Lower Silurian sea, extended, under comparatively shallow water, south-eastwardly from the St. Lawrence and the Ottawa, to the fault which brings up the Quebec group between Gaspé and the Mohawk; and south-westwardly from a line between the Mohawk and Lake Superior, as far as Alabama. All around this shallow area, they descended quickly into deep water; thus constituting a subaqueous promontory from the Laurentian and Huronian rocks of the north, and forming, with these, what Mr. James D. Dana has termed the nucleus of the North American continent.

Ancient continent.

But although the great volume of the Quebec and Potsdam groups, shows that over the area occupied by them, there must have existed a deep sea during the Potsdam period; it is to be remarked, that many of the members, both of the lower and upper parts of the Quebec group, have by no means the characters of deep-sea deposits. It has already been stated, that the beds of passage between the littoral portions of the Potsdam and Calciferous formations, suggest the opinion, that, towards the termination of the Potsdam era, a gradual sinking of the surface had occurred. In order to obtain the conditions for the accumulation of the coarser sediments, which commence near the base of the Quebec group, it must be supposed, that, shortly after the beginning of the Calciferous period, a great continental elevation occurred; carrying the littoral deposits of the Potsdam, and the beds of passage just mentioned, high above the sea, and bringing the area at the base of the Quebec group comparatively near to the surface. The successive coarse deposits of the group indicate a subsequent gradual subsidence, at unequal intervals, probably with subordinate oscillations, until the early shallow-water strata were again submerged; to be first partially covered over by deposits of the Chazy forma-

Deep palæozoic sea.

Continental elevation.

tion, and then, almost universally, by those of the Trenton and Hudson groups.

Palæontological breaks.

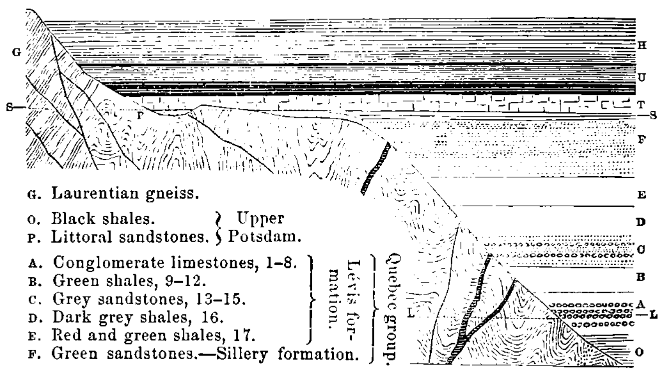
In this way may be explained the break which occurs in the succession of life between the Calciferous and Chazy, in the shallow-water deposits of these formations between the Allumettes Island and Montreal, as well as among the Mingan Islands. The interruption in the succession of deposits between the base of the Trenton group and the Potsdam, at St. Ambroise; and that between the same base and the Laurentian, from the north shore of Lake Huron to Kingston, as well as in the vicinity of St. Paul and Murray Bays, and at Lake St. John on the Saguenay, is in the same way accounted for. The break in the succession of life between the Chazy and the Trenton group, is not so great as that between the Calciferous and the Chazy. It is not yet quite certain, that, at the marginal outcrop of the latter formations in Canada, a single species passes upwards into the Chazy; while about one sixth of the species of the Chazy are known to occur in the Birdseye and Black River formation, at the base of the Trenton group. It seems to be in accordance with this, that we have evidences of a somewhat sudden submergence at the commencement of the Trenton period, and a somewhat rapid accumulation of its lower strata, the Birdseye and Black River limestones. Where these rest upon the Huronian and Laurentian series, the beds of contact are often composed of angular fragments of the underlying rock; and it frequently happens that the surface on which these beds rest, is rough, and broken into sharp projecting ledges and deep fissures, which were filled up and covered over by the deposits in question, before sufficient time had elapsed to permit the surface to be worn down. Instances in illustration of this occur on the Snake Islands, west of Lacloche, in Lake Huron, where the Birdseye and Black River formation rests on the quartzites of the Huronian series; and at Marmora, where it is supported by Laurentian rocks. Dr. Dawson has pointed out a striking instance of these phenomena at Hog Lake in Huntingdon; other examples occur at Sloat's Lake in Loughborough and its vicinity, as well as at Kingston Mills. The same conditions may be observed in the neighborhood of Murray Bay.

Base of the Trenton.

Slope of the ancient coast.

As an instance of the probably rapid slope of the bottom of the Lower Silurian sea from shallow to deep water, during the Potsdam period, in the neighborhood of Quebec, we see that the surface of the quartzose gneiss now supporting the Trenton formation at the Falls of Montmorenci, must have been 7000 feet above the gneiss under the island of Orleans; while the distance between the two positions does not much exceed a mile and a half. This would give a slope of nearly forty-five degrees; and perhaps it would not be extravagant to take this as representing the inclination along the whole line to Alabama. As the Potsdam and Quebec groups accumulated, the edges of their strata would abut against this slope; and ultimately both these, and the early shallow-water deposits on the higher terrace, would be covered over by the Birdseye and Black River, the Trenton, the Utica, and the Hudson River formations. This we have endeavored to represent in the accompanying ideal diagram; in which it

300.—SUPPOSED ARRANGEMENT OF THE STRATA BEFORE THE BREAK.



The above numbers refer to the section, page 227.

T. Trenton group of limestones.
U. Utica shales.
H. Hudson River sandstones and shales.
L. L. Sea level at the commencement of the Quebec period.
S. S. Sea level at the close of the Potsdam, and also at the beginning of the Trenton period.

Vertical scale of the section, one inch to a mile.

will be perceived that the lowest of these formations is shown as resting (at P.) on one of those littoral deposits of Potsdam sandstone, like that at St. Ambroise, which are still met with along the marginal outcrop.

Northern shallow sea. The strike of this rapid slope in the bottom of the ancient sea, coinciding with the break, had, as already indicated, a general north-eastward bearing, from Lake Champlain to the vicinity of Cape Chatte. The present trend of the Laurentian gneiss, from the neighborhood of Quebec to Pointe des Monts, has a rude parallelism with it; but farther down the valley of the St. Lawrence, while the line of break turns gradually eastward, and ultimately south of east, in Gaspé, the trend of the gneiss becomes northward for about sixty miles, then eastward for three hundred miles, and finally north-eastward for two hundred miles more, to the Atlantic extremity of the Straits of Belle Isle. This divergence of the two lines would lead us to anticipate an area of shallow water during the Lower Silurian period; so protected from disturbance that any strata occurring there, might be expected to present a comparatively horizontal attitude, like that of the Lower Silurian formations on the same side of the break to the west. We accordingly find, in the Mingan Islands, in Anticosti, and on the Straits of Belle Isle, the Lower Silurian deposits in such an attitude. In the latter locality, however, the volume of the undisturbed strata would appear to indicate that the bottom shelved more gradually before reaching the slope. The increase of the dip in approaching Bonne Bay, suggests that we may expect to find the break somewhere in that neighborhood.

Anticosti area.

Results of lateral pressure.

Without enquiring into the origin of the forces which may have produced the corrugations of the earth's crust, we may suppose that if a sufficient lateral pressure were applied to the strata thus accumulated and arranged, there would result a series of parallel folds running in a direction at right angles to that of the force, with prevailing overturn dips towards the line of resistance. The solid crystalline gneiss in the case before us, offering more resistance than the newer strata, there resulted a break coinciding with the inclined plane at the junction of these with the gneiss. The lower palæozoic strata, pushed up this slope, would then raise and fracture the formations above, and be ultimately made to overlap the portion of these resting on the edge of the higher terrace; after probably thrusting over to an inverted dip, the broken edge of the upper formations. The shallow-water strata of the higher terrace, relieved from pressure by the break, would remain comparatively undisturbed; and thus the limit of the more corrugated area would coincide with the slope between the deep and shallow waters of the Potsdam period. The resistance offered by the buttress of gneiss would not only limit the main disturbance; but it would probably also guide or modify, in some degree, the whole series of parallel corrugations, and thus act as one of the causes giving a direction to the great Appalachian chain of mountains.

CHAPTER XII.

THE ANTICOSTI GROUP AND THE GUELPH FORMATION.

THE ROCKS OF ANTICOSTI: THEIR EQUIVALENTS IN WESTERN CANADA.—GUELPH FORMATION; MIDDLE SILURIAN.—FOUR DIVISIONS OF THE GROUP IN ANTICOSTI: THEIR DISTRIBUTION AND THICKNESS.—ANTICOSTI GROUP IN GASPE: IN WESTERN CANADA.—ONEIDA CONGLOMERATE; MEDINA AND CLINTON FORMATIONS; THE GREY BAND.—RED AND GREEN SHALES AND SANDSTONES; THEIR DISTRIBUTION.—NIAGARA FORMATION; SHALES AND MAGNESIAN LIMESTONES; THEIR DISTRIBUTION.—GUELPH FORMATION; DOLOMITES; ITS DISTRIBUTION.

At the close of Chapter IX., we have given a section of the Hudson River rocks, as they occur at the west end of Anticosti. The strata of this formation occupy nearly the whole of the north side of the island; and extend from Fox Point, which is towards the east end, to Junction Cliff, on the south side, about four miles from the west end. The remaining portion of the island is occupied by newer rocks, to which the name of the Anticosti group has been given. Their position in the geological series, is that occupied by the Oneida conglomerate, the Medina sandstone, the Clinton group, and the Niagara group, of the New York geologists; but these subdivisions, although apparent in the western basin, disappear in the Anticosti strata, which are lithologically unlike their equivalents in Western Canada. In that region, the Niagara formation, which corresponds to the summit of the Anticosti group, is followed by what we have named the Guelph formation, and makes up with it the Middle Silurian.

Middle Silurian.

First division.

The rocks of this group on the island of Anticosti, may be considered in four divisions; the first and lowest of which, in immediate succession to the Hudson River formation, is as follows, in ascending order:—

1.

	Ft.	in.
1. Greenish argillo-arenaceous shale, interstratified in the upper half with beds of grey limestone, from one to three inches thick,....	2	6
2. Yellowish-grey compact argillaceous limestone, with few observed fossils,...	10	0

	Ft.	in.
3. Yellowish-grey compact argillaceous limestone, interstratified with light reddish-grey limestone beds of from one to three inches thick, with many fossils,	20	0
The preceding beds compose Junction Cliff, as well as White Cliff, in Ellis Bay. The fossils consist chiefly of the following species: *Stenopora fibrosa*, *Halysites catenulatus*, an undetermined *Heliolites*, *Favosites Gothlandica*, *Petraia gracilis*, two undescribed species of *Ptilodictya*, *Leptæna sericea*, *Strophomena rhomboidalis*, *S. pecten*, *Orthis lynx*, *O. Salteri*, *O. Huxleyi*, *O. Panderi*, *O. porcata*, *O. Laurentina*, an undescribed species of the same genus, *Orthisina Verneuili*, *Lingula Forbesi*, *Pentamerus reversus*, *Atrypa marginalis*, a new species of *Athyris*, *Murchisonia papillosa*, with two undetermined species of the same genus, *Pleurotomaria Americana*, *Bellerophon bilobatus*, *B. acutus*, *Ambonychia radiata*, an undetermined species of *Orthoceras* and one of *Ascoceras*, two undetermined species of *Asaphus*, one of *Encrinurus*, and one of *Dalmanites*.		
4. Measures partly concealed; but supposed to be of the same character as the preceding, both lithologically and palæontologically,	25	0
5. Ash-grey argillaceous limestone, in beds of from one to three inches thick, alternating with beds of calcareo-argillaceous shale of from five to seven inches. Both of these are interstratified with light grey pure limestone beds, one or two inches thick; no fossils have been observed in this part,	6	0
6. Ash-grey argillaceous limestones and shales, interstratified as before with pure limestones. These beds occur about one mile east of Junction Cliff, and contain very nearly the same fossils as before; with the addition of *Lingula quadrata*, *Pleurotomaria Thalia*, and an undetermined *Cyrtoceras*. All of the species are found loose and well preserved in the debris, as well as standing out in relief on weathered surfaces,	20	0
7. Ash-grey argillaceous limestones and shales, with purer limestones, as before. The fossils are not so well preserved, in consequence of the action of the sea,	41	0
8. Measures concealed,	21	0
9. Grey limestone, interstratified with grey and sometimes greenish calcareo-argillaceous shale; the lowest bed is characterized by *Beatricea undulata*, and *Murchisonia gigantea*. The *Beatricea* is here of a larger size than the examples found in the Hudson River formation. One specimen obtained is ten feet and a half long, six inches in diameter at the larger end, and five inches at the other. Some fragments of others were found to be ten or even fifteen inches in diameter, and, if the length were proportionate, must have been probably over thirty feet long,	12	0
10. Light yellowish-grey limestone, in beds of from half an inch to an inch in thickness, with occasional partings of calcareo-argillaceous shale. They contain abundance of *Strophomena pecten*, and two small and probably undescribed species of *Atrypa*,	5	0
11. Yellowish-white coralline limestone; the corals consist chiefly of four genera, comprehending *Stenopora fibrosa*, *Favosites Gothlandica*, *Halysites catenulatus*, and an undetermined *Heliolites*. They are aggregated in dome-shaped masses, from one to three		

	Ft.	in.
feet in height, and sometimes as much as six feet in diameter. These are surrounded by an ash-grey argillaceous limestone, and cause the overlying beds, conforming to the masses, to have the appearance of slightly undulating strata,	5	0
This coral bed is met with at Point Laframboise, at Cape Henry, which is the west horn, and at Cape Eagle, the east horn of Ellis Bay; the three points comprehending four miles on the strike. In addition to the fossils already mentioned, there are in the last twenty-two feet, undetermined species of *Palæophyllum* and *Ptilodictya*, with *Petraia gracilis*, *Leptæna sericea*, *Strophomena rhomboidalis*, *Orthis lynx*, *O. Laurentina*, *O. Salteri*, *O. Huxleyi*, *Pentamerus reversus*, and an undetermined *Encrinurus*.		
12. Grey limestone, with argillaceous partings; some of the beds contain *Strophomena rhomboidalis*, *S. pecten*, and *Ambonychia radiata*; with some undescribed species,	62	0
13. Grey compact argillo-calcareous beds, slightly bituminous, interstratified with argillaceous bands; these beds form Bear Head. They contain but few fossils, which are mostly obscure; among them are *Orthis Salteri* and *Pentamerus reversus*,	42	0
14. Measures supposed to be similar to the last, but not thoroughly examined; they constitute Long Point,	35	0
	306	6

The dip of these beds is S. 13° W. at Junction Cliff, and S. 10° W., one mile east of it; at White Cliff it is S. 4° W., at Eagle Cape, S. 18° W., and at Bear Head Point, S. 21° W.: the average would be about S. 13° W. The inclination is a little over 100 feet in a mile, and the direct distance across the strata is three miles. The distance occupied by these rocks, alongthe coast, from Junction Cliff to Long Point, is eight miles and a quarter. As a whole, they appear to be softer than those of the Hudson River formation, and offer no very remarkable cliffs along the coast; while their erosion has given rise to Ellis or Gamache Bay, as well as to the depression which holds Gamache Lake, and the creek emptying it at the head of the bay.

2.

Second division.

Immediately overlying the upper beds of the last division, there occur, at Long Point, about twenty feet of light grey limestone, in beds of from two to six inches thick, filled with *Pentamerus Barrandi*. These beds can be traced along the coast, sometimes in the cliff, but generally on the beach, and in the reef between high and low water as far as Becscie River; a distance of nine miles. Additional strata, characterized by the same fossil, are occasionally seen in the cliff, for fourteen miles farther, to Otter River. That part of the following ascending section which overlies the Pentamerus beds, 1, is observed in the twelve miles beyond Otter River, and reaches to within a mile of Jupiter River.

	Ft.	in.
1. Ash-grey and light reddish-grey limestones, in beds of from two to six inches thick; interstratified in the upper part with conglomerate beds of some thickness, at intervals of from two to ten feet. The pebbles are calcareous, from one to three inches in diameter, and lie flat in the beds. Many of the strata are filled with *Pentamerus Barrandi;* with this, however, are associated in some beds, *Favosites Gothlandica*, *Halysites catenulatus*, *Stromatopora concentrica*, with undetermined species of *Petraia* and *Ptilodictya*, *Strophomena pecten*, an undetermined species of *Rhynchonella*, and an *Obolus* or *Athyris*,..	100	0
2. Dark ash-grey slightly bituminous limestone, in beds of from two to six inches, with calcareo-argillaceous partings, weathering to a light orange-brown; conglomerate layers with limestone pebbles occur at irregular intervals. The lowest six feet are characterized by the occurrence, in some abundance, of an undescribed species of *Athyris*, and the following additional fossils are met with throughout the mass: *Favosites Gothlandica*, *Stromatopora concentrica*, *Halysites catenulatus*, undetermined species of *Petraia*, *Ptilodictya*, and *Diphyphyllum*: *Strophomena Philomela*, *S. Leda*, *Orthis Salteri*, an undetermined *Pleurotomaria*, *Murchisonia gracilis*, and several undetermined species of *Orthoceras*,........	20	6
3. Dark ash-grey slightly bituminous limestone; with calcareo-argillaceous partings, weathering light orange-brown, as before. It contains *Stenopora fibrosa*, undetermined species of *Petraia* and *Ptilodictya*, *Strophomena Leda* and *Orthis Salteri*,..............	34	6
4. Reddish-grey slightly bituminous limestone, with calcareo-argillaceous partings as before, and holding *Stenopora fibrosa*, *Favosites Gothlandica*, undetermined species of *Aulopora*, *Petraia*, and *Ptilodictya*, *Strophomena Leda*, *Orthis Salteri*, undetermined species of *Rhynchonella*, *Leperditia*, and *Beyrichia*, with *Calymene Blumenbachii*. Some of the beds near the top are characterized by deep serpentining grooves, about a quarter of an inch wide, with raised edges; apparently the track of some species of mollusk,........	36	0
5. Reddish-grey limestone, in beds from one quarter of an inch to three inches thick, some of which weather to a reddish-brown; interstratified with occasional conglomerate layers of from two to four inches thick. Some beds at the base are marked by the same grooves as before, and others, in one or two places, contain *Stenopora fibrosa*, *Favosites Gothlandica*, an undetermined *Petraia*, *Strophomena Leda*, and *Orthis Salteri*,........................	73	0
6. Measures concealed,..	40	0
7. Grey yellowish-weathering limestone, containing but few fossils; those met with are *Stenopora fibrosa*, *Favosites Gothlandica*, *Halysites catenulatus*, an undetermined *Petraia*, *Strophomena Leda*, *Orthis Salteri*, *Atrypa congesta*, in some abundance towards the base, and an undetermined *Rhynchonella*. The surface of one bed towards the middle is characterized by marks, which are probably the result of weathering. The bed is a couple of inches thick, and is worn into a multitude of rather deep connected pits, about an inch wide and two or three inches long, in each of which is perceived a fragment of a shell, standing with its edge up. There is generally a rude parallelism in the pits, but some of them cross others, and some descend nearly through the bed,..............	34	0

		Ft.	in.
8.	Measures concealed,...	17	0
9.	Ash-grey, smoke-grey, and reddish-grey, slightly bituminous limestones, in beds of from one quarter of an inch to ten inches thick, weathering yellowish-brown in some parts. About two thirds from the bottom, there occur slender serpentining fucoids of a yellowish-white, very conspicuous from the contrast of color. In addition to these, there are met with, in different parts of the mass, *Stenopora fibrosa*, *Favosites Gothlandica*, *Halysites catenulatus*, with undetermined species of *Petraia*, *Ptilodictya*, and *Heliopora ; Strophomena pecten*, *S. Leda*, *Orthis Salteri*, *Atrypa reticularis* (occurring for the first time, near the bottom), undetermined species of *Pleurotomaria* and *Murchisonia*, a small undetermined *Orthoceras*, *Calymene Blumenbachii*, and an undetermined *Encrinurus*,..	65	0
10.	Measures concealed,...	27	0
		447	0

The total distance which these rocks occupy along the coast, from Long Point to within a mile of Jupiter River, is thirty-six miles.

3.

Third division.

The third division of the group commences where the previous series terminates, and reaches to South-West Point; occupying a distance of a little more than seven miles, in a direction very nearly S. S. E. The dip of the strata is very constant in direction, not varying in any part more than about five degrees from the average, which is S. 7½° W.; while the inclination is sometimes 200 feet in a mile, and at other times quite inappreciable. With the exception of some portions concealed at the base, and more at the summit, the measures are visible the whole way; forming cliffs of from twenty to one hundred and fifty feet.

The following is the sequence of the strata in ascending order :—

		Ft.	in.
1.	Measures concealed,...	27	0
2.	Greenish-grey and brown fine arenaceo-argillaceous shales, interstratified with one another, in thin beds; no fossils are seen,....	60	0
3.	Yellowish-grey and light drab argillaceous limestone, slightly bituminous; in beds of from one to five inches, cut by parallel joints running N. 85° W., with an occasional joint running oblique to that course. The jointed structure and the soft nature of the rock, cause large masses of it to fall from the cliff by the action of the sea, which is here encroaching rapidly on the land. Among the fossils, which are generally in a good state of preservation, are *Favosites Gothlandica*, an undetermined *Graptolithus*, *Stricklandia* like *S. lens*, *Atrypa reticularis*, *A. hemispherica*, undetermined species of *Rhynchonella*, *Athyris*, *Cyrtodonta*, *Avicula*, *Myalina*, *Cyclonema*, *Orthoceras*, *Ascoceras*, and *Cyrtoceras*, *Calymene Blumenbachii*, *Phacops Orestes*, and *Illænus orbicaudatus*,........	80	

	Ft.	in.
4. Light-drab argillaceous limestone, slightly bituminous, weathering white; interstratified with yellowish limestone, weathering yellowish-brown; both in beds of from two to three inches thick. The fossils are not numerous, but weathered surfaces present well preserved specimens of an undetermined *Ptilodictya*, *Strophomena Leda*, *S. pecten*, *Atrypa reticularis*, *A. hemispherica*, *Stricklandia brevis*, *Phacops Orestes*, and *Calymene Blumenbachii*, ...	22	6
5. Ash-grey and light drab limestones interstratified, both slightly bituminous, in beds of from half an inch to two inches. The exposed surfaces are nearly white, and show fossils, of which a large number are weathered nearly black. Among them are *Stenopora fibrosa*, undetermined species of *Ptilodictya* and *Petraia*, *Leptæna transversalis*, *Strophomena pecten*, *S. antiquata*, *Orthis Salteri*, *Atrypa congesta*, *A. reticularis*, *A. hemispherica*, an undetermined *Athyris*, *Stricklandia brevis*, an undetermined *Cyclonema*, *Phacops Orestes*, *Calymene Blumenbachii*, with undetermined species of *Encrinurus* and *Lichas*, ...	42	6
6. Ash-grey and light drab limestones interstratified; both slightly bituminous, in beds of from two to three inches, holding in the upper part *Stricklandia lens* in some abundance,.....................	10	3
7. Ash-grey and light-drab limestones interstratified, both slightly bituminous and crowded with *Stricklandia lirata*, ...	2	6
The position of the beds is just west of the last brook but one, in approaching South-West Point.		
8. Measures concealed, with one foot of light drab argillaceous slightly bituminous limestone in the middle,..........................	51	0
9. Light drab argillaceous limestone, slightly bituminous, in beds of from half an inch to three inches, containing numerous fossils, of which exposed surfaces present excellent specimens, weathered black; while the edges of the beds along the cliff, yield others quite detached from the rock. Among them are *Stenopora fibrosa*, *Favosites Gothlandica*, undetermined species of *Petraia*, *Heliopora*, and *Ptilodictya*; *Leptæna transversalis*, *Strophomena Philomela*, *S. pecten*, *Orthis Salteri*, *Stricklandia lens*, *Spirifera radiata*, an undescribed *Athyris*, *Atrypa reticularis*, undetermined species of *Cyclonema* and *Orthoceras*, *Calymene Blumenbachii*, *Phacops Orestes*, and an undetermined *Encrinurus*,....................	87	6
The position of the beds, 9, is a little east of the last brook, in approaching South-West Point.		
10. Measures concealed at the bight of the cove, north of South-West Point,..	157	6
	540	9

4.

Fourth division.

In immediate sequence to the concealed beds which constitute the summit of the last division, the following strata occur, in ascending order, and form the whole of the area of what is called South-West Point.

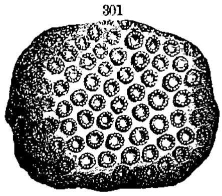
	Ft.	in.
1. Light smoke-grey somewhat granular limestone in beds from two to six inches thick, with thin partings and patches of green argillo-calcareous shale. Iron pyrites is disseminated through the lower four feet, sometimes in single cubes, and sometimes in aggregations of these, forming nodules of one or two inches in diameter, and extending, at the top of the four feet, into patches of from six to eighteen inches in diameter, and from half an inch to an inch thick. The upper eight or nine feet hold fossils, which are well displayed in the same beds, at the Jumpers, between two and three miles east of South-West Point. They consist chiefly of *Stromatopora concentrica*, *Stenopora fibrosa*, *Favosites Gothlandica*, *F. favosa*, *Halysites catenulatus*, *Zaphrentis Stokesi*, *Alveolites Labechei*, one undetermined species of *Petraia*, two of *Heliolites*, two of *Cyathophyllum*, and one of *Ptychophyllum*, *Leptæna transversalis*, an undescribed species of *Strophomena*, with *S. rhomboidalis*, *S. Philomela*, *S. pecten*, *Orthis Salteri*, *O. elegantula*, *O. Davidsoni*, *Pentamerus oblongus*, *Stricklandia brevis*, *S. lens*, *Spirifera radiata*, two undetermined species of *Athyris*, one of *Rhynchonella*, *Atrypa reticularis*, *A. hemispherica*, *A. congesta*, two undetermined species of *Cyclonema*, and one or two of *Pleurotomaria*, *Murchisonia turricula*, two undetermined species of *Bellerophon*, and three or four of *Orthoceras*, *Calymene Blumenbachii*, *Phacops Orestes*, with undetermined species of *Illænus*, *Encrinurus*, *Lichas*, *Dalmanites*, *Leperditia*, and *Beyrichia*,	10	9
2. Yellowish or reddish white granular limestone, with thin vein-like patches of calcareo-argillaceous shale disseminated through it. The beds of limestone are from three to seven inches thick. Among the organic remains, almost all of which are included among those of the preceding beds, is an undetermined and characteristic *Ptychophyllum*, some specimens of which are a foot in diameter. *Favosites Gothlandica* also occurs in tables of half an inch thick, and sometimes three feet in diameter,........................	7	6
3. Yellowish-white granular limestone, in beds of from six to eighteen inches thick; often separated by thin partings of green argillo-calcareous shale, which is also disseminated in small patches through the bed. The fossils are few in species, being chiefly the ruins of crinoidal columns, which in some cases form the entire mass of a bed,......................................	39	0
4. Yellowish-white granular limestone, in beds of from six to eighteen inches thick; consisting of masses of organic remains, of which crinoidal columns constitute the larger part; some of them being three quarters of an inch in diameter. Other fossils are met with; among which are *Stromatopora concentrica*, *Favosites Gothlandica*, *F. favosa*, *Halysites catenulatus*, *Alveolites Labechei*, with undetermined species of *Petraia*, *Fenestella*, *Cystiphyllum*, and *Cyathophyllum*; *Strophomena rhomboidalis*, *Orthis Davidsoni*, *Atrypa reticularis*, *A. hemispherica*, an undetermined *Rhynchonella* and an undescribed *Cyrtia*, *Cyclonema varians*, *C. percingulata*, an undetermined *Orthoceras*, *Illænus orbicaudatus*, *I. grandis*, *Calymene Blumenbachii*, with undetermined species of *Lichas* and *Cheirurus*,	16	0
	69	3

This is the highest series of strata met with on the island, and its lithological characters are so well marked that it is scarcely possible to mistake it for any of those which precede. The South-West Point light-house stands on the beds, 4; and similar beds occur in the cliffs on both sides of a cove, about two miles west from the Chicotte River; while the rocks met with at the intermediate points which have been visited, appear to correspond with one part or other of this series.

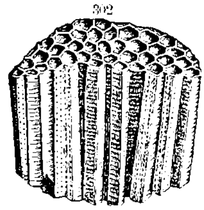
The rocks in these cliffs, exhibiting about thirty feet of the strata, appear to be somewhat disturbed; the dip and strike are irregular, and the inclination sometimes amounts to as much as twelve degrees. These strata can be traced to within about half a mile of the Chicotte River, and

301-303.—ZOOPHYTA.

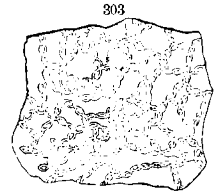
301



302



303



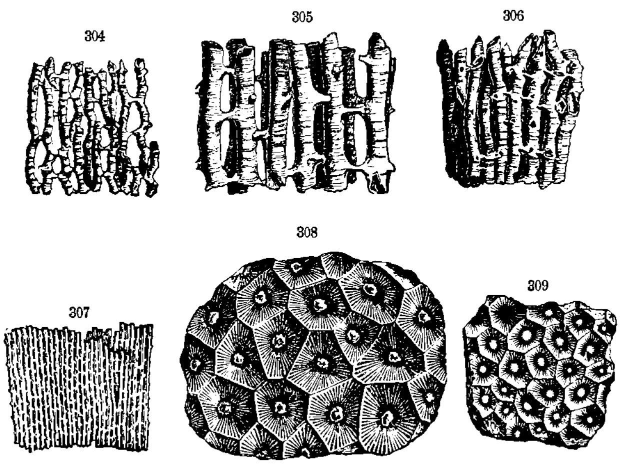
301.—*Heliolites interstincta* (Linnæus).
302.—*Favosites Gothlandica* (Goldfuss).
303.—*Halysites catenulatus* (Linnæus).

as no instance of them has been observed farther to the eastward, the Chicotte River may be assumed as their limit. This would give to the second division, a stretch of thirty miles along the coast.

Eastward from the Chicotte River, the upper beds of the subjacent or third division of the series, preserve a nearly horizontal attitude in twelve separate exposures, in a distance of about twenty-five miles, to South Point. What are considered to be the same measures, are continued to Cormorant Point, about twenty miles still farther; in the course of which, they suffer a few moderate undulations. Beyond this point, which presents a cliff of twenty or thirty feet high, the coast gains upon the measures; and at the distance of about two miles and a half, there occurs a dislocation running N. 37° E.; producing a downthrow on the east side, of forty-five feet. Between Cormorant Point and this dislocation, there is exposed a thickness of 123 feet of ash-grey limestone, supposed to include the equivalents of the strata exposed from Chicotte River, and to represent the summit of the third division; which is concealed near South-West Point. The fossils observed in these strata, from the Chicotte River to the fault, are *Stenopora fibrosa*, *Stromatopora concentrica*, an undetermined *Heliopora*, *Favo-* Third division.

sites Gothlandica, *F. favosa*, *Halysites catenulatus*, *Zaphrentis Stokesi*, *Alveolites Labechei*, with undetermined species of *Cyathophyllum*, *Ptilodictya*, *Petraia*, and *Graptolithus*, *Leptœna transversalis*, *Strophomena rhomboidalis*, *S. pecten*, *S. Philomela*, *Orthis Salteri*, *O. Davidsoni*, *O. elegantula*, *Pentamerus oblongus*, an undetermined *Stricklandia*, and *S. brevis*, *Spirifera radiata*, *Atrypa reticularis*, *A. congesta*, *A. hemispherica*, undetermined species of *Rhynchonella*, *Athyris*, *Cyrtodonta*,

304–309.—ZOOPHYTA.



304.—*Syringopora reteformis* (Billings).
305.—*S.*——— *verticillata* (Goldfuss).
306.—*S.*——— *Dalmani* (Billings).
307.—*S.*——— *compacta* (Billings).
308.—*Strombodes pentagonus* (Goldfuss).
309.—*S.*——— *gracilis* (Billings).

Avicula, *Cyclonema*, *Murchisonia*, *Pleurotomaria*, *Conularia*, and *Orthoceras*; with *O. persiphonatum*, *Calymene Blumenbachii*, *Phacops Orestes*, and undetermined species of *Encrinurus* and *Illœnus*.

The remaining part of the third division composes the coast eastward to Heath Point, and northward round East Point; where the strata present a cliff of 120 feet, and reach to the west side of the cove immediately beyond the point. They consist of ash-grey, light smoke-grey, and yellowish-grey limestones, containing fossils similar to those in the corresponding portion of the division to the westward. Their thickness is about 428 feet; making the whole volume of the third division, at the east end of the island, about 550 feet.

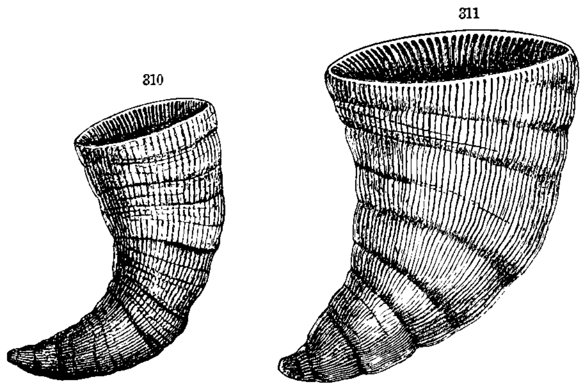
The rocks on the north side of the island, at the east end, which, from their position in the succession there, are supposed to represent the second division, have as yet been too imperfectly examined to determine accurately their volume; which however is estimated to be about 480 feet. Nothing has been observed to establish their exact equivalency; so that it is from the relations which they bear to what is above and below them, rather than from what the north and south exposures have in common, that they are considered as equivalents. On the north coast, they occupy ten miles and a half, and deep water prevails along the whole distance. In most places, the sea beats against a precipitous cliff at high water, and in some parts even at low water; while there are but two or three coves at which a landing can be easily made. It would require very calm weather to effect a thorough examination; and on account of the storms at the time of our visit, it was only at the two extremes of the distance that measurements were made. Second division.

The upper part of the series consists of grey limestones; twenty-five feet of which, at the summit, of a yellowish tinge and slightly bituminous, are a very marked coral-bed, which can be followed a considerable way along the coast. This bed is irregular in its surface, some masses of coral rising from one to five feet high, with a horizontal diameter of from two to ten feet. The overlying bed conforms in some degree to these inequalities, and gives the strata the aspect of having been disturbed. The corals consist of *Stenopora fibrosa*, *Favosites Gothlandica*, *Halysites catenulatus*, with undetermined species of *Heliolites* and *Cyathophyllum*. In a lead-grey limestone beneath the coral-bed, *Leperditia Anticostensis* occurs in considerable abundance.

After an unexamined interval, giving about 200 feet in thickness, sixty feet of yellowish-grey slightly bituminous limestone occur, in beds of from half an inch to four inches. These are separated by thin layers of calcareous shale, and hold two or three undetermined species of *Ptilodictya* and *Petraia*, *Stenopora fibrosa*, *Favosites Gothlandica*, *Halysites catenulatus*, *Orthis Salteri*, *Strophomena pecten*, *S. Leda*, *S. rhomboidalis*, undetermined species of *Rhynchonella* and *Atrypa*, with *A. congesta*, *Stricklandia lirata*, *S. brevis*, undetermined species of *Murchisonia*, *Pleurotomaria* and *Orthoceras*, *Calymene Blumenbachii*, *Illænus orbicaudatus*, and an undetermined *Asaphus*. This mass occurs in Sandtop Bay, between which and Gull Cape, there is an unexamined interval, giving eighteen feet. In Gull Cape, and in Gull Cove beyond, a section of 128 feet consists, at the top, of fifty-eight feet of dark grey slightly bituminous limestone, followed by twenty feet of light yellowish-grey bituminous limestone. This rests on thirty feet of greenish calcareo-arenaceous crumbling shale, and is terminated by twenty feet of lead-grey thin bedded limestone, which are interstratified with similar shales. The fossils observed in this section are an undetermined *Petraia*, *Favosites Gothlandica*, an undetermined *Strophomena*, *Orthis Salteri*, *Rhynchonella robusta* (occurring in great abundance in the shale), an undetermined species of *Athyris*, *Pentamerus oblongus*, *P. Barrandi* (one valve seen in the shale), with undescribed species of *Cyclonema*, *Murchisonia*, and *Orthoceras; Phacops Orestes* and *Illænus orbicaudatus*.

First division. The first division stretches on the north side of the island, from Gull Cove and Reef Point, to Table Head, a distance of about seven miles, and is again partly visible in the bight of Prinsta Bay; where it occupies about two miles. As is the case in the neighborhood of Ellis Bay, the cliffs composed

310, 311.—ZOOPHYTA.



310.—*Petraia calicula* (Hall).
311.—*Zaphrentis Stokesi* (Edwards and Haime).

of the rocks of this division at Fox River, are low, not exceeding thirty or forty feet. The deep excavation which here forms the harbor, shows another feature, which the two extremities of the first division have in common. The upper part of this division is concealed in the lagoon of Fox River, as well as on the outside of Reef Point, which is the eastern horn of Fox Bay; but about 180 feet of the lower part, consist of grey argillaceous and arenaceous limestone, with greenish and grey calcareo-argillaceous shales. The total thickness of the division is computed to be about 296 feet, and the fossils collected from the strata exposed, are undetermined species of *Petraia*, *Ptilodictya* and *Pasceolus; Stenopora fibrosa*, *Strophomena rhomboidalis*, *S. pecten*, *Orthis lynx*, *O. Salteri*, *O. Laurentina*, undescribed species of *Rhynchonella* and *Athyris*, undetermined species of *Avicula*, *Pleurotomaria* and *Murchisonia*, with *M. gigantea*, undetermined species of *Straparollus*, *Orthoceras*, and *Cyrtoceras; Calymene Blumenbachii*, and an undetermined species of *Asaphus*.

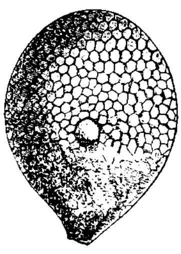
The total thickness of the Anticosti group, as displayed at the opposite ends of the island, would thus appear to be very nearly the same; the comparison being as follows:— Thickness of the group.

	WEST END.		EAST END.	
	Ft.	*in.*	*Ft.*	*in.*
1st division,........................	306	6	296	0
2nd "	447	0	480	0
3rd "	540	9	551	0
4th "	69	3	69	3
	1363	6	1396	3

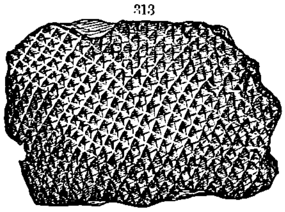
It is only the coast of the island that has yet been examined; so that the geographical distribution of these divisions in the interior, is for the present conjectural. The very moderate slope which the measures everywhere present, however, renders it very probable, that, while there will be a general

312, 313.—TUNICATA.

312



313



312.—*Pasceolus Halli* (Billings).
313.—*Ischadites Canadensis* (Billings).

regularity in the parallelism of the escarpments, any deeply worn water courses that may be transverse to the strike, will produce considerable indentations in the lines of outcrop.

There are evidences of the existence of the Anticosti group on the south side of the Shickshock mountains, on the Chatte and Matanne Rivers, and, farther to the westward, on the Metapedia and Great Metis Rivers; but it has not yet been found practicable to determine its southern limit, and to separate it from the newer rocks in that direction. The corrugated condition of the rocks of the Gaspé Peninsula, and the difficulties of exploration, arising from the uninhabited state of the interior, have prevented that accumulation of facts, which is required to establish a detailed classification of its rocks. It is therefore for the present found necessary to arrange them in larger divisions than in Western Canada. What is known of the Anticosti group on the south side of the St. Lawrence, will The group in Gaspé.

be stated in describing that region in another chapter. For the present, we shall follow out the distribution of the same group in Western Canada, and shall then describe the Guelph formation, which succeeds it in that part of the province.

ANTICOSTI GROUP IN WESTERN CANADA.

THE MEDINA AND CLINTON FORMATIONS.

In Ulster county, New York, according to the state geologists, the Hudson River formation is followed by a quartzose conglomerate, constituting the Shawangunk Mountain; which sometimes attains a thickness of 500 feet; and in Oneida and Oswego counties, becomes a grey, fine grained, hard, even-bedded sandstone. This is often spotted with red stains, from peroxyd of iron; and contains thin interposed layers of greenish shale, similar to the underlying Hudson River shales; the two formations showing a gradual passage from the one to the other. At Oswego, the mass is about a hundred feet thick, and some few fragments of undetermined fossils have been met with in it. In the two counties last named, the Oswego sandstone runs from New Hartford to Oswego, a distance of about eighty-five miles; and to the westward, sinks beneath the waters of Lake Ontario.

Medina in New York.

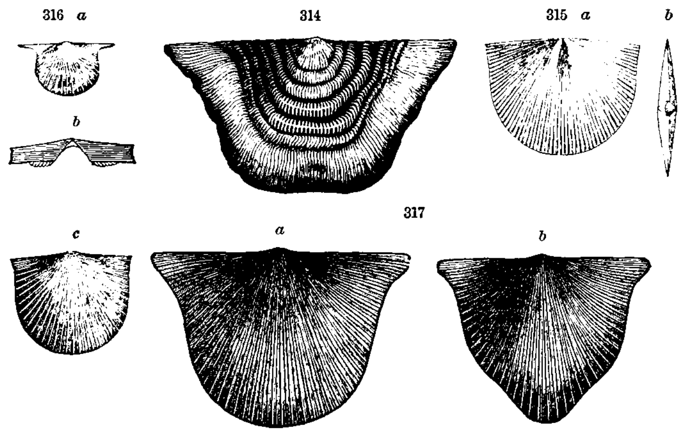
In going upwards, this grey sandstone passes into the red sandstone of the Medina formation; the two differing lithologically, near the junction, in little more than in color. A gradual passage is thus established, in New York, between the Hudson River and the Medina formations. The latter, at Rochester, consists of a great mass of red marls, and red marly or shaly sandstones, banded and spotted with green, and surmounted by about ten feet of grey or whitish sandstone; to which succeed about twenty feet of red shales and sandstones, as before; with *Arthrophycus Harlani*. The series is terminated by seven feet of grey sandstone, known as the Grey band; and the whole volume of the formation may be somewhat under 600 feet.

Oneida conglomerate.

In Oneida county, this sandstone is often a conglomerate, with quartz pebbles rarely exceeding three quarters of an inch in diameter; from which it has been designated the Oneida conglomerate. In some places, it attains the thickness of twenty-five feet; and it is supposed by Prof. Hall to be the equivalent of the conglomerate of the Shawangunk Mountain. To the eastward of Oswego, the Medina formation, like the sandstone beneath it, dies out; and in the southern part of Herkimer county, the Clinton formation, about to be described, is only separated from the Hudson River shales, by a small thickness of the Oneida conglomerate. This, in its turn, also disappears, still farther to the east; and at the base of the Helderberg hills, the whole Middle Silurian series is represented by only a few feet of strata. (Hall's Palæontology, Vol. II, p. 1.)

On the Genesee River, the Grey band is succeeded by twenty-three feet of green shale, supporting a bed of oolitic fossiliferous peroxyd of iron of fourteen inches. Above this are fourteen feet of a limestone, described as silicious, but more probably magnesian; characterized, among other fossils, by *Stenopora fibrosa*, *Strophomena Clintonensis*, *Atrypa hemispherica*, *A. congesta*, and more particularly by *Pentamerus oblongus*. This is followed by twenty-four feet of green shale, succeeded by eighteen feet of a limestone Clinton in New York

314–317.—BRACHIOPODA.



314.—*Strophomena rhomboidalis* (Wahlenberg).
315.—*S.* ——— *pecten* (Linnæus); *a*, ventral; *b*, hinge view.
316.—*S.* ——— *Leda* (Billings); *a*, ventral valve; *b*, portion of the area of ventral valve, magnified to show the striated teeth; *c*, ventral valve of a specimen without ears, —supposed to be the same species.
317.—*S.* ——— *Philomela* (Billings); *a*, and *b*, two specimens of different forms.

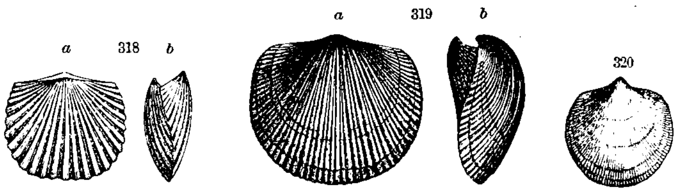
like the last; containing the characteristic species, *Spirifera radiata* and *Beyrichia lata*. These beds constitute the Clinton formation; which has here a thickness of about eighty feet. On the Oswego River, it appears from the geological map of the State Survey, to have a greater breadth, but its thickness is not stated; it gradually thins down however, to the eastward, and disappears in Montgomery county.

To the westward, the Medina and Clinton formations run in two parallel zones along the south side of Lake Ontario, and cross the Niagara River

Medina in Canada.

into Canada; the Medina increasing, and the Clinton diminishing in volume. On the south side of Lake Ontario, the base of the Medina is concealed under the waters of the lake; but it is exposed on the north side, to the eastward of Oakville, near the line between the counties of Halton and Peel; where it succeeds to the Hudson River formation, without the intervention of the grey sandstone of Oswego. At the base, it consists of red and green striped slaty sandstones and shales, with a few obscure fucoids. At Wellington Square, one of its members, about 400 feet from the base, crops out as a thick red coarse grained sandstone; which yields to the influence of the weather, on exposure, and is therefore unfit for building purposes. The remainder of the series of beds, up to the lower band of grey sandstone, is made up of red shales or marls, with green spots and stripes; interstratified with thin bands of red sandstone. The upper

318-320.—BRACHIOPODA.



318.—*Orthis Davidsoni* (DeVerneuil); *a*, dorsal; *b*, side view.
319.—*O.*—— *porcata* (McCoy); *a*, dorsal view; *b*, side view.
320.—*O.*—— *elegantula* (Dalman).

part of the formation is well displayed on the north side of Burlington Bay; and from Hamilton to the Niagara River, sections of it may be seen in almost every brook that has worn a channel from the ridge to the lake. The best development of this part occurs on the Niagara River, where there is exposed a section, including the Grey band, of more than 200 feet. These strata can be traced, dipping up the river, on both sides, from Queenston and Lewisville, to within a quarter of a mile of the cataract; the direct distance being about four miles. The total thickness of the formation at the western end of Lake Ontario, is computed to be 614 feet. The only organic remains which have been obtained from it, are *Arthrophycus Harlani*, near the top of the red portion at St. Catherines; with an undescribed fucoid, and *Lingula cuneata*, from the forty-ninth lot of the township of Niagara.

In Canada, for reasons which will be stated in describing the Niagara formation, it is found convenient to limit the Clinton to the strata beneath the Pentamerus band, and to include this band in the Niagara formation. On the Niagara River, the Clinton is thus limited to a few feet, but it gradually augments in thickness to the northward.

In the cutting of the Welland Canal at Thorold, about seven miles to the west, the Grey band is a white fine-grained sandstone, somewhat irregularly deposited; the beds thinning out, and occasionally coming to wedge-shaped terminations. When of sufficient thickness, they afford excellent material for the purposes of construction, and altogether constitute a mass of about ten feet. Immediately above this band, the Clinton appears, consisting of four feet of bluish and greenish argillaceous shale, presenting fucoids on the surfaces of the beds: among these are fine examples of *Arthrophycus Harlani*, especially near to the underlying sandstone. The shales here show no indication of the fossiliferous iron ore beds. Thorold.

At Mr. Goodenow's quarry, about a mile and a half west from the village of Thorold, and immediately above the Grey band, which is there ten feet thick, there occur the following Clinton strata, in ascending order:—

	Ft.	*in.*
Bluish-green argillaceous shale,..................................	4	0
Bluish-grey limestone, abounding in iron pyrites for an inch on the top,	2	9
Bluish-drab argillaceous limestone, yielding a hydraulic cement,....	3	1
	9	10

In the neighborhood of Hamilton, the Grey band is about twelve feet thick, and the Clinton strata which succeed are—

	Ft.	*in.*
Blue thin-bedded limestone, with thin partings of bituminous shale,.	9	0
Bluish thin-bedded limestone, somewhat slaty in the lower part,...	3	6
Green shale, with thin irregular beds of limestone,...............	19	0
Measures concealed, but supposed to be similar shales,............	18	0
	49	6

On the Sydenham road, on the sixteenth and seventeenth lots of the first range of Flamborough West, near Dundas, the whole formation appears to be still thicker. The following are the details of the section in ascending order:— Flamborough.

	Ft. in.	*Ft. in.*
Whitish and grey sandstone with ferruginous spots, in two beds, constituting the Grey band,................................		8 6
Grey thin shaly sandstones, weathering yellowish, and divided by partings of bluish-grey shales; containing, in addition to fucoids, *Atrypa plano-convexa*, *Modiolopsis orthonota*, a new species of *Cyrtodonta*, and *Murchisonia subulata*,......................	0 11	
Grey compact calcareous sandstone in two beds, with a thin parting of pyritiferous shale; small nodules of iron pyrites, with fucoids and other fossils, stand out on exposed surfaces. Among them are *Stenopora fibrosa*, *Zaphrentis Stokesi*, crinoidal columns, *Heliopora fragilis*, *Ptilodictya crassa*, *Phænipora ensiformis*, *Strophomena rhomboidalis*, *Orthis elegantula*, *Rhynchonella neglecta*, *Athyris naviformis*, *Atrypa plano-convexa*, and *Tentaculites distans*,..	1 9	

	Ft.	in.
Dark bluish-grey limestone, sometimes of a purple tinge, and weathering to a pale red; in beds separated by partings of bluish-grey shale, passing into black and sometimes buff; containing, among other fossils, *Stenopora fibrosa*, *Zaphrentis Stokesi*, *Heliopora fragilis*, *Ptilodictya crassa*, *Phœnipora ensiformis*, *Rhinopora verrucosa*, *Fenestella prisca*, *Strophomena rhomboidalis*, *S. pecten*, *Orthis lynx*, *O. elegantula*, *Rhynchonella neglecta*, *Athyris naviformis*, *Atrypa reticularis*, *A. plano-convexa*, *Spirifera radiata*, *Modiolopsis orthonota*, a new species of *Cyrtodonta*, *Murchisonia subulata*, *Orthoceras*, *Calymene Blumenbachii*, and *Encrinurus punctatus*, ...	7	0
Bluish-grey argillaceous shales, with green layers, and thin bands of impure limestone, which hold fossils similar to the last. The lower beds are marked with small green spots,...............	8	0
Buff shales, with thin bands of limestone holding *Stenopora fibrosa*, an undetermined *Petraia*, *Heliopora fragilis*, *Rhinopora verrucosa*, *Strophomena rhomboidalis*, *Orthis lynx*, *Atrypa reticularis*, *A. plano-convexa*, and *Athyris cylindrica*. The disintegrated shales of this and the previous division are used as fire-clay,....	12	0
Measures concealed,...	7	4
Bluish-grey calcareo-arenaceous shale, with argillaceous bands, ...	11	0
Green and grey calcareo-argillaceous and arenaceous shale, with calcareous sandstones towards the top. The beds hold a few fossils; among which are *Heliopora fragilis*, *Ptilodictya explanata*, and two or three undetermined species of *Ctenodonta*,....	10	8
Red calcareous sandstone in thin beds,..........................	1	0
Green argillo-arenaceous shale,................................	2	0
Red marly shale,..	4	0
Red ferruginous calcareo-arenaceous rock, being a very earthy hæmatite, holding various fossils. Among them, in addition to fucoids, are *Stenopora fibrosa*, *Heliopora fragilis*, an undetermined *Rhynchonella*, *Avicula emacerata*, *A. rhomboidea*, an undetermined *Orthonota*, and *Dalmanites trisulcatus*. In the equivalent of the same stratum, on the eleventh lot of the first range of the township, besides most of the previous species, there are met with *Rhinopora verrucosa*, *Ptilodictya explanata*, *Strophomena rhomboidalis*, *Rhynchonella neglecta*, *Avicula alata*, with undetermined species of *Cyrtodonta*, *Ctenodonta*, *Murchisonia*, and *Orthoceras*. This probably represents the iron ore bed of Rochester, ...	7	0
Red ferruginous calcareo-arenaceous rock, of the same character as before, becoming reddish-brown at the top; with partings of red marly shale. Corals and bivalve shells occur in some abundance in the bed,...	1	8
Red argillaceous shale, with green stripes and patches, and with thin bands of red and green limestone,...........................	5	0
Pale green argillaceous shale, with three bands of limestone,......	5	0
Greenish calcareo-argillaceous and arenaceous shale, with thin divisions of a more decidedly green shale,......................	1	3
Pale bluish-green calcareous sandstone, with nodules of iron pyrites and ferruginous spots and stripes. Obscure fucoids, corals, and shells occur in the bed,..................................	1	9

	Ft. in.	Ft. in.
Pale bluish-green calcareous sandstone, with partings of bluish-green shale, marked by nodules of iron pyrites and by ferruginous stains. Corals, encrinites, and broken shells occur in great abundance at the top,..	3 10	
Bluish-green argillaceous shale,................................	1 3	
	——	92 5
		100 11

The strata of this section are limited by a bold escarpment, composed of the rocks of the Niagara formation, which succeeds. By this escarpment, they are easily traceable from Flamborough West, in a north-easterly direction, through Flamborough East into South Nelson. On entering the latter township, they take a sweeping turn northward, and maintain a general course somewhat westward of north, for seventy-five miles, from South Nelson to Collingwood. The inclination of the measures being very Collingwood.

321-225.—BRACHIOPODA.

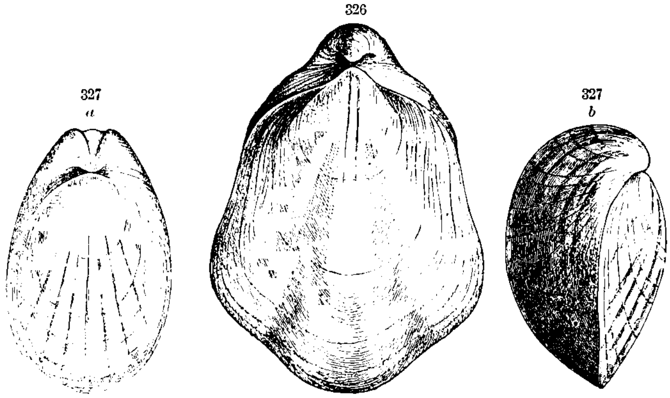
321.—*Rhynchonella rugosa* (Hall).
322.—*R.* ———— *camura* (Hall).
323.—*R.* ———— *cuneata* (Hall).
324.—*R.* ———— *brevirostris* (Hall).
325.—*R.* ———— *neglecta* (Hall).

small, probably not exceeding thirty feet in a mile, the outcrop of the series, particularly at the summit, presents a very indented outline, running into deep bays in the valleys of the principal streams; where bold ravines are worn in the rock above. Two of the main indentations are on the Credit in Caledon, and on the Nottawasaga in Mono; between which, the limit of the series spreads out considerably to the eastward in Adjala and Albion. Several minor indentations occur north of this, in Mono and Mulmur, and deeper ones on the Noisy and Mad Rivers in Nottawasaga. From Collingwood, the general outcrop turns to the north-west; but it presents a very deep sinus, southward, up the valley of the Beaver River, reaching nearly to the centre of the township of Artemisia; and another up the valley of the Bighead, in St. Vincent, Sydenham, and Holland. A third indentation carries the outcrop a few miles up the Sydenham River; which flows through the town of Owen Sound into the bight of the bay.

Though the Clinton strata are thus easily traced, by the conspicuous escarpment which rises precipitously above them, they themselves are but seldom seen, being for the most part concealed by a talus of debris. The base of the series, however, is nearly as well marked as the summit, by the sandstone of the Grey band; which crops out from below them, and forms a low but distinct terrace.

Grey band. The Grey band is seen at intervals, all the way from Flamborough West to the township of Mono; varying in thickness from ten to twenty feet, but preserving a pretty uniform lithological character. It is exposed also in many places in Nottawasaga and Mulmur. On the twenty-fourth lot of the tenth range of the former, it attains the thickness of thirty-five feet; above which, the Clinton strata present a volume of ninety-two feet. The Grey

326-327.—BRACHIOPODA.

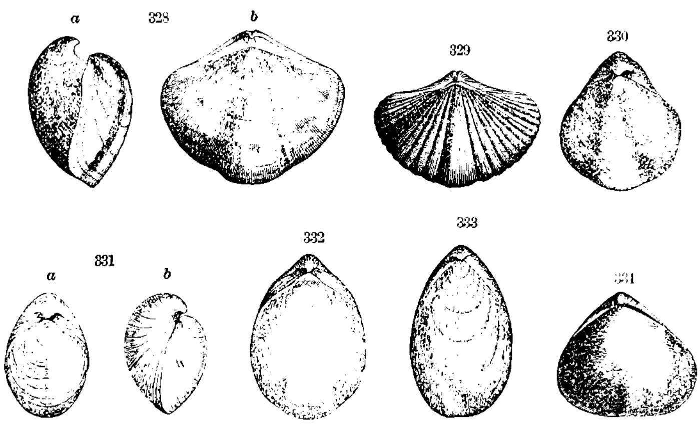


326.—*Pentamerus oblongus* (Somerley).
327.—*P.*——— *Barrandi* (Billings); *a*, dorsal view; *b*, side view.

band has not yet, however, been observed in any of the townships west of Nottawasaga and Collingwood. In several places in the township of Sydenham, the thin bedded limestones of the Clinton formation are seen to rest upon the red and green shales of the Medina; thus proving the absence of the Grey band to the westward, unless perhaps in isolated portions. This sandstone, wherever it has been examined between Queenston and Collingwood, is of a whitish or pale grey color, sometimes striped and spotted with ferruginous stains. It is always well adapted for building purposes, and is, in many instances, a very beautiful and easily wrought material. It has been extensively quarried near Hamilton and Dundas, at Waterdown in the township of Flamborough East, as well as near Georgetown in Esquesing; and it is equally fit for use nearly all the way along its outcrop, to the township of Nottawasaga. In many places towards the north, it is sufficiently free and uniform to yield very good grindstones ; for the manufacture of which it is used from Orangeville to the vicinity of Bowmore, in Nottawasaga. These various applications render the Grey band of considerable economic importance in the district.

The upper parts of the Medina formation are seen beneath the Grey band, in several places along their outcrop northward ; but the lower parts being much covered with drift, it is not easy to trace the limits of the base. The thickness of the series greatly diminishes in that direction; Owen Sound.

328-334.—BRACHIOPODA.

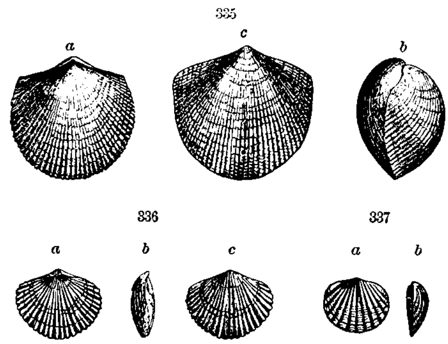


328.—*Spirifera radiata* (Sowerby) ; *a*, side view ; *b*, dorsal view.
329.—*S.* —— *Niagarensis* (Conrad).
330.—*Athyris naviformis* (Hall).
331.—*A.* —— *umbonata* (Billings) ; *a*, dorsal view; *b*, side view.
332.—*A.* —— *crassirostra* (Hall).
333.—*A.* —— *cylindrica* (Hall).
334.—*A.* —— *nitida* (Hall).

and on the twenty-fourth lot of the tenth range of Nottawasaga, it scarcely attains 200 feet. With this diminished volume, however, it appears to be spread out, more extensively than elsewhere, in the townships of Collingwood, Euphrasia, St. Vincent, and Sydenham. Over a considerable part of these townships, the red marls, in a disintegrated state, form an excellent surface soil; and in many places in this area, they are seen in place, where the ground is broken by ditches, the channels of brooks, and road cuttings. In these townships, the Clinton formation also spreads out somewhat wider than usual; and the red ferruginous band which marks the upper part of it, is met with in several exposures; though nowhere sufficiently charged with iron to constitute a workable ore. In the second lot of the fourth and fifth ranges of St. Vincent, in a bed of bluish shale, near the summit of the formation, crystals of gypsum are disseminated in some abundance.

Owen Sound. At Owen Sound, the Medina rocks are limited above by about twenty feet of dolomite, which here constitutes the base of the Clinton formation. This dolomite, which is of a yellowish-color and weathers yellowish-brown, contains, in great numbers, a few species of silicified fossils; among which are an undetermined *Petraia*, *Strophomena rhomboidalis*, and an undescribed *Orthis*, resembling *O. testudinaria*. Between it and the base of the massive limestones, which are classed with the Niagara series, the

335-337.—BRACHIOPODA.



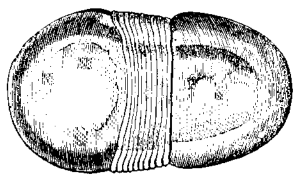
335.—*Atrypa reticularis* (Linnæus); *a*, dorsal; *b*, side, and *c*, ventral view.
336.—*A.* —— *plano-convexa* (Hall); *a*, dorsal, *b*, side, and *c*, ventral view.
337.—*A.* —— *hemispherica* (Sowerby); *a*, dorsal, and *b*, side view.

surface is covered with red clay. The strata from which this is derived, no doubt represent the iron ore bed, and are seen in several places within a circuit of three miles. From the bight of Owen Sound, the Medina and Clinton formations are traceable along nearly the whole lake front of the township of Keppel; and in the vicinity of Cape Commodore, their entire thickness can be determined by actual measurement. Strata of the Hudson River formation here constitute the base of a cliff; above which the red and green Medina shales present a volume of 109 feet. Resting upon these, the Clinton formation shows about thirty-six feet of thin bedded magnesian limestone; between which and the abrupt overlying escarpment of the Niagara series, there is a thickness of about 150 feet. In this, the strata are partially concealed; but a considerable portion of them appears to be red shales. The base of the Clinton appears to cross Colpoy's Bay, at about three and a half miles, and the summit, at about two and a quarter miles, from its western extremity; leaving a mile and a quarter for the breadth occupied by the formation. From this, it would appear that the slope of the strata in this part, is about 120 feet in a mile.

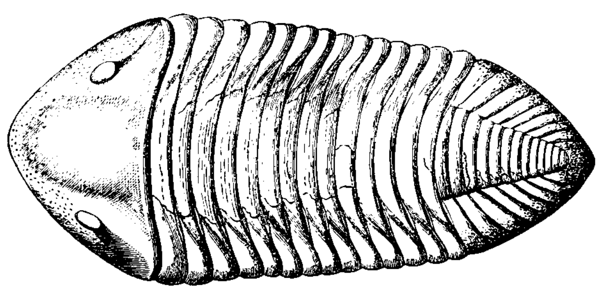
The same two formations occupy the lake front of the townships of Albemarle and Eastnor, with the exception of the peninsula terminating in Cape Crocker. This consists of Hudson River strata; and is overlooked from the westward by a bold escarpment, in the lower part of which the two formations occur. The summit of the Medina series disappears beneath the water at Cape Dundas; while the Clinton continues along the

338, 339.—CRUSTACEA.

338



339



338.—*Bumastes Barriensis* (Murchison).
339.—*Homalonotus delphinocephalus* (Green).

water line, as far north as Cape Chin, rising at Cape Gun and Point Hungcliff to about the height of a hundred feet.

At Cabot's Head, the very summit of the Medina formation is seen at the water's edge; and there rest upon it about twenty-six feet of a dolomite, similar in its color and its weathering to that of Owen Sound; which it also resembles in holding silicified fossils. Here the species are *Stenopora fibrosa*, *Favosites Gothlandica*, an undescribed species of *Diphyphyllum*, *Stromatopora concentrica*, *Strophomena rhomboidalis*, *S. pecten*, *Orthis Davidsoni*, *Atrypa plano-convexa*, with undetermined species of *Murchisonia* and *Pleurotomaria*. On the dolomite, repose 103 feet of red marly sandstones, partially striped and spotted with green, and interstratified

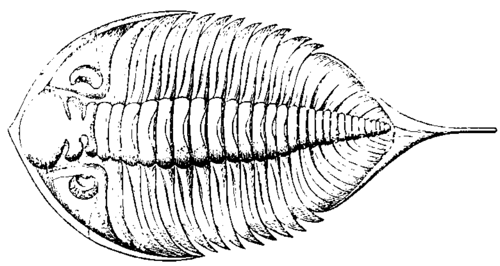
Cabot's Head.

with beds of red and green argillaceous shale; none of which exceed six or eight inches in thickness. The green argillaceous beds appear to be quite free from calcareous matter, and the stone is carved by the Indians into tobacco pipes. These red and green strata are succeeded by about fifty-five feet of green calcareo-argillaceous shales and thin bedded limestones, and terminated by the massive limestones of the Niagara series.

At the base of a cliff composed of the red strata, loose fragments are met with, which strongly resemble the earthy hæmatitic iron ore of Rochester. They are marked by *Heliopora fragilis* and *Ptilodictya explanata;* which characterize the ore bed elsewhere. It would appear that the red strata of Cabot's Head, are only an expansion of the ferruginous beds which underlie the Pentamerus band at Flamborough West.

Proceeding north-westward, these red beds are found in place on the north-eastern point of Horse or Fitzwilliam Island; and the subjacent dolomites, on a small island about a couple of miles northward.

340.—CRUSTACEA.



340.—*Dalmanites limulurus* (Green).

Manitoulin Island

From this, the dolomitic strata, striking into the Great Manitoulin Island, reach Manitoulin Gulf; near the upper end of which they are exposed on the east side, composing a cliff of about forty feet in height; on the beds of which, at the summit, a great many silicified fossils are weathered into relief. They here consist chiefly of the species *Stenopora fibrosa*, an undetermined *Petraia*, *Strophomena rhomboidalis*, *S. pecten*, an undetermined species of *Orthis*, *O. lynx*, and *O. Davidsoni*, with *Atrypa plicatula*. The red strata of the Clinton above, and those of the Medina below these dolomites, are here covered up; but about thirteen miles to the westward, on Tecumseh Lake, a red marly clay, probably derived from the Clinton formation, is washed up from the base of the Niagara limestones.

It is probable that the Clinton formation extends through the length of the Grand Manitoulin Island, as well as that of Cockburn and Drummond Islands, striking across the various deep bays, which indent all these islands on the north side. Its position in these bays must be somewhat north of their most southern parts; and in crossing the largest bay of the Grand Manitoulin, its strike would seem to carry it under the water, not far south of Barrie Island. The probability of the continuance either of this or of the Medina formation, is supported by the reported occurrence of red strata on the Sucker River, on the Michigan side of St. Mary River, nearly opposite to the southern extremity of St. Joseph Island: this would be in the strike of the Clinton. From Tecumseh Lake westward, however, it is only by the position of the Niagara strata above, and those of the Hudson River below, that its course, and that of the Medina, can be inferred; no exposures belonging to these formations having yet been observed in Canada, in that direction.

THE NIAGARA FORMATION.

The rocks of this formation in the state of New York do not extend farther eastward than the township of Litchfield in Herkimer county; falling short of the termination of the Clinton deposits, in that direction, by about forty miles. The formation first appears in that part of the state as an unimportant mass of dark bluish impure concretionary limestone, enclosed in shales of the same color. The concretionary layers, which do not exceed a few feet in thickness, present a mammillated surface; the elevations varying in diameter from three inches to three feet. New York.

As the formation extends westward, its volume gradually increases; and at Rochester it attains a thickness of about 180 feet, consisting of about a hundred feet of very fossiliferous blackish-blue calcareo-argillaceous shale, supporting eighty feet of limestone. This is composed, at the base, of bluish-grey silicious limestone fit for hydraulic purposes; followed by bluish-grey sub-crystalline thin bedded limestone, with partings of black shale; to which succeeds a lighter grey sub-crystalline contorted and concretionary limestone. On this rests a dark bluish-grey thick bedded bituminous limestone with irregular cavities and with masses of chert; followed by a brownish-grey bituminous thin bedded limestone, holding occasional nodules of the same mineral.

At Lockport and Niagara, the thickness of the shale, as given by Mr. Hall, is eighty feet, and that of the limestone 164 feet. The shale includes, at the top, a few beds of argillaceous limestone, yielding a good water cement, and constituting a passage to the calcareous rock above. The lower part of this consists of a grey cemented mass of broken encrinal columns, often beautifully variegated with red. To this succeeds a thick bedded grey sparry limestone, followed by beds of a darker color, upon which rest a brownish bituminous limestone, sparry below, and marked by the presence of the sulphurets of zinc and of lead above. The whole is crowned by a series of dark grey slaty calcareous beds, with mammillated surfaces, separated by thin laminæ of bituminous shale. A large proportion of these limestones has been ascertained to be magnesian. In the slope and precipice over which the rapids and the cataract of Niagara fall, the whole thickness of these limestones is exposed; so that to this series, with the shales below, the geologists of New York have given the name of the Niagara group.

Base of Niagara series.

The bluish-black shales which in the state of New York afford a well marked division between the Clinton and Niagara formations, are available for this purpose but for a short distance in Canada. To the northward, these shales thin out and disappear; and it is for the present very difficult to distinguish them in that direction. We therefore propose to include in the Niagara series, the two bands of limestone which underlie the shales, and which, in New York, constitute the upper part of the Clinton formation. So far as they have been examined in Canada, these two limestone bands contain no Clinton fossils, but such as pass upwards into the Niagara; and the upper band here possesses one or two species, which, in New York, are considered to belong to the latter group only. There would thus appear, at present, to be no palæontological reason why these limestones may not be considered the base of the Niagara formation; while geographically they present a very marked feature for a considerable distance, and afford a convenient means of describing the distribution of the two formations.

Thorold section.

Including these limestones, the Niagara strata seen in the cutting of the Welland Canal, near Thorold, in immediate succession to the Clinton formation, are as follows, in ascending order:—

	Ft.	in.
1. Bluish-grey magnesian limestone, with partings of bluish calcareous shale. Concentric rings of discoloration are observable around small cavities lined with calcspar, which occur generally at the surface of vertical joints, cutting the strata at right angles. The circles are usually so large as to cross the divisional planes of several beds. *Pentamerus oblongus* and *Stricklandia Canadensis* occur in abundance,......................................	10	0
2. Grey coarse grained sub-crystalline limestone, with disseminated iron and copper pyrites; the bed abounds with fossils, among which, on the canal, are *Atrypa reticularis*, *Rhynchonella cuneata*, and *Athyris cylindrica*,......................................	10	0
In the upper five feet of this bed, in Mr. Goodenow's quarry, a mile and a half to the westward, there are fragments of an undetermined species of *Rhodocrinus*, of *Eucalyptocrinus decorus*, and *Cyathocrinus ornatus;* the latter two species are given as characteristic of the Niagara series of New York.		
3. Bluish-black bituminous shale, with thin bands of impure limestone, holding trilobites and a few shells. Among the trilobites, *Dalmanites caudatus* is frequent. In some places, thin bands of gypsum		

Ft. in.

occur, giving a riband-like aspect to the shale. Small nodules of gypsum are also sometimes met with, as well as crystals of iron pyrites. This shale constitutes the base of the Niagara group of New York,.................................... 55 0 — Gypsum.

4. Bluish-grey argillaceous limestone, yielding excellent water cement, which was much used in building the locks of the Welland Canal, 8 0 — Water lime.

5. Dark bluish bituminous limestone, in some places yielding material fitted for purposes of construction, as at Mr. Keefer's quarry at Thorold. The upper and under surfaces of adjacent beds are often united by suture-like joints; the parts interfitting being sometimes two inches in depth, with vertical columnar sides, usually glazed with a thin pellicle of argillaceous matter. Crystals of galena are frequently met with in these beds, which contain many fossils. Among these, where the rock is cut through by the Welland railway, about 200 yards on the strike from the canal, are *Stenopora fibrosa, Favosites Gothlandica, F. Hisingeri, Heliolites interstincta, Halysites catenulatus, Alveolites repens, Petraia calicula, Zaphrentis Stokesi, Z. Marcoui*, an undetermined *Diphyphyllum, Stephanocrinus angulatus, Eucalyptocrinus decorus, Caryocrinus ornatus, Stromatopora concentrica*, an undetermined *Fenestella, Leptæna transversalis, Strophomena rhomboidalis, S. pecten, S. profunda? Orthis elegantula, O. hybrida, Spirifera crispa, S. radiata, S. Niagarensis, Atrypa reticularis, Rhynchonella neglecta, R. cuneata, Athyris nitida, A. crassirostra, Cyrtena pyramidalis, Avicula subplana, Platyostoma Niagarensis, P. hemispherica, Acroculia Niagarensis, Calymene Blumenbachii, Encrinurus punctatus, Dalmanites caudatus, Homalonotus delphinocephalus*, and *Bumastes Barriensis*, 8 0

6. Light and dark grey magnesian limestone, in beds varying from six to ten feet in thickness, constituting a building stone of the best description. It is a cemented mass of broken encrinites, with a few additional fossils, and in some parts holds geodes filled with snow-white gypsum,....................................... 26 0

7. Bluish bituminous limestone well suited for purposes of construction, though inferior to the preceding mass. It holds many fossils, principally corals,.. 7 0

124 0

This section represents all the beds of the series which are crossed on the canal, up to the highest part of the ridge, near Thorold: but it does not reach the summit of the series by probably ninety feet. Proceeding westward, the volume of the black shales diminishes, while that of the limestones beneath them augments; and in the neighborhood of Hamilton and Ancaster, we have the following succession, in ascending order:— Hamilton section.

Ft. in. Ft. in.

1. Light grey magnesian limestone, weathering yellowish, and holding *Pentamerus oblongus* in great abundance,.......... 1 6
Grey magnesian limestone, with geodes of calcspar in the lower, and broken encrinites in the upper part,.................. 9 3 10 9

	Ft.	in.	Ft.	in.
2. Bluish argillaceous and arenaceous shale, with thin bands of sandstone,	5	0		
Grey arenaceous limestone,	3	5		
Bluish shale,	1	0		
Bluish-grey argillaceous limestone, with geodes of calcspar; this is probably fit for water cement,	5	7	15	0
3. Whitish limestone, with geodes of calcspar, containing nodules and patches of chert in considerable abundance,			16	6
4. Bluish-black bituminous shale with thin bands of limestone holding fossils; the shale, which is in very thin laminæ, presents surfaces covered with bituminous matter, and nodules of chert are sometimes met with in the limestone,			6	0
5. Grey strongly bituminous limestone, very unevenly deposited,	5	0		
Reddish-grey, drab-weathering, bituminous, magnesian limestone, moderately thin bedded; with partings of bituminous shale. The limestone holds disseminated crystals of galena associated with pearl-spar. This is equivalent to the bluish-black shale, 3, of the previous section,	5	0	10	0
6. Grey compact tough magnesian limestone,	3	0		
Bluish magnesian limestone, weathering into small pits on the surface, and containing small nodules of a carbonaceous matter, resembling coal,	3	0		
Blue and grey compact magnesian limestones,	3	0		
Grey compact magnesian limestone,	3	0		
Bluish magnesian limestone, weathering into irregular pits on the surfaces of the beds. The rock holds small masses of carbonaceous matter as above,	3	0		
Bluish-grey compact magnesian limestone, presenting under the influence of the weather a rough pitted surface,	5	0	20	0
			78	3

Blende and galena

The limestones, 5, which overlie the black shales, 4, form the upper part of the ridge which extends between the falls of Niagara and the village of Ancaster. They are highly bituminous, and for the most part magnesian for the whole distance; and they abound in fine cabinet specimens of selenite, celestine, pearl-spar, blende, and galena. Crystals of the latter mineral exist in greater or less quantity, in nearly all the limestones from the Pentamerus band to the summit of the upper beds; but they are in the greatest abundance in the latter, especially in the township of Clinton, near the village of Beamsville, where an unsuccessful attempt was made by Mr. Lee to establish a lead mine upon what was supposed to be a lode, on a lot of the eighth range of the township, which is the property of Mr. R. Comfort. The supposed lode, however, appears to be rather one of the open joints or fissures, running E. and W., by which these rocks are intersected in many places. In the locality in question, the fissure, which is filled up with drift, is crossed by small cracks, the walls of which are invested with crystals of pearl-spar and galena. The ore is also seen on each side of the main fissure, and is moreover disseminated throughout the limestone, near the fissure.

Northward from this, the black shale, 4, maintains for a few miles the thickness which it presents in the last section, and it is recognized above the beds already described as composing the Clinton formation, on the sixteenth and seventeenth lots of the first range of Flamborough West, near Dundas (p. 313). In ascending order, these succeeding beds are— Flamborough West.

	Ft. in.	Ft. in.
1. Grey magnesian limestone, with *Pentamerus oblongus* in abundance, and a few other fossils, chiefly fucoids; besides a *Fenestella*, and an undetermined trilobite,....................	1 0	
2. Blue magnesian limestone, in very even and regular beds, of which the thickest are from sixteen to eighteen inches; separated by partings of bluish-grey shale. The limestone is used for building purposes; it is fossiliferous, and shows fucoids, crinoidal joints with *Favosites Gothlandica*, and undetermined species of *Fenestella*, *Orthis*, and *Rhynchonella*, ...	7 0	
3. Light grey magnesian limestone in one bed; this is used for building purposes and is known by masons and quarrymen as the five-feet band. It holds fossils, among which are crinoidal columns, *Fenestella tenuis*, *Strophomena pecten*, *Orthis elegantula*, *Rhynchonella neglecta*, *Athyris naviformis*, *Atrypa reticularis*, and *Spirifera radiata*,.................	5 6	13 6
4. Bluish-grey calcareo-arenaceous shale, passing into black; it is hard and solid in the bed, but disintegrates and crumbles into a clay, when exposed to the atmosphere; with the exception of thin interstratified beds, which resist the weather. Among its fossils are fucoids, *Stenopora fibrosa*, fragments of crinoids, *Ptilodictya crassa*, *Rhinopora verrucosa*, *Retepora angulata*, *Fenestella prisca*, *Strophomena rhomboidalis*, *S. pecten*, *Orthis elegantula*, *Rhynchonella robusta*, *R. neglecta*, *Athyris naviformis*, *Atrypa reticularis*, *Spirifera radiata*, and *Cyclonema obsoleta*. In the same bed, on the eleventh lot of the first range of the township, are *Fenestella tenuis*, *Rhynchonella cuneata*, and an undetermined *Platyostoma*, ... (Black shales.)		6 0
5. Bluish-grey magnesian limestone, composed chiefly of broken encrinites. The beds are from three to four feet thick, and are separated by very thin layers of buff colored argillaceous shale. This limestone forms an excellent building stone, for which it is used, as well as for burning. It holds fossils, among which are fucoids, *Stenopora fibrosa*, *Favosites Gothlandica*, *Zaphrentis Stokesi*, *Eucalyptocrinus decorus*, and fragments of other crinoids, *Strophomena rhomboidalis*, *S. pecten*, *Rhynchonella neglecta*, *Athyris naviformis*, *Atrypa reticularis*, *A. plano-convexa*, *Spirifera radiata*, *S.* ——? *Orthoceras undulatum*, and *Calymene Blumenbachii*,..............	19 3	
6. Dark bluish-grey argillaceous shale; this is a well marked band, and may be traced for some distance on the strike,...	1 0	20 3

	Ft.	in.	Ft.	in.
7. Blue and grey limestone, including bands of white, buff, and grey chert, and thickly studded with chert nodules. Besides fucoids, it holds *Favosites Gothlandica*, crinoidal fragments, *Ptilodictya crassa*, *P. ensiformis*, *Rhynchonella neglecta*, and *Dalmanites caudatus*,	20	0		
8. Brownish bituminous magnesian limestone, with small disseminated crystals of galena, and a few fossils,	10	0		
9. Grey bituminous magnesian limestone in rough irregular beds,	5	0		
10. Measures concealed,	5	0		
11. Black bituminous magnesian limestone in thin irregular layers,	2	0		
12. Black bituminous shale,	1	0		
13. Dark brown very bituminous magnesian limestone, in thin beds with rough irregular surfaces,	2	0		
14. Dark brown bituminous magnesian limestone, holding disseminated crystals of galena,	5	0		
15. Black fissile shale,	2	0		
The beds, from 8 to 15 inclusive, are fossiliferous, and contain, among other species, in addition to fucoids and crinoidal columns, *Strophomena rhomboidalis*, *S. pecten*, *Rhynchonella neglecta*, a new species of *Athyris*, *Atrypa reticularis*, an undetermined species of *Cyrtodonta*, *Encrinurus punctatus*, and *Conularia Niagarensis*. The equivalents of these beds at the Peak, on the north-west side of Dundas, contain, in addition to these, *Favosites Gothlandica*, *Orthis hybrida*, an undetermined *Lingula*, *Athyris nitida*, *Spirifera bicostata*, *S. radiata*, *Pentamerus oblongus*, *Murchisonia subulata*, and *Calymene Blumenbachii*.				
16. Dark very bituminous magnesian limestone with black shale at the top, and with numerous fossils,	3	0		
17. Dark brown bituminous magnesian limestone,	2	0		
18. Black bituminous shaly limestone,	1	0		
19. Measures concealed,	2	0		
20. Black bituminous magnesian limestone with obscure fossils in the lower part,	8	0		
21. Dark grey slaty limestone in thin layers, with an occasional band of six inches,	4	6		
22. Dark brown bitumino-arenaceous shale, with fossils,	0	6		
23. Brownish bituminous limestone with partings and thin bands of dark brown bituminous shale,	15	0	88	0
In the beds, from 16 to 23 inclusive, the fossils, in addition to fucoids and crinoidal columns, are, among others, *Strophomena rhomboidalis*, *Rhynchonella neglecta*, a new species of *Athyris*, *Atrypa reticularis*, an undetermined *Cyrtodonta*, and *Encrinurus punctatus*.				
			127	9

In this section, the black shale of the Niagara Falls is supposed to be represented by the bed, 4, underlying the massive encrinal limestones, 5; but it produces no marked feature in the form of the surface.

The rocks of the section in the neighborhood of Dundas, however, form two separate and distinct terraces. The lower and more marked escarpment presents the strata beneath the band of cherty limestone, 7, which caps the precipice at Flamborough West. The upper escarpment, composed of the dark colored bituminous magnesian limestones and their accompanying beds, rises more gradually, in a succession of steps; terminating at the summit in a wide extent of table-land. Dundas.

Northward from Flamborough East, the massive beds of encrinal limestone, 5, which pass below the cherty band, form the crest of the lower escarpment, and appear to gradually increase in thickness in that direction. At Mr. McNaughton's farm, on the seventh lot of the seventh range of Nassagaweya, there is a vertical precipice, in some places a hundred feet in height. It is capped by the encrinal band, while the Pentamerus bed is probably at the base; but though the stratigraphical place of the black shale would thus be in the cliff, it has not yet been detected. Nearly the whole mass of rock appears to be a light grey drab-weathering limestone; usually presenting a black surface in the cliff, from the presence of minute lichens. Much of it appears to be magnesian, and it for the most part abounds in encrinites. It is well adapted for building purposes, but it seems too porous to be made available as a marble. Some of the beds are well adapted for burning to quick-lime, and these probably contain a smaller proportion of magnesia. Though the very base of the limestone is concealed by a talus of debris, its near proximity is indicated by the copious streams of water which flow along its whole outcrop, from the more argillaceous beds beneath, and issue from among the debris; depositing in their course, large quantities of calcareous tufa. Nassagaweya

In a cutting for the Grand Trunk Railway at Limehouse, on a tributary of the Credit, on the twenty-first lot of the sixth range of Esquesing, the base of the Niagara limestone is seen resting on the beds of the Clinton formation. This has there a thickness of only thirty-four feet; not much more than one third of what it presents in Flamborough West. It consists of ten feet of a bluish shale, resting on the Grey band as a base, and overlaid by seven feet of red shale, which represents the iron ore bed. To this succeeds eight feet of bluish shales, followed by nine feet of water-lime. This bed of water-lime rests on a thin bed of arenaceous shale, with a thin seam of reddish sandy clay holding crystals of iron pyrites, and supports a light grey partially magnesian limestone, belonging to the Niagara series; of which only twenty-seven feet are exposed in the cutting. The characteristic *Pentamerus oblongus* has not been seen here. The species observed are *Strophomena pecten*, an *Ischadites* allied to *I. Kœnigi* (the first instance of the genus on this continent), and *Calymene Blumenbachii*. Esquesing.

The river Credit, in Caledon, is flanked on both sides by the cliffs of the Niagara limestone, in some places a hundred feet high; these, in ascending the valley, meet on the ninth lot of the fourth range of the township, near

River Credit. Bellefontaine, and form a crescent-shaped precipice; over which the river falls in a cascade. In the valley of the Nottawa, similar cliffs prevail; and at Orangeville, some of the rock, of a yellowish-white, would take a sufficient polish to constitute a very useful marble. The cliffs continue through Mulmur and Nottawasaga; and on the twenty-fourth lot of the twelfth range of the latter township, the whole mass of this limestone, to the highest part of the escarpment, has been ascertained by measurement to be about 160 feet thick. As far as seen, its color appears to be greyish at the base, gradually passing upwards into buff or yellowish-white; most of the beds being banded with the two colors. The rock, which is magnesian, is harder in the lower than the upper part, and appears to be encrinal for most of the thickness; the encrinites abounding towards the top. It maintains the same colors and characters along what is called the Blue Mountain ridge, through Collingwood, to the point where the ridge approaches nearest to Lake Huron; and it is probable that the formation thus far does not diminish in volume.

Artemisia. In the valley of the Beaver River, in Euphrasia and Artemisia, the same limestone has a thickness of at least 120 feet. At the head of the valley, on the twenty-sixth lot of the tenth range of Artemisia, the stream falls over a precipice of seventy feet of this magnesian limestone. Flowing thence rather to the east of north, it is flanked on both sides by bold escarpments of the rock, which gradually separate from one another; leaving between them a beautiful and fertile valley, which in a distance of about eight miles, attains a breadth of three miles. In several places the escarpment becomes perpendicular; and in a precipice on the right side of the valley, about the tenth lot of the third range of Euphrasia, forty-seven feet of the rock appear to constitute a single massive bed, without divisional planes. The color of the rock is, as before, a pale buff or yellowish-white, and the weathered parts display obscure encrinites and corals.

The escarpment on the left side of the valley continues northward into St. Vincent; and then makes a sharp turn to the westward, running for ten miles in that direction on the right or southern side of the valley of Big Head River; which is supplied from it with several tributaries. On Sydenham. the left side of this stream, and between it and Owen Sound, the limestone spreads out into a high flat-topped hill, situated chiefly in Sydenham, and presenting to the north-east a vertical escarpment. The encrinal portion of the limestone is well displayed at the summit, while the characteristic *Pentamerus oblongus* occurs on both sides, at the base, in the first range of South Sydenham.

The two streams which flow into the bight of Owen Sound, the Potawatamie from the south-west, and the Sydenham from the south, fall over precipices of twenty and fifty feet respectively, of the lower part of the same limestone; the bottom of which is from twenty to thirty feet beneath the cascades. On the thirteenth lot of the second range of Derby, the escarpment which runs between these two falls, presents a height of sixty feet; at the base of which, there occurs a bed abounding in corals. Among the species are *Favosites Gothlandica*, *Heliolites interstincta*, *Syringopora reteformis*, *S. Lyelli*, *Halysites catenulatus*, and *Zaphrentis Stokesi;* in addition to which, there is found *Pentamerus oblongus*.

The rock of the escarpment in this neighborhood abounds in excellent material for the purposes of construction. About two miles south by east from the town of Owen Sound, there are unworked strata of a white or pale grey color; of which the upper beds are from two to four feet thick, and the lower ones occasionally over twelve feet. The upper bed might be quarried to an almost boundless extent, and would give a very fine and lasting stone. The lower beds are likewise fit for building purposes; but being at the base of an abrupt precipice, they cannot be so conveniently quarried. Large loose blocks, however, skirt the escarpment, and these would furnish a supply for a great length of time. About a mile and a half up the Sydenham River, there has lately been quarried from the lower beds of the escarpment, some fine stone for the light-house constructed on Griffith's Island. The road south from Owen Sound, on the line between Sydenham and Derby, crosses the base of the limestone, about a mile and a half from the town. After a rather sharp ascent over the lower part of the escarpment, it gradually rises for some distance, and reaches what is considered the summit of the formation, on the sixth lot; the total thickness being about 150 feet. Owen Sound.

Across the whole of the western peninsula, the summit of the Niagara formation is so much covered with drift, that it would be very difficult to trace it with any degree of precision; or to connect in an intelligible manner the scattered exposures of Niagara strata to the westward, with the rock of the lower escarpment, were it not for the aid afforded by the outcrop of the succeeding rock. Above the east end of the Niagara and Hamilton ridge, the upper limit of the formation probably reaches the lower part of the Chippawa Creek; and passing by Port Robinson on the Welland Canal, it may cross the road between Hamilton and Port Dover, within two or three miles of the former place. It is not, however, certain where it folds over the Dundas anticlinal, there being no exposures whatever upon the axis. The most western appearance of the upper part of the formation, on the south side of the anticlinal, occurs in the vicinity of Ancaster; the most western on the opposite side, about two miles north of Ancaster, on the third lot of the first range of Flamborough West. It may be inferred from the trend of the formation on each side, and from the general shape of the country, that its summit would fold over the axis of the anticlinal, on the line between the townships of Ancaster and Beverley, at about the thirty-fourth lot. Dundas anticlinal.

Proceeding northward, the upper escarpment of the Flamborough West section is found to merge into the plain above, and disappear. Black shales and limestones, such as occur in it, are however met with in the sixth range of Nassagaweya, on the Grand Trunk Railway, between three and four miles back from the edge of the lower or main escarpment. It is probable that the whole formation is carried westward, in a narrow spur, on the axis of a small anticlinal. The effects of this are visible in the neighborhood of Rockwood, on the Eramosa, a branch of the Speed, in the fourth lot of the fourth range of Eramosa, where there is a considerable display of the upper part of the formation. On the one side of the undulation, the strata incline nearly north, at an angle of ten degrees; and on the other, nearly south, at an angle of twelve degrees. The axis of the undulation would thus run about west, which would be nearly at right angles to the general trend of the strata through this part of the country. The undulation thus appears to be a small ridge running down the general slope of the strata, and producing but little effect on the distribution. Exposures of the rock occupy both sides of the stream, in vertical cliffs. The lower part consists of nearly eighty feet of light grey dolomite, in which divisional planes of stratification appear to be absent. Corals and broken encrinites abound in it, associated with other fossils. Among the species are *Favosites Gothlandica*, *Halysites catenulatus*, crinoidal columns, *Rhynchonella cuneata*, *R. camura*, *Spirifera Niagarensis*, with undetermined species of *Fenestella*, *Avicula*, *Bellerophon*, *Orthoceras*, and *Cyrtoceras*. On this mass, there rest about twenty feet of buff or drab colored dolomite, holding nodules and patches of chert; these are succeeded by about five feet of alternating black bitumino-calcareous shale, and dark brown very bituminous limestone. Corals are observed in some of these limestones, and crystals of galena are of common occurrence, both in the limestone and in the shale. In quarrying the dolomite beneath the shales at this locality, there was found a string or small vein of galena, which was followed for a distance of fifteen or twenty feet in one of the beds, to which the ore appeared to be confined. It was accompanied with smaller strings holding the same mineral, which branched from the main one at irregular distances: but the whole vein was quarried out without any appearance of a farther quantity of the ore.

Rockwood.

Quarries have been opened both in the lower and upper masses of this encrinal magnesian limestone, which has been used in constructing the viaduct over the Eramosa, for the Grand Trunk Railway. That from the upper portion appears to be less porous than the lower, and of a better color for architectural purposes; but both are of excellent quality, and will probably be found durable. Caverns occur in the base of the lower mass. One of them extends about a hundred feet under the cliff, with a breadth of about forty feet. The roof, which is eighteen feet high at the entrance, slopes irregularly downwards, and meets the floor at the distance just mentioned; leaving however a passage at either corner. One of these is said to lead to a large space beyond; from which other passages proceed. The roof is studded with small stalactitic incrustations.

From Rockwood westward, the surface of the country falls at about the same rate as the supposed slope of the strata; so that, on arriving at Guelph, we should still have near to the surface, the beds of Rockwood, or strata not far removed from them. Exposures occur about five miles south-westward from Rockwood, at McFarlane's tavern, on the second lot of the third range, division C, of Guelph. They consist of about six feet of black bituminous shales and limestones, similar to the highest beds at Rockwood; succeeded, in ascending order, by the following section, of which the last three feet belong to the Guelph formation:— Guelph.

	Ft.	in.
Dark brown strongly bituminous limestone, probably magnesian, in beds of about one foot each,................................	4	0
Dark brown bituminous limestone, hard, brittle, and nearly compact, in several beds; the color is a shade lighter than the previous beds,	2	0
Dark brown bituminous granular magnesian limestone,............	6	6
Pale buff or yellowish-white magnesian limestone; it holds *Halysites catenulatus*, an undetermined *Zaphrentis*, and imperfect impressions of a few undetermined shells,..........................	3	0
	15	6

On the north side of the anticlinal, the summit of the Niagara series appears to run from Rockwood, towards the east side of the township of Erin; between which and Mulmur, it is only by the outcrop of the overlying formation that its western limit can be determined. It is chiefly by the same mark that it can be traced between Mulmur and Owen Sound; but in this part, the depth of the drift is less, and the upper strata of the series are more frequently exposed.

The bold escarpment formed by the Niagara limestone in Derby, appears about two miles west of the town of Owen Sound; and between this position and Colpoy's Bay, it sweeps round towards the heights above Cape Commodore, in a line conforming in some degree to the shape of the coast, but presenting a less salient curve. The base of the limestone comes upon Colpoy's Bay, and crosses it, probably, about two miles and a quarter from its bight. Thence it keeps rather close upon the north side of the bay; while the escarpment gradually rises, according to Bayfield's chart, to a height of 350 feet above the level of Lake Huron in the bluff which faces Hay Island; to 300 feet in the next bluff north; and to 200 feet in Cape Paulet. The Clinton formation occupies perhaps a hundred feet at the base of the most southern bluff, and is seen in the second; but the summit of the formation comes to the level of the water at the extremity Shore of Lake Huron.

of Cape Paulet. The cliffs along the coast, from this to Cape Chin, are altogether occupied by the Niagara escarpment, and vary in height from 130 to 150 feet, being often nearly vertical. The limestone of which they are composed approaches to white in color; the beds are massive, and a majority of them appear to be magnesian. These cliffs would supply an unlimited amount of a superior material for the purposes of construction. The limestone abounds in corals. Masses which have fallen from the cliff in Isthmus Bay, contain *Favosites favosa*, *Halysites catenulatus*, *Syringopora retiformis*, and undetermined species of *Diphyphyllum* and *Strophomena*, with *Pentamerus oblongus*. The last named species appears also in place, in beds at the level of the lake.

Cabot's Head. The summit of the cliff at Cabot's Head, is, by measurement, 324 feet above the lake; 184 feet of this, at the base, are occupied by the Clinton formation; leaving only 140 feet of the Niagara formation in the escarpment. In the transverse section presented by the coast between Cabot's Head and Cape Hurd, higher portions of the series are however met with. The coast intersects the strata obliquely; but from the position where the base of the limestone comes to the lake, the distance to the strata of Cape Hurd would be, at right angles to the strike, about twelve or thirteen miles. The slope of the strata, as ascertained by a measurement of two miles and a half, being about thirty-seven feet in a mile, the whole thickness of the limestone, provided the dip is constant, would thus be about 450 feet. It is probable, however, that the slope diminishes towards the main body of the lake: this may considerably reduce the thickness, and some part of the strata may belong to the succeeding formation. The rock is of a pale buff or yellowish white, and weathers to a drab. It is divided into massive beds, many of them being nine and ten feet thick; they are cut into rhomboidal forms by two sets of parallel joints, one running N. 85° E. and the other S. 29° E. Some of the thickest beds appear to be a mass of corals, and most of them present a very rough and irregular exterior. Great blocks of the rock, some of them fifty tons in weight, have fallen from the cliffs, and are scattered along the

Cape Hurd. shore. Among the fossils which they contain are *Favosites Gothlandica*, an undetermined *Diphyphyllum*, *Pentamerus oblongus*, with undetermined species of *Pleurotomaria*, *Murchisonia*, and *Orthoceras;* while in the beds in place, near Cape Hurd, there are found, *Stromatopora concentrica* and *Pentamerus oblongus*.

It seems probable that the coast, from Chief's Point to Cape Hurd, a distance of fifty miles, runs very nearly on the strike; but it has still to be ascertained whether the coast may not include some part of the succeeding formation. The rock, all the way, is a whitish sub-crystalline magnesian limestone; presenting at Tobermorey Harbor, Lyell Island, the mouth of the Rivière aux Sables near Chief's Point, and other places, *Pen-*

tamerus oblongus, several undetermined species of *Rhynchonella*, *Murchisonia*, and *Pleurotomaria*, *P. Huronensis*, undetermined species of *Cyrtoceras* and *Orthoceras*, besides *O. undulatum*. The Rankin River, falling into the Rivière aux Sables (north), discharges the waters of a chain of lakes, which, with the river first named, occupy a valley running parallel with Lake Huron, for ten miles; at a distance of two miles from it. A low escarpment occupies the west side of the valley; but we have not yet been able to ascertain whether this may give clearer evidence of the true summit of the Niagara rocks than is afforded by the coast.

Strata similar in almost every respect to the Niagara limestone of the peninsula which ends in Cabot's Head and Cape Hurd, run through the whole of the Manitoulin Islands in succession; of which, with the exception of St. Joseph Island, they compose by far the larger part. These limestones come up to the south front of the Grand Manitoulin, Cockburn, and Drummond Islands; and form the Huron coast of the northern peninsula of Michigan, as far as Martin Bay. The greatest breadth of the formation is on the Grand Manitoulin, where it measures about eighteen miles. The limestone in this part of its course presents, as in other places, a bold escarpment at its base. On the coast, as in the fifty miles from Chief's Point to Cape Hurd, it forms a rugged rocky shore, with shallow water extending out to a considerable distance, in consequence of the smallness of the dip; rendering the navigation somewhat dangerous. The fossils along this range of islands appear to consist chiefly of corals, and there is little difference between them and those already mentioned on the mainland. On the south side and west end of Drummond Island, there are met with *Favosites Gothlandica*, *F. Hisingeri*, *Halysites catenulatus*, an undetermined *Alveolites*, *Stromatopora concentrica*, *Zaphrentis Stokesi*, *Atrypa reticularis*, *Pentamerus oblongus*, with undetermined species of *Orthis*, *Pleurotomaria*, and *Orthoceras*. Manitoulins.

Fitzroy or Horse Island, the Isle of Coves, Flower-Pot Island, and several others between the Grand Manitoulin and Cape Hurd, belong to the Niagara formation. In the Isle of Coves, the rocks are worn into various fantastic shapes; while Flower-Pot Island derives its name from two slender vertical pillars, wider at the top than at the base, which rise up from the water near it; their shapes being produced by the wearing action of the water, aided probably by the effect of ice.

The whole of the massive limestones of the Niagara formation are cavernous; worn fissures receive the waters of the surface, and in some places copious streams burst out at the foot of the escarpment. Tecumseh Lake on the Grand Manitoulin, in the vicinity of Manitouwaning, has an area of about fifty-five square miles, with a height above the level of Lake Huron of 155 feet. While its only visible supply of water is derived from one small stream, this lake furnishes sufficient water for three large brooks; Tecumseh Lake.

which fall from it to the south, the west, and the north. The first of these discharges itself into Lake Huron near Michael Bay on the south side of the island; the second, which leaves Tecumseh Lake at its western extremity, feeds a succession of small lakes, and falls into Beaufort Bay; while the third, flowing to the north, supplies two small lakes, and eventually terminates in Shequenandod Bay. Another large lake is said to occupy a portion of the island between Beaufort Bay and Bayfield Sound; but no examination of it having yet been made, the height and size of this lake cannot be stated. It appears probable that these two lakes may be connected by a subterranean channel, and thus the waters of Tecumseh Lake may result from the drainage of a considerable part of the island.

Springs and caverns.

On the twelfth lot of the second range of Derby, a spring bursts out from the base of the limestone escarpment, yielding water enough to drive a mill, which is situated within fifty yards of the face of the rock. There is another such spring on the eleventh lot of the first range of the same township, and a water-worn cavern occurs on the twelfth lot of the second range of Mono. Here a branch of the Nottawa River falls for nearly sixty feet, in successive leaps over the edges of massive nearly horizontal beds of a pale buff limestone, which is filled with obscure encrinites; and makes a final fall of twelve feet over a less fossiliferous rock. Just below the latter fall, this rock is worn into a cavern, which presents a length of about fifty feet, with a roof ten or twelve feet high at the entrance, gradually sloping down to the floor, in a breadth of twenty-five feet. Stalactites of two feet in length and six inches in diameter, hang from the roof, and corresponding masses rest on the floor.

THE NIAGARA FORMATION ON LAKE TEMISCAMANG.

About 150 miles to the north-west of the nearest part of the Niagara formation as described above, rocks, apparently of the same age, are met with on Lake Temiscamang. These properly belong to the great northern fossiliferous trough, connected with Hudson's Bay, of which they are probably an outlier. Being however the only portion of the fossiliferous strata on the northern side of the Laurentian mountains, which has come under our examination, they are for the present noticed in connection with the Niagara series of the southern basin. On Lake Temiscamang, they lie unconformably on the slate conglomerates and sandstones of the Huronian series. The absence of all Lower Silurian strata in place, not only on this lake, but wherever the fossiliferous strata of the northern trough have been observed, corroborates the testimony already furnished by the Potsdam formation,—that during the Lower Silurian period, the Laurentian

Northern basin.

Absence of Lower Silurian.

and Huronian rocks on the north were above the sea. It must be remarked, however, that at Lake Temiscamang, there are found lying on the Niagara limestone, loose angular fragments of dolomite, resembling that of the Birdseye and Black River formation of Lacloche and Lake Nipissing, and holding *Strophomena alternata*, species of *Maclurea* like *M. magna*, and *M. Atlantica*, *Orthoceras anceps*, and *O. proteiforme*. The source of these fragments has not yet been ascertained.

In this northern part of its distribution, the lower portion of the Niagara formation is generally arenaceous, and very often a conglomerate; containing large pebbles, fragments, and frequently huge boulders of the subjacent rocks. On the west side of the lake, about fourteen miles from the head, the base of the deposit consists of vast boulders and fragments of the underlying sandstone, in a calcareo-arenaceous fossiliferous matrix; some of the enclosed masses being nine feet in diameter. Near by, are seen the Huronian sandstone strata, great cracks and worn fissures in which are filled with the fossiliferous cement. These lower conglomerate beds are in fact a collection of great blocks of sandstone; which were lying directly upon the strata from which they were derived, when they became enveloped by the sediments of the Niagara formation. It is evident, that the immersion at this period, must have been sudden. Base of Niagara formation.

Higher up in the series, the rock is a buff or light grey limestone, weathering white. The beds vary in thickness from a few inches to two or three feet, and are in some parts interstratified with green calcareous shales. Some of the harder beds abound in chert; many of them are very fossiliferous, and the organic remains are frequently replaced by silica. Among the fossils are *Favosites Gothlandica*, *F. favosa*, *Halysites catenulatus*, *Syringopora verticillata*, an undetermined *Cystiphyllum*, *Stromatopora concentrica*, crinoidal columns in abundance, an undetermined species of *Orthis*, great numbers of *Pentamerus oblongus*, *Atrypa reticularis*, two undetermined species of *Pleurotomaria*, and *Discosorus* (*Orthoceras*) *conoides*.

The thickness of these strata exposed in any one observed section, does not exceed a hundred feet; but it is probable that the total amount of the Niagara formation is here not less than 300 feet, and may attain 500 feet. The limestones constitute the two large islands north of the Hudson Bay Company's post; the two smaller ones between them, besides the island already mentioned at the entrance of the eastern bay, and a very small one on the west coast; as well as the promontory which separates the east from the west bay. The strata lie in the form of a shallow trough, resting sometimes on the sandstones and sometimes on the slates; occupying the breadth of the lake, which is from five to six miles, and extending from the south side of the southern great island to some unknown distance northward.

Ascending Lake Temiscamang, the Huronian slates come in upon the Laurentian gneiss, about three miles below the mouths of the Montreal and

Huronian series.

Metabechuan Rivers, on the west bank; and about three miles above them on the east. They thence occupy both sides of the lake, to within two and a half miles of the Hudson Bay Company's post. In this distance they may have a direct breadth of about seven miles; in which they are affected by one or more undulations, and rise into hills of about 400 feet.

The slates are followed by the sandstones, which cross the lake with a strike N. 70° E., dipping northward at a very small angle. After forming a range of about the same elevation as the slate hills, they reach the Company's post about eighteen miles from the upper end of the lake. Here they are nearly flat, and are overlaid by a hill of gravel, 130 feet in height. On the other side of this, they continue to a distance of about half a mile above the post, and then become interrupted on both sides of the lake, by a mass of syenite; composed of reddish orthoclase feldspar and white colorless quartz, with a sparing quantity of green hornblende.

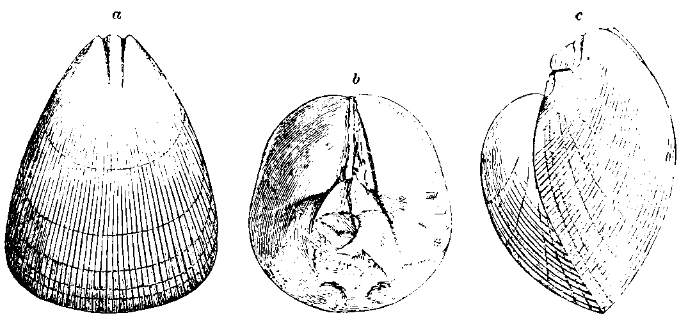
The breadth of this syenite band is pretty nearly three miles, on both sides of the lake. On the west, it is succeeded by the sandstones; which strike along the coast for a distance of four miles, dipping towards the water at a small angle. These are followed by the slates; which come from behind them, and continue in a straight line for nine miles, to the western bay at the head of the lake; forming high perpendicular cliffs for part of the distance, and rounded hills for the remainder. On the east side of the lake, the syenite is succeeded by the slates; the sandstones come upon these on the south side of the southern large island, and the main land near, dipping N. 20° W. at an angle of three degrees. The sandstones and the slates, with their associated conglomerates, make their appearance wherever they are denuded of the overlying limestone; the basset edge of which thinly covers them, as far as the island at the entrance of the eastern or Moose River Bay. Beyond this, the sandstones are seen gently dipping south, in a projecting point to the east of the island. The slates are met with at the mouth, and at the first, second, and third portages of the Rivière des Quinze, or Moose River; and the conglomerates, in the bay to the west of the Blanche. For other details of these Huronian rocks of Temiscamang, see page 50.

THE GUELPH FORMATION.

In Canada, the Niagara rocks are succeeded by a series of strata, which appear to be wanting in the state of New York. They are largely developed in the neighborhood of Guelph and Galt, and we have designated the series as the Guelph formation.

The town of Guelph, in the township of the same name, is situated on the river Speed, about eight miles south-west from Rockwood. Here, in the bed of the stream, under the bridge on the Brock road, there are Guelph. exposed several feet of dark brown very bituminous dolomite; succeeded a little way up, on the left bank, by a mass of whitish coralline dolomite, which appears on the side of the road. About half a mile above Guelph, near the right bank of the Speed, there is a quarry in a whitish sub-crystalline dolomite, the strata of which are altogether about twelve feet thick. All of the beds contain obscure casts of fossils; chiefly of corals and bivalve shells. Among them are, *Favosites Gothlandica*, *Halysites catenulatus*, a new species of *Columnaria*, *Obolus* ———— ? *Megalomus Canadensis*, with undetermined species of *Pleurotomaria* and *Orthoceras*. The strata

341.—BRACHIOPODA.



341.—*Pentamerus occidentalis* (Hall); *a*, ventral valve; *b*, cast of the interior of the umbo of the ventral valve; *c*, side view.

are probably a little higher in the series than those of the same color at the bridge. Similar beds are extensively wrought a little below the town, and yield an excellent building stone. Some of the beds are burned for lime.

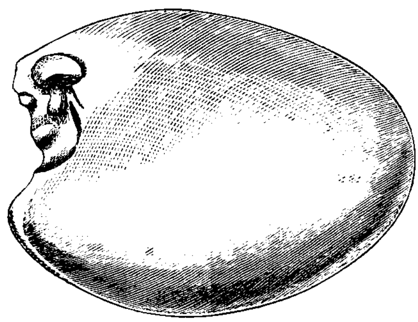
Nearly five miles below Guelph, where a bridge crosses the Speed, on the town line between the fifth and sixth ranges of the Gore of Puslinch, there is a section, consisting, at the base, of fifteen feet of black hard compact bituminous dolomite, without observed fossils: followed by seven feet of brown bituminous strata. On these, rest seven feet of buff or pale drab dolomites, holding obscure fossils. These exposures on the Speed are nearly in the strike of the strata. The light colored dolomites, which are here seen to rest upon dark colored bituminous strata, are regarded as the base of the Guelph formation. See farther, the section at McFarlane's tavern, given on page 331.

The fall from the base of the formation, at Guelph, on the Speed, to the bed of the Grand River, at Breslau, as deduced from the levels on the

Breslau. Grand Trunk Railway, is eighty-two feet. The distance across the strike of the measures, between Guelph and Breslau, is about nine miles; so that if the dip of the strata be taken at twenty feet in a mile, which is perhaps near the truth, the base of the formation would be one hundred feet beneath the bed of the Grand River. The rocks of the Guelph formation are not seen at Breslau; but at points both to the north and to the south, which would include this place in their strike, strata are met with at a level of about sixty feet above the Grand River. This would give for the Guelph dolomites, about 160 feet; which we may assume as the approximate thickness of the formation.

Dolomites. The strata of this formation appear, so far as examined, to be magnesian limestone, having the composition of true dolomites, and are frequently made up of brilliant crystalline strongly coherent grains. The rock is very

342.—LAMELLIBRANCHIATA.



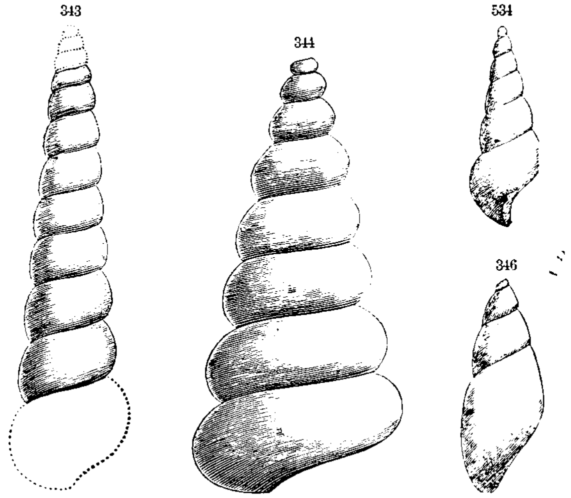
342.—*Megalomus Canadensis* (Hall); cast of the interior.

often porous, and has small drusy cavities; besides which, are those forming the moulds of fossils. In many cases, the shell appears to have been simply enveloped in the rock; and having been afterwards removed by solution, it has left a corresponding cavity. At other times, the interior of the shell was also filled with the dolomite, so that the mould corresponds only to the thickness of the shell; the markings of both the interior and exterior of which are thus preserved. More rarely, the cavities have been subsequently filled up by calcareous matter; so that the substance of the shell appears to have been either replaced or preserved.

Dumfries. The most southern exposure of the summit of the formation, on the Grand River, occurs just above Middleton bridge, on the twenty-first or twenty-second lot of the sixth range of Dumfries. The rock is a light grey dolomite, weathering to a pale drab: it holds fossils of the genera *Zaphrentis Murchisonia*, and *Pleurotomaria*, but they are too obscure to be specifically the north end of the fourteenth lot of the sixth range of Dumfries, with a very gentle dip to the south-west; the distance across the measures being probably two miles. In one of the buff colored beds on the lot just named, in addition to the previous genera, there occurs *Megalomus Canadensis;* being the largest bivalve shell of the formation, and its most characteristic fossil. The rocks of the Guelph formation are again met with, farther up the Grand River, in the vicinity of Galt.

The highest strata here appear to be the same as those above Middleton bridge. The exposures are chiefly on the right bank of the river, but occasionally on both banks; and they extend for some distance, both

343-346.—GASTEROPODA.



343.—*Murchisonia bivittata* (Hall). 345.—*Murchisonia Boydii* (Hall).
344.—*M. ——— macrospira* (Hall). 346.—*Subulites ventricosus* (Hall).

below the town and above it, where quarries are wrought in the rock. The greatest vertical section in any of these is thirty-four feet; but expo- Galt. sures of both higher and lower strata would make the whole thickness upwards of sixty feet. At the top of the formation, in this neighborhood, there are about eighteen feet of hard thin bedded bluish dolomite, beneath which are thirteen feet of pale buff or white dolomite; succeeded by twenty feet of yellowish-white and greyish-white crystalline thick bedded dolomite, in overlapping lenticular masses. The whole mass holds fossils; but these, in the immediate vicinity of Galt, are most abundant in the twenty feet of pale buff thin-bedded dolomite in the middle of the section. The species met with are *Favosites Gothlandica*, *Pentamerus occidentalis*, *Obolus* ———? *Megalomus Canadensis*, *Pleurotomaria* ———?

P. Galtensis, *P. Elora*, *P. solaroides*, *Murchisonia Boydii*, *M. Logani*, *M. longispira*, *M. bivittata*, *M. turritiformis*, *M. Tullia*, *Cyclonema Galtensis*, *C. Thysbe*, *C. Psyche*, *Bellerophon angustata*, *Orthoceras Darwini*, *Cyrtoceras arcticameratum*, *C. Jonesi*, *Phragmoceras Hector*, and *Calymene Blumenbachii*.

The exposures continue all the way to Preston, which is still higher up on the river. Here the banks exhibit a section of from fifteen to twenty feet of coralline magnesian limestone; probably equivalent to the thin bedded pale buff dolomite of Galt, but not so fossiliferous. Exposures continue up the Speed; and at Hespeler, strata occur that are lower in the series than those at Galt; their stratigraphical place being probably near the middle of the formation. A cutting at Hespeler, on the Great Western Railway, exhibits fifteen or twenty feet of pale greyish-white strata; which are not so massive as some of those at Galt, but more fossiliferous. The species observed are *Favosites Gothlandica*, *F. polymorpha*, *Columnaria Galtensis*, *Halysites catenulatus*, *Diphyphyllum irregulare*, *Amplexus laxatus*, *Obolus* ——? undetermined species of *Rhynchonella* and *Athyris*, *Megalomus Canadensis*, *Murchisonia Logani*, *M. bivittata*, an undetermined *Pleurotomaria*, *Cyclonema depressa*, *C. Thysbe*, *Orthoceras Darwini*, and *Cyrtoceras arcticameratum*. Both at Galt and Hespeler, quarries are worked in these magnesian limestones; which yield excellent building stones, easily dressed and probably durable. Some of the beds are burned for lime, which is often rather dark in color, but makes a strong mortar.

Hespeler.

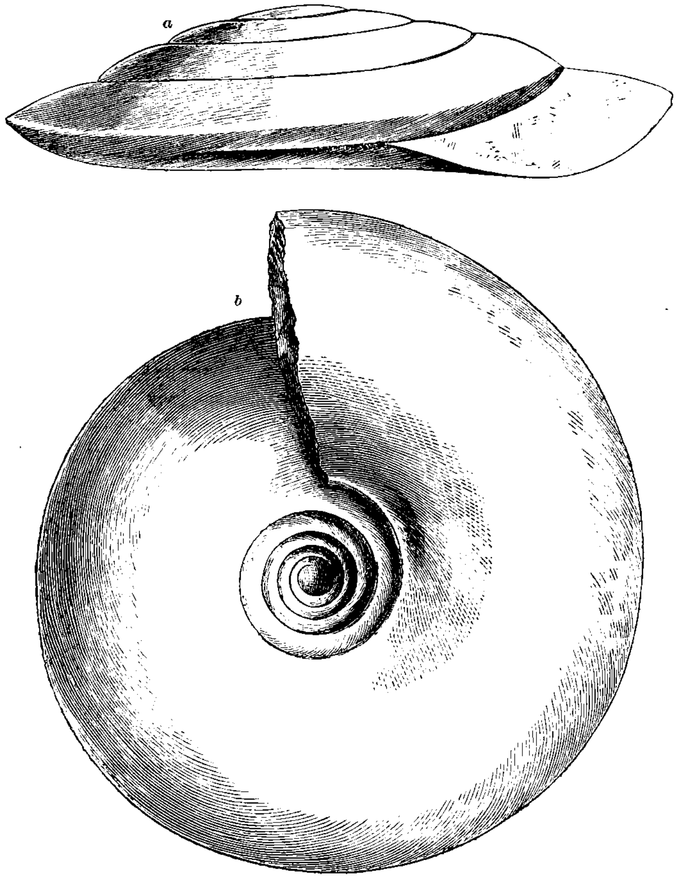
Elora.

About fourteen miles north from Breslau, in Pilkington and Nichol, on the banks of the Irvine and Grand Rivers, near their junction, at Elora, perpendicular cliffs of these dolomites occur; varying in height from seventy-five to eighty or eighty-two feet. The upper portion of these strata is probably near the top of the Guelph formation. The beds in descending order are as follows:—

	Ft.	in.
1. Light drab or reddish compact magnesian limestone, in beds of from three to six inches, with small cavities (probably once holding fossils), and cracks lined with calcspar. The fossils are *Halysites catenulatus*, *Obolus* ——? *Pentamerus occidentalis*, *Megalomus Canadensis*, and *Murchisonia Logani*; with several undetermined species of *Pleurotomaria* and *Orthoceras*, ...	12	0
2. Buff colored coralline magnesian limestone, with a stratum of about three feet, near the middle, filled with *Megalomus Canadensis*; the corals observed are *Favosites Gothlandica*, *F. polymorpha*, and *Stromatopora concentrica*, ...	14	0
3. Pale buff or yellowish-white compact magnesian limestone with a conchoidal fracture, in massive beds holding fossils. Among these are *Favosites Gothlandica*, *Pentamerus occidentalis*, with undetermined species of *Rhynchonella*, *Murchisonia*, and *Orthoceras*,	56	0

At Fergus, which is on the Grand River, at such a distance above the mouth of the Irvine as would give three miles across the measures, a section occurs near Mr. Webster's mill, displaying about twenty feet of strata, which would underlie the preceding. About sixteen feet of these Fergus.

347.—GASTEROPODA.



347.—*Pleurotomaria solaroides* (Hall); *a*, side view; *b*, view of the under side.

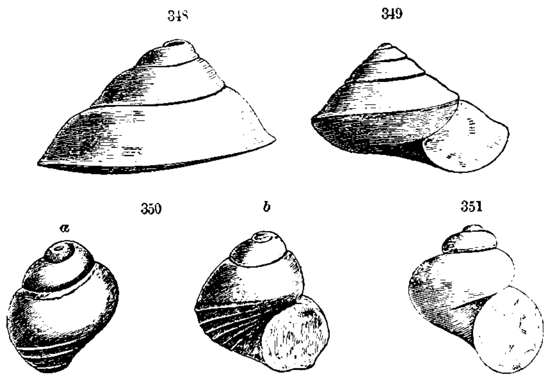
are a pale buff magnesian limestone, with casts and impressions of fossils; among which are *Favosites Gothlandica*, *Megalomus Canadensis*, and *Murchisonia Logani*. The remaining four feet consist of a grey hard magnesian limestone; which rests upon a mass of the same color, but somewhat closer grained, forming the bed of the stream. About a mile farther up the stream, on the land of Mr. James Webster, there are beds of pale yellowish-grey magnesian limestone, weathering to a light buff. These would be still somewhat lower than the beds at Fergus; and contain *Favosites Gothlandica*, *F. polymorpha*, *Pentamerus occidentalis*, *Megalomus Canadensis*, *Murchisonia Logani*, *M. longispira*, and *Pleurotomaria Huronensis*. Some of the Fergus beds yield good lime: they range from two inches to two feet in thickness, but are for the greater part thin and irregular, and, although some of them are used for rough buildings, the stone for facing is brought to Fergus from Guelph.

Exposures of these dolomites are again met with, on the Rocky Saugeen River, upwards of forty miles N. N. W. from Fergus. One of them occurs about three miles beyond Durham, where the Garafraxa and Owen Sound road crosses the river. Here the rock has been quarried for building stone, and for burning into lime. The lower part is a light greenish-grey sub-crystalline magnesian limestone, divided into beds of from eight to ten inches thick, with very obscure fossils; while the upper part is a greyish-white coralline mass, seven feet thick, in several beds, of which the thickest is three feet. Among its fossils are *Favosites Gothlandica*, *Amplexus laxatus*, *Obolus* ——— ? and *Megalomus Canadensis*. Another of these exposures is at the junction of the Rocky Saugeen with the main stream, in the rear of the sixty-second lot of the Bentinck. third range of Bentinck; where about twenty-five feet of the rock are seen on the right bank. The upper twelve feet consist of a rough irregular bed of greyish-white dolomite; underlaid by a buff colored compact stratum, divided into layers of from three to four inches. The fossils found here are *Favosites Gothlandica*, *Pentamerus occidentalis*, *Obolus* ——— ? *Megalomus Canadensis*, with undetermined species of *Murchisonia* and *Pleurotomaria*.

The exposures which have been mentioned between Puslinch and Bentinck, belong to the upper part of the formation, and indicate the strike of its summit northward, as far as the Rocky Saugeen. In this region, with the exception of the space occupied by the westward spur of the Niagara series on the Rockwood anticlinal, the Guelph formation presents a breadth of about twenty-five miles, opposite to Puslinch; which gradually increases to thirty-five miles, opposite to Bentinck. This great breadth is probably due in part to the fact that the country rises with the general slope of the strata, to the edge of the eastern escarpment, though at a somewhat smaller angle; and in part also to a series of north and south undulations, which appear to exist in this region.

Between Rockwood and Erin, the base of the formation forms a small sinus up the Speed, to Everton; while to the southward, it forms another sinus running down the same stream, to Eden. These two turns in the distribution of the rock, are occasioned by an undulation transverse to the Rockwood anticlinal. Its axis, with a bearing a little east of north, would pass under Eden, Rockwood, and Everton, and thence to Orangeville. The sinus which terminates there may owe its origin to the same anticlinal; and it is probable that some of the other deep southward in- Anticlinals.

348-351.—GASTEROPODA.



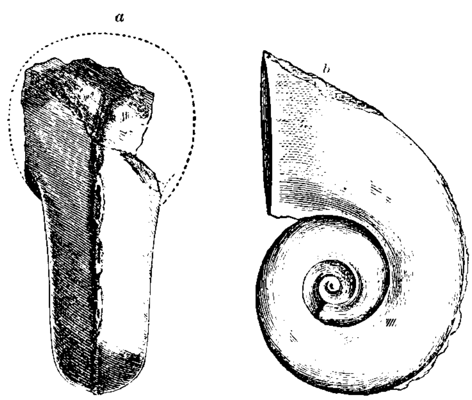
348.—*Pleurotomaria Elora* (Billings).
349.—*P. ——— Galtensis* (Billings).
350.—*Cyclonema sulcata* (Hall); *a* and *b*, two views of the same specimen.
351.—*Holopea Guelphensis* (Billings).

dentations in the outcrop of the formations between Orangeville and Owen Sound, may be due to undulations parallel to this one. The strata over this region are so nearly horizontal, that the dips can scarcely be appealed to as proofs of undulations in the strata; yet we are inclined to believe that the indentations in the outcrops, on the Noisy and Beaver Rivers, and on Owen Sound, are connected with anticlinals. These north and south undulations appear to be related to those already mentioned as affecting the outcrop of the Trenton group, between Kingston and Lake Simcoe. The bearings of the undulations in the latter region, seem to accord with those of the Laurentian folds, as far as these have been ascertained; and the undulations of the Silurian strata may be connected with the inequalities of the surface of the Laurentian rocks, upon which they repose. The thick masses of Silurian sediment accumulated in the ancient Laurentian valleys, would, by their contraction during solidification, undergo a vertical subsidence; which would cause them to dip away from the thinner deposits that covered the Laurentian hills.

From Bentinck, northward, the strike of the summit of the formation appears to continue in the same bearing as between Puslinch and Bentinck, for about twenty-five miles, to the Rivière aux Sables (north). The base, however, folding successively over the supposed anticlinals of the Beaver River and Owen Sound, the breadth of the formation becomes reduced, between the latter place and the Rivière aux Sables (north), to ten miles; which is about the same as that which it appears to have between Guelph and Breslau.

Chief's Point to Cape Hurd. It has already been stated that the strata seen near the mouth of the Rivière aux Sables, at Chief's Point, probably strike along the coast, by Lyell Island, to Cape Hurd; and belong in part to the Niagara formation, whose characteristic fossils are met with in several localities along the shore. These strata, however, have for the most part the lithological

352.—GASTEROPODA.



352.—*Bellerophon angustata* (Hall); *a*, dorsal, and *b*, side view.

characters of the Guelph formation, and some of their undescribed species of *Murchisonia* have a strong resemblance to others found in this series. The *Pleurotomaria Huronensis*, which belongs to the Guelph rocks, occurs on Lyell Island associated with *Pentamerus oblongus*, and other characteristic Niagara species; so that it is not impossible that some of the strata along this coast may constitute a passage between the Niagara and Guelph formation.

The Guelph formation appears to be absent from the state of New York, and in Canada it probably has the form of a great lenticular mass, the limit of which between Niagara and Guelph is uncertain; though it appears to extend beyond Ancaster. In the other direction, it seems to thin out in Lake Huron, before reaching the northern peninsula of Michigan.

CHAPTER XIII.

THE ONONDAGA FORMATION AND THE LOWER HELDERBERG GROUP.

UPPER SILURIAN SERIES.—ONONDAGA FORMATION; CONTAINS SALT AND GYPSUM.—IMPRESSIONS OF CRYSTALS; EPSOMITES.—DISTRIBUTION OF THE FORMATION IN CANADA; GYPSUM OF THE GRAND RIVER; STRUCTURE AND ARRANGEMENT OF THE GYPSUM BEDS.—LOWER HELDERBERG GROUP; ITS DIVISIONS.—UPPER PORTIONS WANTING IN WESTERN CANADA; WATER-LIME GROUP; EURYPTERUS BEDS.—OUTLIERS NEAR MONTREAL; MAGNESIAN CONGLOMERATES; ST. HELEN'S ISLAND.—EVIDENCES OF DENUDATION DURING THE PALÆOZOIC PERIOD.

Salt and gypsum.

The Middle Silurian formations, which have been described in the last chapter, are followed by a series of rocks, noted, in some parts of their distribution, for their deposits of gypsum and for salt springs. The latter are extensively wrought in Onondaga county, New York, and the name of the Onondaga Salt group has hence been given, by the state geologists, to this series of rocks; for which we preserve the name of the Onondaga formation. Succeeding these, is a group of strata, which, from their position in the Helderberg hills, in New York, have received the name of the Lower Helderberg group, and which are regarded as forming the summit of the Silurian system. These two groups, whose position in Canada we propose to describe in the present chapter, constitute the Upper Silurian division.

Upper Silurian.

Onondaga formation.

In the state of New York, the Guelph formation is wanting, and the Onondaga series rests directly upon the Niagara limestones. It is there described as consisting, at the base, of red shales, occasionally marked by green bands and spots. This first division is overlaid by greenish shales and marls, with occasional bands of red shale and of shaly limestone. These strata abound in small veins and nodules of gypsum, and readily disintegrate when exposed to the air. The third division, which is the true gypsum-bearing portion, consists of grey or drab-colored magnesian limestones, with greyish and greenish shales; including two ranges of interstratified masses of gypsum, sometimes with native sulphur. With these is a band of shaly limestone, marked by hopper-shaped cavities, which are supposed to have contained crystals of common salt. Two bands of what was called by Eaton, vermicular limerock, also occur in this division: it is described as a solid drab-colored limestone, with vesicular cavities, of varying sizes,

Impressions of crystals.

up to half an inch in diameter. The fourth or upper division of the Onondaga formation, is a limestone, with columnar markings on the surface of the beds; which were supposed by Mr. Vanuxem to be impressions formed by crystals of sulphate of magnesia, or Epsom salt, during the deposition of the sediments; and were in consequence called by him epsomites. (Geology of New York, Vol. III, p. 108.) These peculiar impressions have already been described in the Marmora lithographic stone of the Trenton group (p. 182), and in the Niagara formation (p. 323); they are also met with in the Corniferous limestone formation. Their origin may be conceived if we suppose large prismatic crystals of sulphate of magnesia to be implanted vertically, and near to each other, in a soft bed of sediment, and to be afterwards removed by solution, leaving moulds which are filled by the next deposited layer; a thin film of black argillaceous mud, which generally divides the beds, covering also the moulds of the crystals. In some of the cherty portions of the Corniferous, we find these columnar markings between layers of chert and limestone. In the dolomites of the Onondaga formation, in Canada, there are also beds containing great numbers of thin lenticular crystals of translucent calcspar, whose greater diameters lie for the most part in the plane of deposit. These, being dissolved out from the weathered surface of the dolomite, give to its surface a curiously fissured appearance, which was noticed by Vanuxem; who did not however explain its origin. The cavities in the vermicular limerock, which is a similar dolomite, are due in like manner to the solubility of carbonate of lime; the cavities, in fresh fractures of the rock, being filled with this mineral in a pulverulent form. Mr. Vanuxem also noticed two other classes of markings on the beds of this formation; the one being cuneiform figures, and the other lines branching off from a stem, at an angle of about thirty-five degrees: these he also ascribed to crystallization. Similar traces are found impressed on some of the thin bedded dolomites of the gypsiferous rocks, on the Grand River; and it may be remarked that all of these, not less than the gypsum, and the hopper-shaped moulds of salt crystals found in New York, show that these rocks were deposited from waters concentrated by evaporation. This condition may account for the absence of organic remains from the Onondaga formation.

Epsomites.

Thickness of the formation.

In the eastern part of New York, the Onondaga formation, like the Middle Silurian series, is but little developed. Commencing as a thin band, at Shannon, in Montgomery county, it attains its greatest thickness, which is about 700 feet, in Wayne county. Running parallel with the shore of Lake Ontario, it diminishes considerably to the westward, until it crosses the Niagara River, and enters Canada, with a thickness which is estimated at between 200 and 300 feet. The salt-bearing strata of this formation, do not appear to extend to the westward of central New York.

Commencing at the Niagara River, the upper beds of the series are seen near the village of Waterloo; and are traceable to the westward, from the eighth lot of the seventh, to the twenty-third lot of the second range of Bertie. Sweeping round towards the shore of Lake Erie, behind Cape Abino, through the influence of an undulation, they are again traceable, from the fifteenth lot of the third range of Humberstone to the Welland Canal, on the twenty-sixth lot of the second range of the same township. Between this outcrop and the Chippawa, the whole of the country is covered by clay. It is probable, however, that the lowest beds occur somewhere near to Chippawa village; as the clay for a considerable extent in that neighborhood, has a red color, such as might be expected from the disintegration of the red shales, which occur at the base of the formation in New York. The same red color also prevails on the Welland Canal, in the vicinity of Port Robinson; though no red shales have yet been seen in place, either there or for upwards of a hundred miles beyond. Distribution.

The exposures of the Onondaga formation in Canada, so far as yet examined, appear to belong chiefly to the upper portions, from the summit to a little below the gypsum-bearing beds. These portions consist of dolomites and soft crumbling shales, which are greenish, and sometimes dark brown or bluish in color, and are often dolomitic. The dolomites are mostly of a yellowish-brown or drab color, and are in beds which seldom exceed a foot in thickness. They often exhibit the vesicular or the lenticular cavities just described. Some beds of a bluish dolomite are also met with; and many of the strata, both above and below the gypsum, contain such a proportion of clay as makes them fit for hydraulic cement. Water cement.

The beds of gypsum are never continuous for long distances, but appear as detached lenticular or dome-like masses; the strata above them being arched over and often broken, while those below constitute an even undisturbed floor. The gypsum is interstratified with the dolomite, and often separated by beds of it. The layers of gypsum may sometimes extend for a quarter of a mile; but they have always been found, on working, to be lenticular in form, and to gradually thin out, until the strata above and below the masses, come in contact. This peculiar structure gives rise to mounds on the surface; which are regarded by the inhabitants, as indicative of the presence of gypsum beneath. Gypsum.

Between the Niagara and the Grand River, the workable masses of gypsum, if any are present, are concealed by the drift; but on the Grand River, they are seen, twelve or fourteen miles above its mouth, in the third range of North Cayuga, and thence are traced to Paris. Their strike appears to coincide with the general course of the river. A large deposit of gypsum, which has been extensively wrought, occurs on the land of Mr. Brown, about three miles below the village of Cayuga, on the left bank of the Grand River. It is supposed to extend over at least sixty Cayuga.

acres, and is generally covered only by drift. In some parts, however, portions of thin dolomitic beds are found, resting upon the gypsum; which is five feet in thickness, and very pure. The lower portion includes some thin interrupted layers of dolomite, which are vesicular when weathered. In a well sunk upon this bed, near the proprietor's house, there were found, beneath the gypsum, about twenty feet of dolomite, containing small portions of gypsum; beneath which, at the bottom of the well, were three or four feet of unmixed dolomite, fit for water cement. The dip of the bed, which is about S. 20° W. < 2°, would carry it under the level of the river: and the position of the summit of the formation, which is seen at a little distance on the other side of the river, would apparently give a thickness of about ninety or one hundred feet above the gypsum. This upper portion of the formation, as seen in Jones's tract, consists of a dark ferruginous shale, with nodules of yellowish-grey chert; interstratified with greenish marl, containing harder layers. The thickness of these beds is about thirteen feet, and they are surmounted by about five feet of yellowish shale and tufaceous dolomite, with vesicular bands.

About five miles above Brown's plaster bed, gypsum occurs in Indiana, on the left bank of the river; and about four miles farther, near to York, on both sides. The following is a descending section of the strata observed in the latter vicinity, near Mount Healy, at the plaster bed of Mr. Taylor:

Oneida.

	Ft.	*in.*
Drab-colored dolomite, with some blue layers, in beds of about five inches, ...	2	3
Greenish shales, ...	3	0
Drab-colored vesicular dolomite, yielding good lime, ...	1	6
Blue thin bedded hard limestone, said to be fit for hydraulic purposes, ...	1	7
Pure white gypsum, with bluish bands, ...	3	6
Blue schistose argillaceous dolomite, some of it fit for water cement, ...	5	0
Grey dolomite, with joints at right angles to the beds, which are thicker at the bottom than at the top, and separated by partings of shale, ...	6	0
	22	10

In the bed of the river at York is a stratum of solid limestone, which would underlie the above section: it holds small quantities of galena. The dip of the measures in this part, judging by the strike of the summit of the formation, is, like that of Cayuga, about S. 20° W.; but it is not easy to determine the slope. If we assume the thickness of the overlying portion to be the same as before, the distance of the summit, which is nearly five miles, would give a slope of about twenty feet in a mile.

Three adits have been opened in this plaster bed at Mount Healy, and afford good opportunities of studying the gypsiferous rocks. One of the most remarkable characteristics is the irregular nature of the bedding. Some of the layers of dolomite immediately below the gypsum, to the east of it, are seen to augment and to then diminish considerably in thickness in the distance of a few feet; giving thus, at first sight, the appearance of undulations, while the beds beneath are completely horizontal. In the central opening, a layer of dolomite, not seen in the others, is interstratified with the gypsum; and in one of the adits, the gypsum bed is observed to thin out, the strata from above bending downwards, and conforming to it. It results from these irregularities in the beds, that sections in different portions are by no means concordant. In one part, three or four feet of dolomite overlie the gypsum bed: the upper part being vesicular, and a portion of it filled with crystalline carbonate of lime. Here, immediately resting upon the gypsum, is a reddish ferruginous layer, followed by two inches of green shale. In another opening, this thin layer of shale is succeeded by a few inches of plastic calcareous clay; to which succeed very thin bedded vesicular dolomites, whose surfaces are marked with the branching lines already described. Farther on, this layer of shale becomes a foot or two in thickness; and it includes portions of travertine, which is sometimes compact like alabaster, and forms considerable masses in the fissures of the overlying beds. At about three feet above the principal mass of gypsum, a second interrupted layer is met with, which is very pure. It is generally only a few inches thick; but it swells to a foot or two in some places, and in others is wanting. Mount Healy.

At Aikman's plaster bed, a mile and a half above York, on the left bank of the Grand River, the mass of gypsum is seven feet in thickness, but is divided into six layers by interstratified bands of dolomite, of from two to six inches; the same band varying in short distances. The upper portion of gypsum is two feet thick, and is pure and white; the lower portions are mixed with dolomite and are less pure. Immediately above the gypsum is a sandy ferruginous layer of from two to six inches; then, after some layers of dolomite, occur eighteen inches of greenish shale; followed by four feet of yellowish vesicular dolomite. For the next two miles, as far as Seneca, the gypsum appears occasionally, in thick rounded masses, enveloped and underlaid by green shales; the lower portions of which sometimes include small interrupted layers of the mineral. York. Seneca.

About two and a quarter miles across the measures, in a direction nearly S. W. from Seneca, there is an exposure at McKenzie's mills, of about twelve feet of beds belonging to this formation, which may be fifty or sixty feet higher in the series than the gypsum. The section consists of drab-colored dolomites, sometimes vesicular, interstratified with hard blue slaty layers, and with green shales; which sometimes include thin dark colored laminæ. The same strata are met with again at Barton Creek, about a mile south from McKenzie's mills. Some of the beds at both places yield good lime, but others are unfit for burning.

About twenty miles above Seneca, gypsum is met with in Brantford, on the seventeenth lot of the third range, the sixteenth lot of the second, and Brantford.

the fifteenth lot of the first range. In the first of these lots, it occurs on the right, and in the other two, on the left bank of the river. In the last of these, the gypsum has been mined by Mr. Tennant, and forms a bed of three feet, underlaid by and imbedded in green shale. Above this, on the river, gypsum is quarried in many places in the vicinity of Paris. At Mr. Coy's, about a mile and a quarter below this town, on the left bank of the river, there appear, as at Mount Healy, to be two ranges of gypsum; the upper of five, and the lower of four feet. These are separated by a layer of four feet of shale, which is also found both above and below them. A short distance above this, on the same side of the river, is a hill, into which an adit has been driven upwards of 250 yards, at right angles to the river; along a gypsiferous bed, different in some respects from those already described. The underlying rock is green shale, upon which rests a layer of three feet of green shale, occasionally mingled with dolomite, and enclosing rounded masses of gypsum, from a few inches to four feet in diameter; around which the enclosing strata are always bent conformably. A thin layer of dolomite covers this bed; but at the end of the adit, it is wanting, and a conical mass of the gypsum is found protruding into the overlying drift clay, which rises to the height of eighty feet above the river. At Paris, on the east bank of the river, between the Great Western Railway viaduct and Mr. Wright's plaster bed, the strata of this part of the formation are very well exposed. Here we have eight or ten feet of tender, brittle greenish argillaceous dolomitic rock, often red-weathering, and passing into a shale. This is overlaid by three feet of dove-colored dolomite, vesicular below, with thin eroded cellular beds; followed by a bed of one foot, compact above, but cellular below, and succeeded by a foot or more of vesicular beds. These are overlaid by about a foot of conglomerate, apparently of vesicular dolomite, with fragments of green shale; the upper part very ferruginous, and decomposing. The whole is overlaid by green shales, more tender and crumbling than those below. These strata are slightly undulating; and as they are concealed near the gypsum quarry, it is not easy to give the exact horizon of this. The upper part of the gypsum bed is intercalated with much dolomite, and for two feet seems made up of alternating lenticular masses of gypsum and dolomite, the latter prevailing at the top, and succeeded by thin bedded cellular dolomites; one portion of which seems to have been broken and re-cemented. Examples of this are seen on the other side of the river just below the viaduct; where the green shales are overlaid by masses of similar dolomite, often stained red, and having apparently been broken, and re-cemented into a kind of breccia.

Paris.

Exposures of strata belonging to the Onondaga formation, are met with at several places on the Grand River, for a distance of about fifteen miles; from Doon, six miles above Galt, to about two miles below Glen Morris.

Between Galt and Preston, on the west side of the river, on a lot adjoining one where the Guelph formation is exposed, there are seen about five feet of brownish shale, interstratified with thin beds of dolomite; in one of which is found an obscure bivalve shell. Similar strata are said to occur two miles below Glen Morris; beyond which the rocks of the formation are concealed beneath a great thickness of drift. In the townships of Maryborough and Peel, on the Canestoga, a branch of the Grand River, however, abundant fragments of the gypsiferous rocks mark the proximity of the outcrop of this formation.

In the township of Normanby, sections, apparently belonging to the lower portions of the formation, occur at Ayton and at Neustadt; both on the banks of a tributary of the Saugeen, known as the South Saugeen River. Near the latter village, are seen about ten feet of thin bedded dolomites, some of which are water-lime. To these succeed six feet of greenish crumbling shales, overlaid by rusty brown, dark red, and green shales; which probably have a thickness of forty feet. At Ayton, there are seen forty-three feet of bluish and drab-colored dolomitic shales, with some harder bands. At Walkerton, in the township of Brant, on the right bank of the Saugeen, there occur, at the base of a section, two feet of greenish dolomite; followed by forty-four feet of a bluish argillaceous rock, with red bands. It contains numerous vesicular cavities, stained red within, and disintegrates on exposure to the weather. This is overlaid by eight feet of drab dolomite; while near by, and apparently overlying this, are thirty or forty feet of drab-colored dolomites. The lower part, compact, and apparently fit for lithography, is interstratified with bands of dark shale. The upper portion is whiter, softer, and filled with small lenticular crystals of calcite: it also holds, in some parts, geodes of the same mineral. Farther down on the Saugeen, at the commencement of a great bend called the Ox-bow, occur vesicular drab colored dolomites, overlaid by a bed of black shale; which is followed by thin bedded buff colored bituminous dolomites, with lenticular crystals of calcite. In less than half a mile across the measures, to the south-west, we come upon the strike of a rock belonging to a higher formation; so that the strata at the Ox-bow probably belong to the higher portion of the Onondaga series; while the red and green shales in the previous section, seem to indicate the base of the formation.

Normanby.

Brant.

Exposures of thin bedded dolomites are met with, at several points, nearly to the mouth of the Saugeen. About a mile below the village of Paisley, in the township of Elderslie, strata of this kind are seen, containing small lenticular crystals of calcite. The lithological characters of many beds at the summit of this formation, are, however, so much like those of the overlying Water-lime group, that it is not easy to draw a line of division between them.

Elderslie.

To the northward of the Saugeen, no further exposures of the Onondaga formation are known in Canada. Gypsum has been said to occur in the largest of the Duck Islands, in front of the Great Manitoulin; but the island proves, on examination, to be covered with drift. The formation is, however, apparently continued, through Lake Huron, to the straits of Mackinaw; where it forms the island of that name, and the points of the mainland on either side.

Acid springs. No brine springs have as yet been observed in this formation in Canada, though feebly saline and sulphurous waters are met with. The springs of Tuscarora and Chippawa, which issue from the Onondaga formation, are remarkable for containing three or four thousandths of free sulphuric acid. A similar spring occurs in the same formation at Byron in New York; and two others, at Niagara and St. Davids, rise from the Medina sandstones. The action of the waters upon the calcareous strata through which they pass, must give rise to sulphate of lime; which might be deposited in lenticular or dome-shaped masses, such as have been described above. Masses of gypsum. Conditions of the surrounding strata, similar to those which we have described, are observed in the gypsiferous formations of other regions, and have been explained by supposing a partial removal of a bed of gypsum, through solution by infiltrating waters; leaving only isolated masses, around which the unsupported superior strata have fallen. Certain appearances of disturbance in the gypseous rocks of the Alps have been explained by supposing that the sulphate of lime was at one time in the form of anhydrite: which, by absorbing water, was converted into gypsum, with a large increase of volume, uplifting the strata around. The beds of gypsum which have been examined in the Onondaga formation in Canada, seem however to have been in all cases contemporaneous with the shales and dolomites in which they are interstratified, and to have no connection with the acid springs of the present time.

If we suppose the gypsum to have been deposited in its present form, in basins, we may conceive, that, when the surrounding and overlying strata were subsequently consolidated by pressure, which would reduce their thickness much more than that of the solid crystalline gypsum, they would conform to the masses of the latter, and appear to dip down on every side; precisely as we now see them in the gypsum quarries which have been described. The hillocks in which the gypsum occurs, appear to be due to the fact that the masses of gypsum, or the hard beds immediately overlying them, have resisted denudation to a greater extent than the softer argillaceous strata; which appear elsewhere to make up a great portion of the formation.

THE LOWER HELDERBERG GROUP.

The rocks of the Lower Helderberg group, which in New York are found overlying the Onondaga formation, appear, with the exception perhaps of their lowest division, to be wanting in Western Canada. Strata of this group are however met with in the vicinity of Montreal; and it is very largely developed in the eastern portion of the province, where it includes a part of the Gaspé limestones. The description of these, for reasons already stated, is reserved for a future chapter.

In the state of New York, the Lower Helderberg group was, by Mr. Vanuxem, separated into the following five divisions, in ascending order: 1, Water-lime group, or Tentaculite limestone; 2, Pentamerus limestone; 3, Delthyris shaly limestone; 4, Encrinal limestone; 5, Upper Pentamerus limestone.

1. *Water-lime group, or Tentaculite limestone.*—In the central part of New York, this division is described by Vanuxem as consisting of from thirty to one hundred feet of limestone, chiefly dark blue in color, and fit for ordinary lime; with two drab colored layers, which yield a hydraulic cement, and give the name of Water-lime to the series. The limestone is often marked by colored bands of sedimentation; and in some parts, it holds nodules of chert, and geodes of celestine, gypsum, and fluor-spar. The beds are often from three to five feet thick, and sometimes exhibit at their surfaces the columnar markings which have been called epsomites. Some of the drab colored beds, which are dolomites, also exhibit the lenticular crystals of calcite, already described. The strata of this division, in their lithological characters, closely resemble the upper portions of the preceding gypsiferous series, with which they were in part confounded by Vanuxem: who classed the beds containing *Eurypterus*, with the Onondaga formation. According to Mr. Hall, the drab colored strata characterized by this remarkable crustacean, are seen, in Oneida county, to underlie the dark blue or black limestone; which abounds in tentaculites and other fossils, and constitutes, in his view, the true base of the Lower Helderberg group. This group, as thus defined, is not seen farther west than the centre of the state; while the drab colored dolomitic beds, which contain scarcely any other fossils than *Eurypterus*, and allied crustaceans, extend throughout western New York, and have been identified through a portion of Western Canada. They rest directly upon the Onondaga formation, and constitute, throughout that region, the summit of the Silurian series.

Water-lime group.

Eurypterus beds.

The Water-lime series, as thus defined, enters Canada opposite to Buffalo, and can be traced pretty continuously, in a band varying from twenty

Bertie.

to forty-five feet in thickness. This series has been found to exhibit its characteristic fossils, in three localities, in Canada.* One of these is on the fifth lot of the tenth range of Bertie, where the following ascending section occurs:—

	Ft.	in.
Dark bluish-grey shaly dolomite,	1	0
Light bluish-drab dolomite (water-lime), in beds of from one inch to one foot; containing *Eurypterus remipes*,	3	6
Grey dolomite in beds of from one to eight inches,	10	0
Measures concealed in an escarpment which rises from the previous bed, but supposed, from fragments by which they are covered, to be of the same character as before,	6	0
	20	6

Jones's tract.

The second locality is on Jones's tract, where, in continuation of the beds already given as constituting the summit of the Onondaga formation, we have the following ascending series:—

	Ft.	in.
Lavender-grey compact dolomite, of a lighter color on the weathered surfaces; it is brittle, with a conchoidal fracture, and presents beds of from two to three inches in thickness,	7	0
Brownish-grey shaly dolomite,	5	0
Greyish-drab dolomite (water-lime), containing remains of *Eurypterus remipes*, and fragments of an undetermined *Ceratiocarus*,	2	6
Grey hard slaty dolomite, weathering brown,	1	0
Brownish-grey porous crystalline dolomite, in beds of from one to three feet thick,	5	0
Grey conglomerate or breccia, composed of a light grey calcareous paste, holding small angular masses of a darker grey and more compact dolomite, with a brownish tint. The whole mass weathers yellowish, and is divided into beds varying from four to twelve inches in thickness,	4	0
Grey porous dolomite, interlaminated with very thin bluish leaves, which in section appear to run irregularly and interruptedly, as if the bed had been broken and re-cemented. The rock, which is lighter colored on weathered surfaces, is divided into beds of from two to ten inches in thickness, and is interstratified with thin beds of fine grained dolomite. It holds nodules of light yellowish chert, weathering almost opaque white, and leaves of dark brownish bituminous shale,	20	6
	45	0

The third locality is at Rattlesnake Falls, on a small tributary of the Grand River, on the thirty-fifth and thirty-sixth lots of the first range

* Figures of the *Eurypterus*, and of some of the characteristic fossils of the Lower Helderberg group, will be given in the Appendix to this volume.

south of the Talbot road, in Cayuga; where a series of beds occurs, very much resembling those of Jones's tract, but showing not more than half the thickness. Fragments of *Ceratiocaris* are seen in a two-feet bed, about six feet from the base, and ***Leperditia alta*** occurs six feet above. Cayuga.

2. *Pentamerus limestone.*—In the eastern part of New York, this is a dark grey concretionary limestone in irregular layers; associated with a small amount of black shale, and holding fossils, of which the most characteristic is ***Pentamerus** galeatus*. It extends from Ulster to Onondaga county, and attains its greatest thickness at Cherry Valley, where it is about thirty feet. It is not recognized in the western part of New York.

3. *Delthyris shaly limestone.*—This division, like the last, occurs only in the eastern part of the state, extending from Ulster to Madison county, and is a mixture of blue drab-weathering calcareous shale and blue limestone. It is very fossiliferous, and takes its name from the frequent occurrence of two species of *Spirifera* (formerly called *Delthyris*), *S. macropleura* and *S. pachoptera*. It appears to attain its greatest thickness in Albany county, where it is stated to be sixty or seventy feet.

4. *Encrinal limestone.*—This is a mass of light-grey limestone, holding a large quantity of broken encrinites; the peculiar crystalline structure of these remains giving a crystalline character to the rock. It contains in great abundance a shield-like pelvis of a crinoid, from which it is sometimes called the Scutella limestone. Its greatest thickness is about twenty-five feet, and it extends, along with the previous division from Ulster to Schoharie county.

5. *Upper Pentamerus limestone.*—This division, which is still more restricted than the preceding ones, is characterized by the *Pentamerus pseudogaleatus*, and by several species of *Rhynchonella*. These local subdivisions however, according to Hall, cannot be recognized at any great distance from the Helderberg mountains; although this group, as a whole, has a wide geographical distribution.

As already stated, none of the members of this group, with the exception of the Water-lime series, are recognized in the western part of New York, or in Western Canada. In Eastern Canada, besides the Gaspé limestones, which belong to the great eastern palæozoic basin, there are evidences of the existence of the Lower Helderberg group in two or three small outliers in the great western basin, near to Montreal; and at a distance of about two hundred miles from the nearest position of the group in New York. Of these, the most important is on the island of St. Helen's, opposite to Montreal.

This outlier appears to repose on the Utica formation; the shales of which, with some of their characteristic fossils, are visible at the upper extremity of the island. The deposit consists principally of a conglomerate, the enclosed masses in which are sometimes rounded, but chiefly angular. Lower Helderberg outlier.

They consist of fragments of Laurentian gneiss; of white quartzose sandstone resembling that of the Potsdam formation; of dark grey limestone, in some cases holding Trenton fossils; of black shale resembling that of the Utica formations; and of red sandstone and red shale similar to those of the Medina. With these fragments are associated others of igneous rocks. All of these, varying in size from a quarter of an inch to five and six inches in diameter, are enclosed in a paste of a light-grey dolomite, which weathers to a reddish-yellow.

St. Helen's Island. The island has a north and south length of about 1200 yards, with a breadth of between 600 and 700, and the conglomerate rises into two small hills, separated by a narrow ravine crossing the island obliquely; the southern hill having a height of about 125 feet. In neither of these hills have there been observed any divisional planes clearly referable to stratification; but there are many parallel vertical joints, running in the bearings S. 30° E., S. 35° E., and S. 60° E. About two thirds of the distance down the east side of the island, nearly opposite to one end of the ravine, there occur two masses of dark grey fossiliferous limestone, weathering to a light grey; which are not magnesian. These are included in a length of about forty yards, and are limited on the east side by the water of the river; they have a breadth of scarcely more than ten feet, and appear to run under the dolomitic conglomerate on the west side. They present, in section, the appearance of two small arches of about four feet in height, separated from one another by a few feet of the conglomerate, and sinking under the same rock on the north and south. Two parallel dolerite dykes, running N. 75° W., cut both the limestone and the conglomerate, their position being partially intermediate between the two fossiliferous masses; which seem to be related to an anticlinal fold, with a dislocation running along the axis. The dolomite and the limestone seem to pass into one another for a few inches, and show no tendency to separate at the junction. The fossils observed in the limestone are *Favosites Gothlandica*, *Strophomena rhomboidalis*, *S. punctulifera*, *Orthis oblata*, an undetermined species of *Rhynchonella* with *R. Wilsoni; Athyris bella*, *Atrypa reticularis*, and two undetermined species of *Spirifera*.

As none of this limestone comes from beneath the conglomerate, where this reposes upon the Utica formation, it is supposed to belong to a small disturbed lenticular portion, lying in or under the conglomerate. Smaller patches of the same limestone, a few feet in diameter, are seen in the forty yards north of the two chief masses; and the whole may be connected beneath. There are other masses of similar limestone, only a few inches in diameter, which are completely enveloped in the conglomerate. It would seem therefore that this magnesian rock is younger than the fossiliferous limestone, upon which it is deposited, inasmuch as fragments of the latter are mingled with those of older rocks in the paste of the conglomerate.

Round Island, which is a little north of St. Helen's, is composed of the same dolomitic conglomerate; and there is no doubt that the channel between the two islands is floored with the same rock. The area occupied by the deposit, including both islands, and making some allowance for what may be concealed by the water on each side, very probably does not exceed half a square mile. The surface of Round Island is not in any part more than ten or fifteen feet above the St. Lawrence, and there does not appear to be any special difference in the composition of the conglomerate in the two islands. The only mass observed in the conglomerate of Round Island, which resembled the newer limestones of St. Helen's, was one of eight or ten inches in diameter, holding an undetermined species of *Heliophyllum*. **Round Island.**

On the north-west side of Isle Bizard, not far from the outcrop of the Chazy formation, but resting on the Calciferous, there occurs an exposure of dolomitic conglomerate so similar to that of St. Helen's, with the exception of the associated masses of Lower Helderberg limestone, that it is most probably of the same age. This outlier has an area of about a hundred paces in length, by about fifty in breadth, and rises to a height of fifty-five feet; forming a bold hillock on a flat country. The paste of the conglomerate has a greyish or slightly greenish color, and weathers to an orange-brown. Many of the enclosed fragments are composed of a sandstone resembling that of the Potsdam formation, and some are of a fine grained dark grey hard silicious slate. The fragments vary in size from a quarter of an inch to five or six inches in diameter. **Isle Bizard.**

On the right bank of the Rivière des Prairies at the White Horse Rapids, about four and a half miles east of the mass on Isle Bizard, there is another of the same description, occupying a somewhat larger area; while about six miles to the west of that on Isle Bizard, there is still another, on the road between St. Eustache and the Indian Mission of the Lake of Two Mountains. It is on the north side of the most eastern of the Laurentian hills of that vicinity, and lies, partly on the Potsdam sandstone, and partly on the Laurentian gneiss; of which latter rock the fragments enclosed in the dolomitic paste are in part composed.

In one of the cuttings for the Grand Trunk Railway, between Point Claire and Ste. Anne, there occurs a strip of a similar dolomitic conglomerate, filling a worn fissure in Trenton limestone. It is about a foot in width and some ten or twelve feet in length, but none of it appears on the surface of the limestone on either side. A fissure crossing the promontory on the west side of Shelburne Bay, near Burlington in Vermont, is described by Mr. C. H. Hitchcock as being filled with a conglomerate dyke. Specimens of this have a remarkable resemblance to the con- **Ste. Anne.**

glomerate of St. Helen's Island, and very probably belong to a contemporaneous deposit.

From these scattered outlying patches, it would appear that a considerable area in the Champlain and St. Lawrence valleys was once continuously covered with rocks of the Lower Helderberg group; while from the unconformable relation of these to the formations on which they repose, it is evident that, prior to the Lower Helderberg period, the older fossiliferous strata had suffered a great amount of denudation. The horizontal surface of the region around these outlying masses, farther shows, that, since the deposition of these newer rocks, denuding agencies cannot have greatly affected the older strata; but that their action has been confined to the Lower Helderberg or to more recent sediments, which have disappeared; and that consequently the geographical distribution of the Lower Silurian rocks in this vicinity, is now essentially the same as it was at the commencement of the Lower Helderberg period.

Besides the two dolerite dykes which have been mentioned, several others of a similar character intersect the dolomitic conglomerate of St. Helen's Island. These strongly resemble a certain set of dykes which cut alike the Utica, Trenton, and Chazy formations at Montreal, and the Laurentian series in Grenville, and are described in their proper place.

CHAPTER XIV.

THE ORISKANY AND CORNIFEROUS FORMATIONS.

BASE OF THE DEVONIAN SERIES.—ORISKANY SANDSTONE.—CAUDA-GALLI GRIT AND SCHOHARIE GRIT OF NEW YORK.—ORISKANY FORMATION IN CANADA.—THE UPPER HELDERBERG GROUP—CORNIFEROUS FORMATION: ITS DISTRIBUTION IN CANADA.—TWO AREAS IN THE WESTERN PENINSULA.—CINCINNATI ANTICLINAL.—THE FORMATION ON LAKE HURON; ON THE DETROIT RIVER.—BITUMINOUS BEDS; PETROLEUM SPRINGS.—UNDULATIONS OF THE FORMATION.

The calcareous rocks of the Lower Helderberg series are followed in New York by an arenaceous group, divided in ascending order as follows: 1, Oriskany sandstone; 2, Cauda-galli grit; 3, Schoharie grit. These divisions there appear to be characterized by distinctive fossils; but in Canada, several of the most characteristic species belonging to the lowest division, ascend into the Corniferous formation, which overlies them all. They are therefore to be looked upon only as local subdivisions of a sandstone formation, which is regarded as the base of the Devonian series. Devonian series.

The Oriskany sandstone is traceable in New York, from the valley of the Hudson in Ulster county, to the neighborhood of Buffalo on Lake Erie, as a band of white or yellowish rather coarse and sharp grained slightly calcareous sandstone, varying in thickness from an inch to thirty feet. It abounds in characteristic organic remains; of which many of the species are of large size, and usually occur as casts and impressions. Remains of plants, described as fossil wood, are said by Mr. Emmons to have been met with in this band, at New Scotland in Albany county. The top of the band is in some places marked by a fucoid, which resembles a cock's tail, and gives its name to the next division. Sandstones.

The Cauda-galli grit, which succeeds, is a crumbling argillaceous sandstone, approaching to an arenaceous shale; passing from bluish-drab below to brownish above. Its usual thickness is not given, but it sometimes attains seventy feet; and it abounds with the peculiar fucoid already mentioned, which covers the surfaces of successive beds of the deposit. The band ranges from Ulster to Herkimer county, but is not known farther west.

The Schoharie grit rests upon the previous bed in Albany county, to which it appears to be confined, and is a brownish decomposing calcareous sandstone, with a thickness of about four feet. It abounds in fossils, which in New York are different from those in the strata above and below.

Oriskany formation. It appears to be the lowest only of these bands which enters Canada at Waterloo, on the Niagara River. In its lithological characters, it does not seem to differ materially from the same rock in New York. The lower beds appear in several places to be composed of chert or hornstone, frequently containing large quantities of iron pyrites, and occasionally beautiful specimens of purple fluor-spar. Chert. This chert is sometimes found to descend continuously, into small vertical fissures in the rock beneath, and, sending out parallel horizontal seams for short distances, to enclose small flat portions of the strata, as if these had been partially broken up before the deposit of the chert. Resting on these beds, there is a sandstone, which is somewhat different in different localities. In the township of Dunn, near Haldimand, it is frequently made up of large angular pieces of hornstone; which, with the numerous large corallines and other fossils present, render it almost useless as a building stone. In the townships of North Cayuga. Oneida and North Cayuga, particularly on the forty-sixth, forty-ninth, and intermediate lots of the first range north of the Talbot road, in the latter township and the corresponding lots in the former, there are large exposures of the rock. It is composed of fine grains of white quartz, in some parts so closely cemented as to assume the characters of a white compact quartzite. In other parts, it is made up of coarser grains of quartz, some of them being an eighth of an inch in diameter and pretty well rounded. With these, there are occasionally grains of feldspar. The rock in these cases, being sometimes slightly calcareous, disintegrates by exposure to the weather. The beds are massive, and from six inches to six feet thick. They are in many places well adapted for building purposes, and some of them have been applied to the manufacture of millstones for grinding oats. The sandstone in some parts very much resembles the white beds of the Potsdam formation; but it passes from white to light grey, and, in some places, through yellowish to brown. It is not improbable that portions of it would be found sufficiently free from iron to be used for glass-making. The greatest thickness of the mass may be about twenty-five feet; but though now and then attaining ten feet, it seldom exceeds about six, and it is frequently wanting between the Water-lime series and the overlying Corniferous formation.

The rock abounds in organic remains. The species met with in the exposures in North Cayuga just mentioned, are *Favosites Gothlandica*, *F. hemispherica*, *F. turbinata*, *Zaphrentis prolifica*, *Heliophyllum exiguum*, *Cystiphyllum sulcatum*, an undetermined *Coscinium*, *Strophomena rhomboidalis*, *S. inæquistriata*, *S. perplana*, *S. magnifica*, *S. magniventra*, *S. ampla*, *Chonetes hemispherica*, *Orthis musculosa*, *Centronella glansfaga*, *Stricklandia elongata*, *Rensselaeria ovalis*, *R. ovoides*, *Pentamerus* *aratus*, *Spirifera arenosa*, *S. arrecta*, *Cyrtia rostrata*, *Atrypa reticularis*, *Conocardium trigonale*, *Avicula arenosa*, *Platyostoma ventricosa*, *Platyceras nodosum*, undetermined species of *Turbo* and *Orthoceras*, *Calymene Blumenbachii*, *Phillipsia crassimarginata*, *Dalmanites anchiops*, with an undetermined species of fish.* The band being thin, it generally appears in its distribution as a very narrow border to the succeeding formation. The exposure in North Cayuga, which is the largest that has been seen in Canada, does not exceed 230 acres, and the Oriskany formation is not yet known to extend beyond the township of Windham.

THE CORNIFEROUS FORMATION.

In New York and in Western Canada, the sandstone just described, or, where this is wanting, the Water-lime series is followed by bituminous limestones, holding a large amount of chert or hornstone; from which the name of Corniferous has been given to the formation. In New York, it is divided into two masses, supposed to be distinguished by characteristic fossils, and, in some degree, by lithological peculiarities. The lower portion consists of beds of a light grey limestone, occasionally almost altogether composed of broken encrinal columns and corals, and having much the appearance of the beds at the base of the Niagara limestone; particularly when, as in this, the organic remains are of a reddish tinge. It then yields a handsome variegated marble, and it generally affords good stone for building and for lime-burning. The strata are in many localities separated by thin layers of green shale; nodules of chert are common, and towards the top, in some places, beds of this silicious mineral alternate with those of limestone, forming a passage to the upper portion. This is a limestone of a compact texture, and varies in color from drab and light grey, through different shades of blue, to black; having, in this case, black shales associated with it. The hornstone which occurs in the lower division, is frequently very largely developed in this, and sometimes constitutes nearly the whole of the strata. The rock is fossiliferous, but not so abundantly as the one below, and the corals are in smaller proportion. The lower division attains, in New York, a thickness of twenty feet, and has there been called the Onondaga limestone; a title not to be confounded with that of the underlying Onondaga formation, or Salt group. The name of Corniferous limestone is, by the New York

Encrinal limestone.

Hornstone or chert.

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* Figures of some of the characteristic fossils of this formation will be given in the Appendix to this volume.

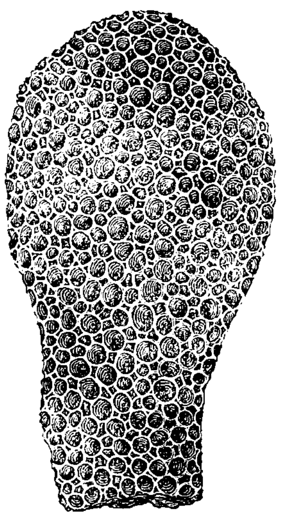
geologists, restricted to the upper division, which has in that state a thickness of about seventy feet. These two portions, with the addition of the local Schoharie grit, make up what they have described as the Upper Helderberg group.

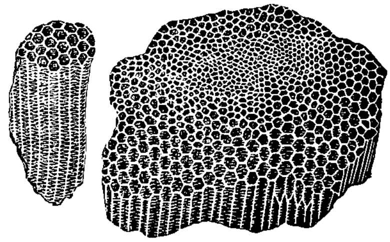
Upper Helderberg.

In Western Canada, we find that many of the fossils of the Corniferous limestone pass up from the Oriskany sandstone; and the intermediate

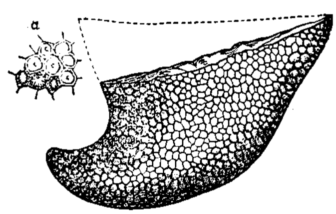
353-355.—ZOOPHYTA.

353 b 354 a





355 b



353.—*Favosites basaltica* (Goldfuss); club-shaped variety.

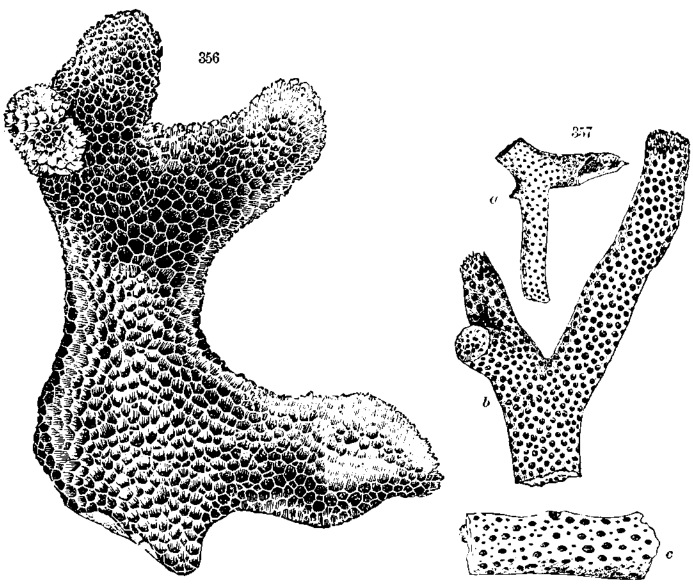
354.—*F.* —— *hemispherica* (Yandell and Shumard); *a*, specimen showing the variations in the size of the cells; *b*, specimen showing the incomplete transverse diaphragms.

355.—*F.* —— *turbinata* (Billings); *a*, portion of the surface enlarged, showing the different appearances of the cells when closed; *b*, side view of a small imperfect specimen.

Onondaga limestone, with its encrinites, can no longer be recognized as a distinct formation. We therefore unite the two limestones under the name of the Corniferous formation.

The surface occupied by this formation in Western Canada is probably between 6000 and 7000 square miles. A great part of this however is deeply covered by drift, so that the exposures are comparatively few. To the eastward, this formation is bounded by the outcrop already assigned to the underlying strata; the limits of which in many parts have as yet been but imperfectly traced. The whole of the province to the west and south of this line, belongs to the Corniferous formation; with the exception of a belt of higher Devonian rocks, which crosses the country from Lake Huron to Lake Erie, and divides the region into two areas. These newer strata occupy a saddle-shaped depression on the great Cincinnati anticlinal, which runs nearly east and west through the peninsula; while the course of this depression or synclinal is nearly north and south, from Plympton on Lake Huron, to Oxford on Lake Erie. The belt of higher rocks has a breadth of only about twenty-five miles on the anti- **Synclinal**

356, 357.—ZOOPHYTA.



356.—*Favosites cervicornis* (De Blainville).
357.—*F.* —— *polymorpha* (Goldfuss); three specimens.

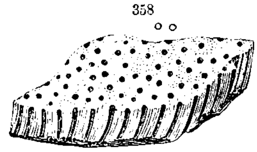
clinal, between the Thames and Sydenham Rivers; but on either side, it spreads to the north-east and to the south-west, along the shores of the two lakes.

Outliers of the higher rocks may very probably yet be found within these areas of the Corniferous formation; and subordinate undulations may, in some places, bring to the surface, domes or ridges of the Oriskany and Onondaga formations. The only evidences as yet obtained of the probable outcrop of these inferior rocks, within the areas in question, are found in two localities on the shore of Lake Huron; the one at Goderich, and the other at Point Douglas.

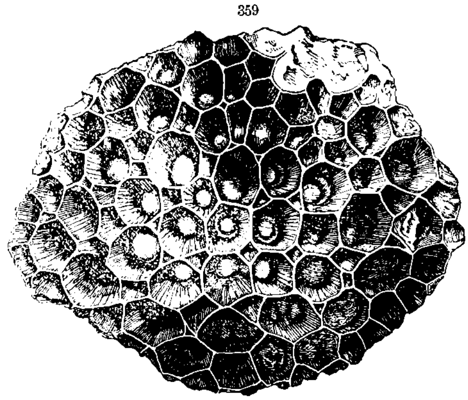
ss of n. The generally small dip of the strata, and the frequent occurrence of slight undulations, render it very difficult to find the succession of the beds, or to determine with accuracy the whole thickness of the Corniferous formation. The great extent occupied by it in Western Canada, however, makes it probable that it must be much more considerable here than in New York. In the townships of Woodhouse and Townsend, where there are frequent exposures, the breadth at right angles to the

358, 359.—ZOOPHYTA.

358



359



358.—*Fistulipora Canadensis* (Billings).
359.—*Michelinia convexa* (D'Orbigny).

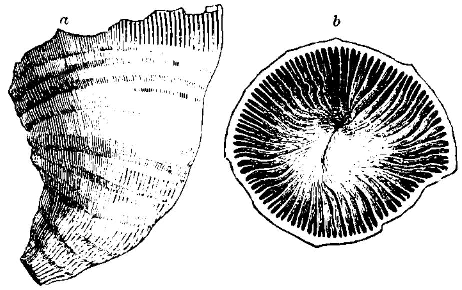
strike is upwards of ten miles. The fall of the surface, in that distance, is estimated at 140 feet; so that if the average slope does not exceed thirty feet in a mile, there would here be a thickness of about 160 feet of the Corniferous limestone. The strata, which in Michigan are considered as the equivalents of this formation, have, according to Prof. Winchell, a thickness of about 350 feet; so that it would appear that the thickness gradually augments to the westward.

ition. The formation enters Canada from New York, nearly opposite Buffalo, and is traceable, in a narrow belt, along the shore of Lake Erie, resting on the Oriskany sandstone: or, where this is wanting, on the Water-lime series. At Horn's quarry, in Bertie, two miles below Ridgway station, on the

railway, there is a section of nearly twenty-four feet; and at various points Bertie.
on the lake, or at a short distance inland, sections of from ten to twenty

360-363.—ZOOPHYTA.

360



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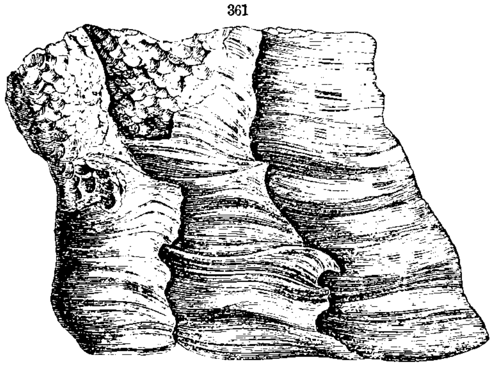
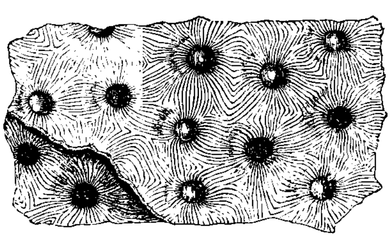


362

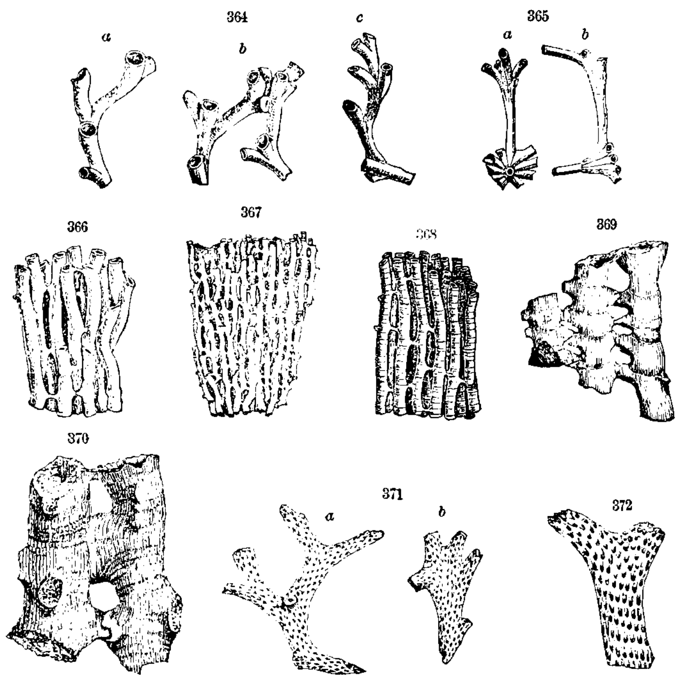
363



360.—*Zaphrentis prolifica* (Billings) ; *a*, side view ; *b*, view of the cup.
361.—*Cystiphyllum aggregatum* (Billings).
362.—*Haimeophyllum ordinatum* (Billings).
363.—*Phillipsastrea Verneuili* (Edwards and Haime).

feet have been observed, as far as Woodhouse and Middleton. In many parts, it is quarried for building purposes; while some portions abound in t beds. chert, which forms beds of from one to four inches, or exists in nodules like flints in the limestone. Many of the beds contain silicified organic remains. These, in some localities, as in North Cayuga and at Port Colborne, are found weathered out and loose, in great abundance, at the

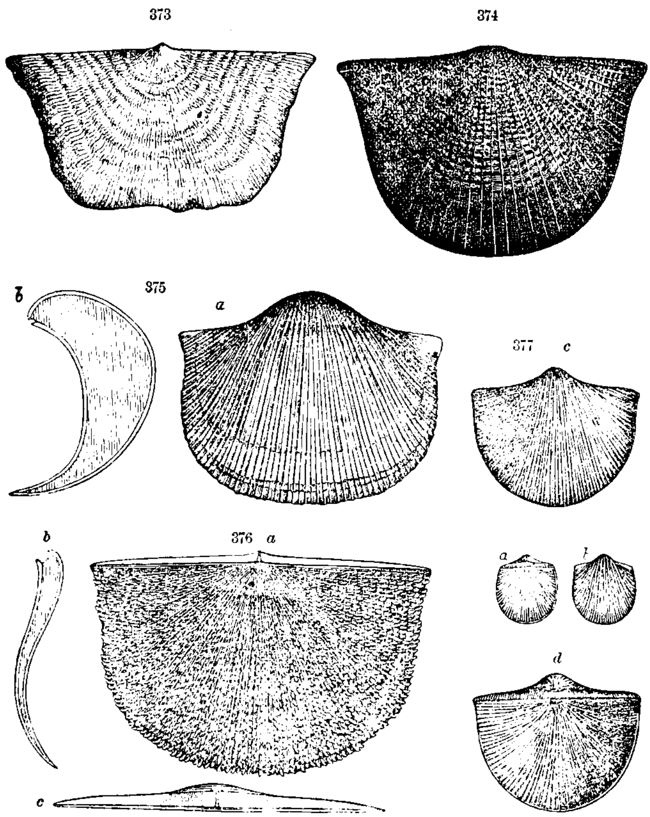
364-372.- ZOOPHYTA.



364.—*Aulopora cornuta* (Billings); *a, b, c,* three specimens.
365.—*A.* ——— *umbellifera* (Billings); *a, b,* two specimens.
366.—*Syringopora Maclurei* (Billings).
367.—*S.* ——— *Hisingeri* (Billings).
368.—*S.* ——— *perelegans* (Billings).
369.—*Eridophyllum Simcoense* (Billings).
370.—*E.* ——— *Verneuilanum* (Edwards and Haime).
371.—*Alveolites labiosa* (Billings); *a, b,* two specimens.
372.—*A.* ——— *cryptodens* (Billings).

surface of the ground. Some of the beds are little more than an aggregate of silicified organic remains; with so little calcareous matter, that the whole mass coheres, after the carbonate of lime has been dissolved out. The Corniferous limestones, unlike the great mass of the Middle and Upper Silurian strata, in Western Canada, effervesce freely with acids, and are not dolomitic. Some of the beds are marked with epsomites, as on the lake shore near Port Dover, where these impressions occur

373–377.—BRACHIOPODA.

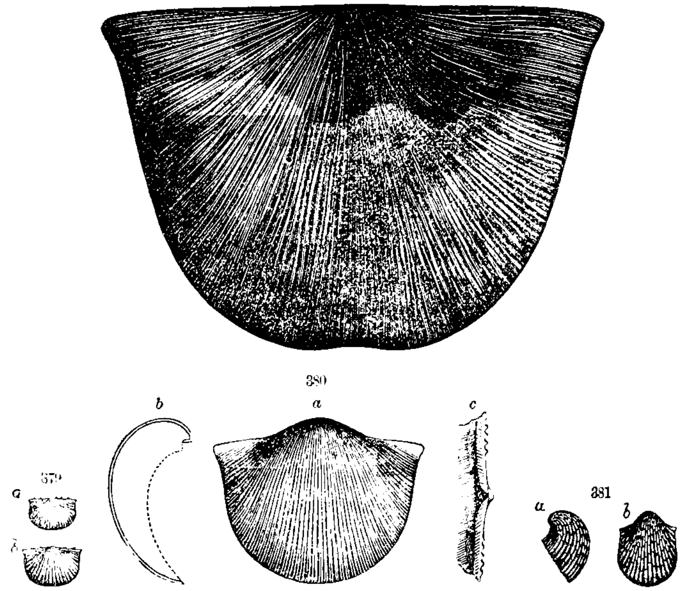


373.—*Strophomena rhomboidalis* (Wahlenberg).
374.—*S.* ——— *Patersoni* (Hall).
375.—*S.* ——— *inæquistriata* (Conrad); *a*, ventral aspect; *b*, longitudinal section.
376.—*S.* ——— *ampla* (Hall); *a*, dorsal aspect; *b*, longitudinal section; *c*, view of the area.
377.—*S.* ——— *demissa* (Conrad); *a*, *b*, *c*, *d*, different views of two specimens.

between layers of limestone and chert; the latter being apparently the overlying bed. These strata are often highly bituminous: petroleum is found in many places, filling the pores of the corals, and in one case a drusy leum. cavity in a *Pentamerus*. Instances of oil-bearing coral beds are met with at Horn's quarry in Bertie; near Gravelly Bay in Wainfleet; and near the village of Jarvis. In other beds, however, the cells of the corals are empty. In some parts along the lake shore, thin layers of bituminous shale are met with in the limestones.

378-381.—BRACHIOPODA.

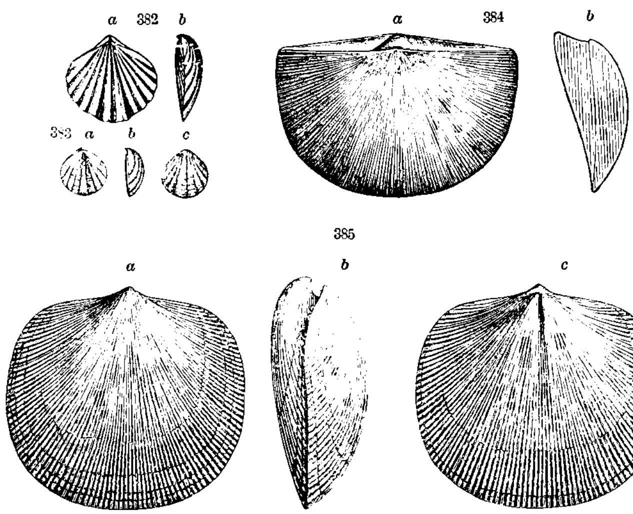
378



378.—*Strophomena ampla* (Hall).
379.—*Chonetes* —— ? *a* and *b*, ventral valves of undetermined species.
380.—*C.* —— *hemispherica* (Hall) ; *a*, ventral aspect ; *b*, longitudinal section ; *c*, view of the hinge line, showing the bases of the spine, and the striated area.
381.—*Producta* —— ? a small and undetermined species ; *a*, side view ; *b*, ventral view.

To the west of the Grand River, in the counties of Haldimand and Norfolk, the Corniferous limestones are often seen resting on the Oriskany formation, and forming small eminences; which present escarpments, with the sandstone at their base. These limestones are here of a drab color, and abound in chert. The organic remains with which the strata abound, are entirely silicified in many of the beds; while in others, they have undergone no such change. Among the species characterizing these and the immediately succeeding beds, constituting probably about twenty feet of the formation, are *Fistulipora Canadensis*, *Favosites Gothlandica*, *F. hemispherica*, *F. basaltica*, *F. turbinata*, *F. cervicornis*, *F. polymorpha*, *Michelinia convexa*, *M. intermittens*, *M. favosidea*, *Syringopora Maclurei*, *S. Hisingeri*, *S. perelegans*, *Zaphrentis prolifica*, *Z. gigantea*, *Z. exiguum*, *Heliophyllum Eriense*, *H. Cayugaense*, *H. Canadense*, *H. colligatum*, *Phillipsastrea*

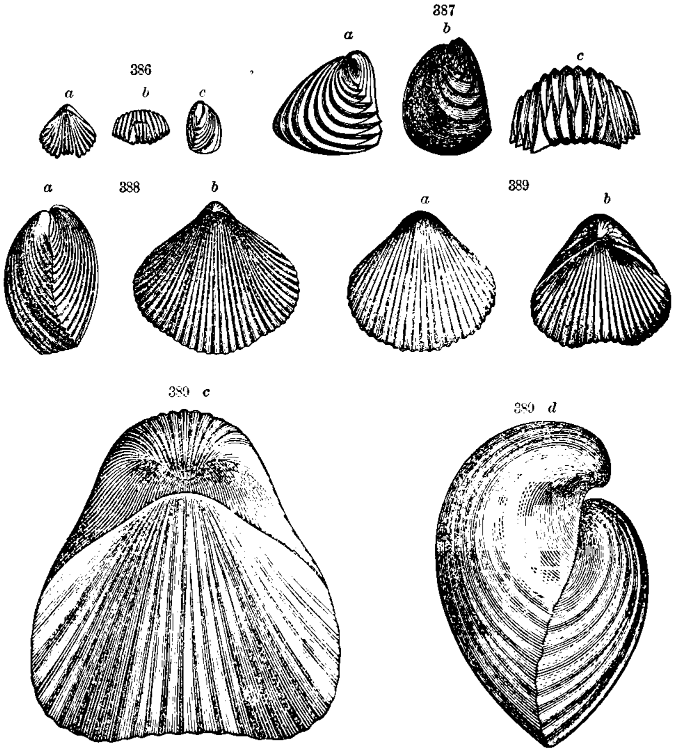
382–385.—BRACHIOPODA.



382.—*Leptocœlia flabellites* (Conrad); *a*, dorsal, and *b*, side view.
383.—*L.* ——— *concava* (Hall); *a*, *b*, *c*, three views of the same species.
384.—*Streptorhynchus Pandora* (Billings); *a*, dorsal valve; *b*, longitudinal section.
385.—*Orthis Livia* (Billings); *a*, ventral, *b*, side, and *c*, dorsal view.

gigas, *Clisiophyllum Oneidaense*, *Blothrophyllum decorticatum*, *Eridophyllum Verneuilanum*, *E. Simcoense*, *Diphyphyllum arundinaceum*, *D. stramineum*, *Cystiphyllum sulcatum*, *C. Senecaense*, *C. grandis*, *Orthis Livia*, *Streptorhynchus Pandora*, *Strophomena rhomboidalis*, *S. ampla*, *S. perplana*, *S. Pattersoni*, *S. inæquiradiata*, *S. demissa*, an undetermined species of *Chonetes* with *C. arcuata*, *Rhynchonella Thalia*, *R. Tethys*, *Pentamerus aratus*, *Stricklandia elongata*, *Centronella glans-faga*, *C. Hecate*, *Leptocœlia flabellites*, *L. concava*, *Spirifera duodenaria*, *S. fimbriata*, *S. raricosta*, with undetermined species of the same genus, *Cyrtena rostrata*, *Athyris Clara*, *A. Clusia*, *Spirigera concentrica*, *Atrypa reticularis*, *Conocardium trigonale*, *Platyostoma ventricosa*, two undetermined species of *Orthoceras*, and one of *Cyrtoceras*, *Phacops bufo*, *Phillipsia*

386-389.—BRACHIOPODA.



386.—*Rhynchonella Thalia* (Billings); *a*, *b*, *c*, three views of a specimen.
387.—*R.* ——— *Tethys* (Billings); *a*, *b*, side views of two specimens; *c*, front view.
388.—*R.* ——— *Medea* (Billings); *a*, dorsal, and *b*, side view.
389.—*Pentamerus aratus* (Conrad); *a*, *b*, ventral and dorsal views of a small specimen; *c*, *d*, dorsal and side views of a large specimen.

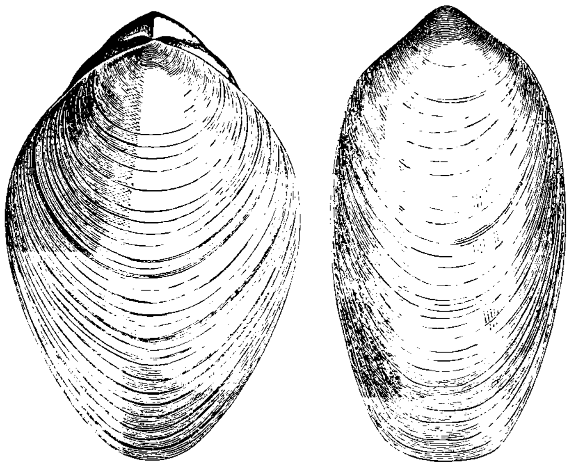
crassimarginata, two undetermined species of *Dalmanites*, with remains of fishes.

Higher in the series, along the same line of country, blue limestones, sometimes to the amount of twenty feet, with grey beds in less volume, are associated with cherty layers, and interstratified with bands of a drab-colored limestone. These strata are sometimes quarried, and yield stone fit for building purposes.

An outcrop of the Corniferous limestone occurs near Woodstock, nearly on the axis of the main east and west anticlinal of the peninsula. To the north of this exposure, the western boundary of the formation is traced by the abundant fossils, which are found loose on the surface, in Wallace and Elma. Farther on, escarpments of twenty or thirty feet of the limestone, run through the west half of Carrick, and are said to extend southward into Howick; while, to the north, the outcrop of the formation crosses the Woodstock.

390.—BRACHIOPODA.

a 390 b

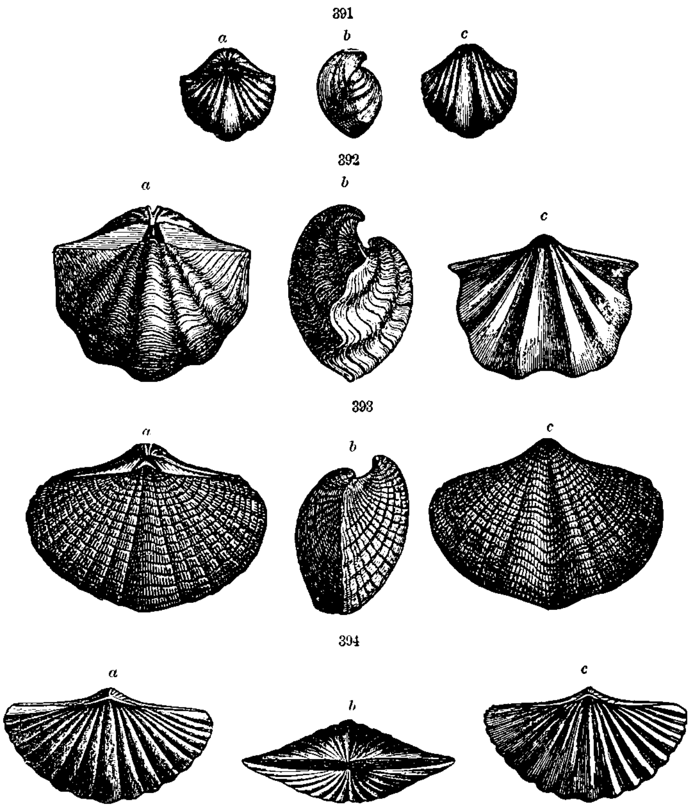


390.—*Stricklandia elongata* (Vanuxem); *a*, *b*, two specimens, showing the narrow and the broad forms.

south-west corner of Brant, and is seen upon the Teeswater, near the east line of Greenock. The general trend of the strata would bring them upon Lake Huron, near the mouth of the Saugeen River. No exposures have, however, been observed at this point, nor for seven miles to the south-west, along the coast. Beyond this, however, nearly horizontal buff-colored beds appear, at about two feet above the edge of the lake; holding numerous organic remains, which are frequently replaced by chert. These beds come out at intervals along the shore, the surface of the same stratum being sometimes exposed for a considerable distance: they occupy altogether a distance of four or five miles. Among the fossils found here, are *Favosites Gothlandica*, *Zaphrentis prolifica*, *Syringopora Hisingeri*, *Erido-* Lake Huron.

phyllum Verneuilanum, *Strophomena rhomboidalis*, *S. inæquistriata*, *S. perplana*, *Orthis Iowensis*, *Spirifera gregaria*, *S. bimesialis*, *Cyrtena*

391-394.—BRACHIOPODA.

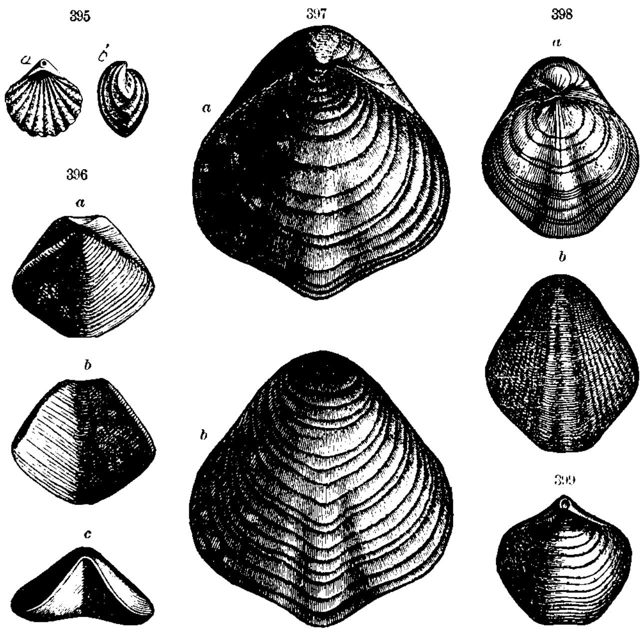


391.—*Spirifera gregaria* (Hall) ; *a*, *b*, *c*, three views of the same specimen.
392.—*S.*——— *raricosta* (Conrad) ; *a*, dorsal, and *b*, side view ; *c*, ventral view of a partially exfoliated specimen.
393.—*S.*——— *fimbriata* (Conrad) ; *a*, *b*, *c*, different views of the same specimen.
394.—*S.*——— *duodenaria* (Hall) ; *a*, dorsal view ; *b*, view of the hinge line ; *c*, dorsal view of another specimen.

rostrata, *Athyris Maia*, *Atrypa reticularis*, *Lucina elliptica*, *Conocardium trigonale*, and *Phacops bufo*.

Beyond this, another interval of concealment occurs, to within three miles of Point Douglas. Here, a yellowish calcareous sandstone skirts the coast line; and proceeding along the beach towards the point, the sandstone is found to be associated with calcareous beds, holding numerous nodules of chert, with black bituminous shales, and blue and drab dolomites; one bed among which is fit for hydraulic cement. The whole of these strata appear to be devoid of fossils; but they contain crystallized celestine, quartz, and calcite, in geodes and fissures. A black band, Point Douglas.

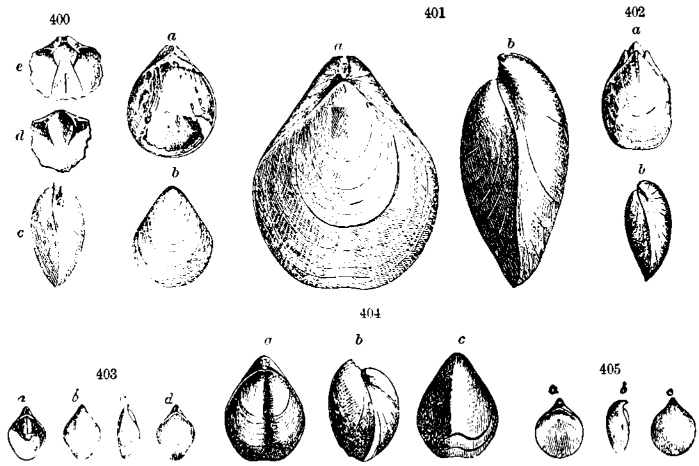
395-399.—BRACHIOPODA.



395.—*Retzia Eugenia* (Billings); *a*, dorsal, and *b*, side view.
396.—*Athyris unisulcata* (Conrad); *a*, dorsal, and *b*, ventral view; *c*, view of the front margin.
397.—*A.*—— *Clara* (Billings); *a*, dorsal, and *b*, ventral view.
398.—*A.*—— *Maia* (Billings); *a*, dorsal, and *b*, ventral view.
399.—*Spirigera concentrica* (Von Buch); specimen with the front margin truncated.

of a coarsely granular texture, overlies the sandstone, and appears to be composed of an aggregate of imperfect crystals of calcite; while the color results from the presence of bituminous matter, which exists, in greater or less proportion, in all of the beds. Ascending in the section, which at Point Douglas displays a thickness of twelve feet, thin calcareous beds of a dark color occur, separated by very thin layers of black bituminous shale. Above them, the upper part of the cliff is occupied by thin blue layers, with pale yellowish beds, sometimes more than a foot in thickness, marked by small lenticular crystals of brownish calcite, and by epsomites. Portions of these non-fossiliferous strata continue to occupy the coast to the southward, with gentle undulations, to a point about half a mile beyond Little Pine Brook. Here, fossiliferous cherty beds, similar to

400-405.—BRACHIOPODA.



400.—*Charionella Circe* (Billings); *a*, dorsal view of a specimen which shows some remains of spiral appendages; *b*, ventral, and *c*, side view; *d*, portion of the interior of the dorsal valve, showing the absence of a hinge plate; *e*, fragment of the ventral valve of *C. Doris*.

401.—*C.*——— *Doris*? (Hall); *a*, dorsal, and *b*, side view.

402.—*C.*——— ———; *a*, *b*, an undetermined species, perhaps a small specimen of *C. Doris*.

403.—*Centronella Hecate* (Billings); *a*, specimen showing the loop; *b*, *c*, *d*, different views of another specimen.

404.—*C.*——— *tumida* (Billings); *a*, *b*, *c*, three different views.

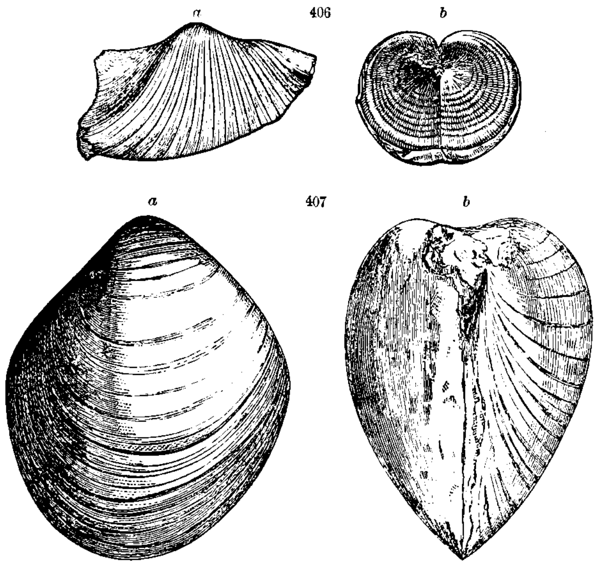
405.—*C.*——— *glans-fagea* (Hall); *a*, *b*, *c*, three different views.

those on the other side of Point Douglas, are seen, overlying the highest of the strata already mentioned, in detached isolated portions, for upwards of a mile; beyond which, no rock is exposed for upwards of twenty-five miles.

Kincardine. Near the village of Kincardine, in the sixth and seventh lots of the township of that name, is a quarry on the land of Mr. C. R. Barker, where from fifteen to twenty feet of the formation are exposed, consisting for the most part of thick bedded light and dark grey granular limestones; which are quarried both for building stone and for burning, and yield a very white lime. The lighter colored beds contain a few corals. No chert was observed here, but the rocks are bituminous; and towards the top, are thinner beds, interstratified with layers of a dark brown inflammable shaly limestone, some specimens of which contain a large proportion of asphaltum.

Where the line between the townships of Ashfield and Colborne meets the lake, a little south of Port Albert, on the Ashfield or Nine-mile River, rocks come from beneath the high clay cliffs which face the water, and Ashfield River.

406, 407.—LAMELLIBRANCHIATA.



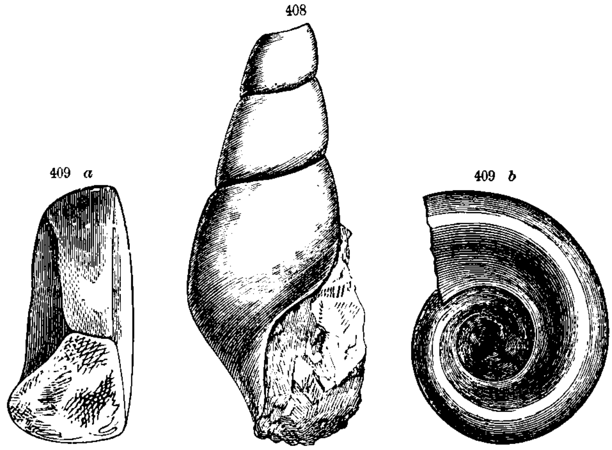
406.—*Conocardium trigonale* (Conrad); *a*, side view; *b*, view of the anterior extremity.
407.—*Vanuxemia Tomkinsi* (Billings); *a*, side view; *b*, posterior view.

are seen at intervals along the shore, for about a mile. The greatest section here exposed does not afford a vertical thickness of more than six feet. The rocks resemble a part of those of Point Douglas: they are destitute of fossils, and consist, in ascending order, of grey calcareous and bituminous sandstones, cherty limestones, brown calcareous beds striped with thin bituminous shales, and pale yellowish dolomitic layers, sometimes three feet thick; marked by lenticular crystals of calcite, or by cavities from which such crystals have disappeared. At the falls of the Ashfield River, about a quarter of a mile above Port Albert, there is exposed a series of thick bedded dark grey calcareous sandstones, with buff colored silicious limestones, both holding organic remains, which are more numerous in the latter; the most abundant species being *Spirifera bimesialis.* These fossiliferous beds, like those at Point Douglas, probably overlie the unfossiliferous strata.

On the Maitland River, about four miles in a direct line from the shore of Lake Huron, there occurs on the first lot of the first range of Colborne, an exposure of yellowish-drab limestone, holding among its fossils *Favosites Gothlandica*, *F. polymorpha*, *Zaphrentis prolifica*, *Stropho-*

408, 409.—GASTEROPODA.

408 409 *a* 409 *b*



408.—*Loxonema Cotterana* (Billings).
409.—*Euomphalus De Cewi* (Billings) ; *a*, front view; *b*, view of the umbilicus.

mena rhomboidalis, *S. inæquistriata*, *S. ampla*, an undetermined species of *Orthis*, *Spirifera gregaria*, *S. bimesialis*, *Athyris Maia*, *Atrypa reticularis*, *Avicula decussata*, *Lucina elliptica*, and *Phacops bufo*. Beds similar to those seen on the coast and the river near Port Albert, and probably a continuation of them, occur in a cliff lower down on the Maitland, near Goderich. The following is a descending section of them :—

Goderich.

	Ft. in.	Ft. in.
1. Dark grey thin bedded bituminous limestones, holding organic remains; with epsomites between two of the beds. Among the fossils are *Favosites Gothlandica*, *Zaphrentis prolifica*, *Strophomena inequistriata*, *S. rhomboidalis*, *Spirifera gregaria*, *Athyris Clara*, *Atrypa reticularis*, and *Lucina elliptica*,..............		24 0

	Ft. in.	Ft. in.
2. Measures concealed by clay and debris,........................	12 0	
3. Pale grey or drab fine grained sandstone, marked with ferruginous spots and stripes, and mottled with blue and yellowish colors; no fossils appear,..	2 0	
4. Brownish calcspar, an aggregation of irregular crystals arranged in a bed,...	0 1	
5. Dark brown fine grained sandstone, striped with bituminous layers; the rock is very soft and easily disintegrated, until after exposure to the air, when it becomes hard,..................	2 6	
		16 7
		40 7

At the bridge across the Maitland River, about half a mile from the town of Goderich, and at a short distance below the place where the above section was measured, the following unfossiliferous beds are found exposed in a continuation of the same cliff. Four feet of dark grey bituminous and silicious limestone, followed by two feet of brecciated beds, are seen, which probably correspond to a portion of the measures, 2, concealed above. To these succeed—

	Ft. in.
3. Pale yellowish calcareous sandstone, with ferruginous stripes and spots,	1 10
4. Brownish calcspar, an aggregation of irregular crystals arranged in a bed,..	0 6
5. Yellowish sandstone, with bituminous and ferruginous spots,..........	3 0
6. Dark grey or brownish bituminous dolomite, with small lenticular crystals of calcspar; some beds contain a large quantity of chert, and thin partings of bituminous shale,..............................	4 0
	9 4

There is little doubt that the fossiliferous beds in all these various exposures, from Fort Douglas, belong to the Corniferous formation; while the lower non-fossiliferous strata bear a strong resemblance, in their mineral character and general aspect, to the Water-lime series. Their arrangement shows that we have here one of the minor undulations, to which allusion has been made.

In the south-western area, which includes the region between the lakes Erie and St. Clair, the Corniferous limestones appear to become somewhat lighter in color, and more granular in texture, than they are to the east. In this respect, they approach in character to the rocks of the same formation in Ohio, and others of the western states of the American Union. A section of about twelve feet of the formation is displayed on the banks of the north branch of the Thames, at the village of St. Mary, between the sixteenth and eighteenth ranges of Blanchard. The rock is exposed for about a mile and a half above, and for the same distance below the bridge, which here crosses the river. Its color

South-western area.

St. Mary.

is a light drab, occasionally weathering to a greenish tinge; it is very bituminous, and holds numerous fossils. Among these are *Favosites Gothlandica*, *F. hemispherica*, *F. polymorpha*, *Zaphrentis prolifica*, *Strophomena rhomboidalis*, *S. demissa*, *S. inequistriata*, *S. ampla*, an undescribed species of *Orthis*, with two or three of *Chonetes*; *Spirifera bimesialis*, and fragments of a large undetermined species of this genus with very numerous ribs; *Cyrtena rostrata*, *Athyris Maia*, *Atrypa reticularis*, *Lucina elliptica*, *Vanuxemia Tomkinsi*, an undetermined species of *Avicula*, with two or three others of lamellibranchiate shells, three or four undetermined species of *Orthoceras*, *Phacops bufo*, and the remains of fish.

Malden. At Malden, near Amherstburg, which is upwards of a hundred miles to the westward of St. Mary, the limestones of the formation are whitish-grey and sometimes light buff, and some of the beds are granular. The fossils which they contain are *Favosites Gothlandica*, *F. hemispherica*, *F. polymorpha*, *Syringopora Hisingeri*, *Michelinia convexa*, *Zaphrentis prolifica*, *Strophomena rhomboidalis*, *S. inequistriata*, *S. demissa*, *S. perplana*, *S. ampla*, an undetermined *Orthis*, *Spirifera fimbriata*, *S. varicosa*, *Athyris Clara*, *Atrypa reticularis*, *Lucina elliptica*, *Conocardium trigonale*, *Phacops bufo*, *Phillipsia crassimarginata*, with an undetermined *Orthoceras*, and the remains of fish. These beds yield a very fine building stone at Malden, where they are extensively quarried: the beds are from one to two feet in thickness, and nearly flat. For a considerable space in the neighborhood, they are seldom covered by more than two or three feet of soil, and in some parts are seen at the very surface. At the base of some of the sections at Malden, there is a compact layer of a buff color, somewhat resembling lithographic stone in appearance; but for lithographic purposes it seems to be too brittle. All of these beds burn to good lime.

Oil-bearing beds. The limestones of this formation are all more or less bituminous, and bitumen exists in many of them in a liquid form, as petroleum or rock oil, filling the cells of the corals and other fossils. The corals often prevail in distinct bands, some of which will be saturated with the oil, while those above and below will have little or none. In working Mr. Horn's quarry, which has already been mentioned, on the thirteenth lot of the second range of Bertie, the oil is seen to impregnate particular beds, which are in great part made up of the remains of a species of *Heliophyllum*. These corals, in various attitudes, are arranged in bands varying in breadth from three to six inches; and in their open cells, the petroleum is lodged. The intermediate parts of the rock, which contain no oil, are composed of a mass of broken organic remains, chiefly encrinites; while in the coral-bearing beds, these comminuted crinoids serve as a paste to fill up the interstices among the corals.

The petroleum springs which rise from this formation in Tilsonburgh, probably have their origin in such bituminous beds; and other springs of the same character, which issue in Enniskillen from strata above the Corniferous, very probably ascend, through these newer rocks, from the same formation. Some of these springs appear to be on the line of the great anticlinal, which runs through the western peninsula; and subordinate undulations of a similar character will be found connected with others. The oil being lighter than water, and permeating with it the strata, naturally rises to the highest part, which is the crown of the anticlinal; whence it escapes to the surface by some of those cracks which are usually found in such positions. These petroleum springs, by the aid of wells and artificial borings, have been found to yield a very large supply; and the uses of the oil having been greatly extended by recently discovered modes of refining it, a new industry, to be noticed in a separate chapter, has arisen in Western Canada and other places where petroleum springs occur.

Petroleum springs.

It will be observed, that the positions of these anticlinal forms in Western Canada thus become a matter of economic importance. The general course of the main anticlinal can be readily traced by means of the distribution of the formations. It would appear that the crown of the arch runs in a gentle curve, from the western extremity of Lake Ontario, by Woodstock; in the neighborhood of which, the base of the Corniferous formation folds over it. Proceeding thence by the Thames, in the general bearing of the Great Western railway, it would reach the town of Chatham, and then pass to Pigeon Bay on Lake Erie. The springs of Enniskillen would appear to be north of this axis, and they may probably be on a subordinate one parallel with it; which may be connected with the undulation that has already been mentioned as affecting the outcrop of the Guelph formation at Rockwood. Small undulations in the Corniferous formation, are observable at several places in that part of its distribution which borders on Lake Erie, from the Niagara River to the township of Windham. Two of these are indicated by curves in the outcrop of the base; one of them, already alluded to, near Point Abino, and another obliquely crossing the Welland Canal in the second range of Humberstone: the course of both is probably about south-west. Opposite dips in some of the exposures of the strata, indicate other undulations. One of these occurs on the thirteenth lot of the first range of Rainham, where the direction of the undulation is nearly north-west; and another is shown in the large exposure of Oriskany sandstone on the town line between Oneida and North Cayuga, where the axis of the undulation is about south-west.

Undulations.

CHAPTER XV.

THE HAMILTON FORMATION AND THE PORTAGE AND CHEMUNG GROUP.

UPPER DEVONIAN ROCKS IN NEW YORK.—MARCELLUS SLATE.—HAMILTON GROUP.—TULLY LIMESTONE.—GENESEE SLATE.—PORTAGE GROUP.—CHEMUNG GROUP.—HAMILTON FORMATION IN WESTERN CANADA: ITS DISTRIBUTION.—BLACK SHALES BELONGING TO THE BASE OF THE PORTAGE GROUP; THEIR DISTRIBUTION IN WESTERN CANADA.—DEVONIAN ROCKS OF MICHIGAN AND NEW YORK.

Upper Devonian strata.

In the state of New York, the Corniferous limestones are succeeded by a series of shales, limestones, and sandstones, which are designated in ascending order as follows: 1, Marcellus shales; 2, Hamilton group; 3, Tully limestone; 4, Genesee slates; 5, Portage or Nunda group; and 6, Chemung group. These together make up the Erie division of the New York geologists, which is regarded as the summit of the Devonian system; and are followed, in that state, by the Catskill group of sandstones, which are considered as the base of the Carboniferous system.

The Marcellus shale is described as a black or brown bituminous shale or pyroschist, often pyritiferous, and very much resembling that of the Utica formation. The lower portion contains thin layers of dark colored impure fossiliferous limestone, and concretionary calcareous masses, which have the internal structure of septaria. In the upper part, the shales are destitute of organic remains, and lighter in color; becoming olive-grey, and passing into the succeeding formation. The black color of these lower shales formerly led to explorations for coal in this formation; and the borings then made, show that its greatest thickness, which is towards the Hudson River, may be one hundred feet; while to the westward, in which direction it has been traced to Lake Erie, it does not exceed half that volume.

Hamilton group.

The Hamilton group in New York, consists of a series of olive-colored or bluish calcareo-arenaceous and argillaceous shales, weathering to ash-grey or brown. In its eastern distribution, some beds of sandstone occur, near the middle of the series; while to the westward, it becomes more argillaceous, and includes a band of encrinal limestone, besides layers of septaria. Towards the east, it is said to resemble the Hudson River formation, and to have a thickness of from 300 to 700, and even 1000 feet; while to the west, it presents the characters of the shales at the base of the Niagara formation, and has a thickness of a little more than 200 feet. This, according to Mr. Hall, consists, in ascending order, of—

	Feet.
Olive shales, with *Pterinea*, *Cypricardia*, and *Strophomena*,.............	80
Coarse grained shales, with numerous fucoids, and with a hard calcareous stratum at the top,..	40
Bluish and greyish-blue very fissile shales, with large numbers of *Atrypa*, *Orthis*, *Spirifera*, and *Strophomena*,..............................	90
	210

To this succeeds the Tully limestone; a blackish-blue concretionary fossiliferous stratum, which has a thickness of twenty feet, in the eastern part of New York, but thins out westward, and disappears before reaching Lake Erie.

Genesee slates.

The Genesee slates consist of black bituminous shales, so like those of the Marcellus division that it is difficult to distinguish them, without the aid of fossils. They exfoliate where their edges are exposed to the weather; but retain their black color, except in those portions where pyrites occurs. These shales are interstratified with occasional bands of flagstones, and include septaria, some of which contain petroleum and a white crystalline hydro-carbon, while others hold crystallized selenite, calcite, and quartz. The upper part of these strata contains a few fossils. The Genesee slates extend from Chenango county to Lake Erie. Towards the east, they attain a thickness of from 100 to 150, and even, according to Emmons, of 400 feet: but to the westward, according to Mr. Hall, their volume is reduced to about twenty-four feet.

Portage group.

The Portage group consists, in ascending order, of: 1, A shaly sandstone, in the eastern and middle parts of the state; becoming, to the westward, a series of greenish crumbling shales; within which, at eight feet from the base, is included a band of black shale, like the Genesee slate. From a thickness of one hundred and ten feet, in the east, these strata are reduced to thirty-three feet, on Lake Erie. 2, A series of beds, which, to the eastward, are chiefly sandstones; but, towards Lake Erie, present an alternation of black and green sandy shales, with thin sandstone layers. Farther west, they consist of a thick mass of black shales, followed by several hundred feet of alternating green and black shales, without sandstones. 3, Soft thin bedded sandstones below, followed by thick massive layers above. The total thickness of this group is estimated by Mr. Hall at 1400 feet. Casts of shrinkage cracks, mud furrows, and lines of flow, mark the surface of the sandstone beds; and the structure called cone-in-cone occurs in the argillaceous ones. Fucoids abound in the group, *Fucoides graphica* characterizing the lower, and *F. verticalis*, the upper portion. In addition to these, fossils of the following genera occur:

Cyathocrinus, *Orthis*, *Spirifera*, *Avicula*, *Ambonychia*, *Cardium*, *Astarte*, *Lucina*, *Nucula*, *Bellerophon*, *Ungulina*, *Orthoceras*, *Clymenia*, and *Goniatites*.

Chemung group. The Chemung group consists at the base of olive shaly sandstones, followed by black slaty shales, with septaria. To these succeed green shales, with grey sandstones, supporting grey and olive shales and shaly sandstones; the proportion of the softer and harder masses varying in different places. The greatest thickness of the group is said to be about 1500 feet, diminishing gradually from south-eastward to north-westward. It is well characterized by its fossils, which are abundant, and consist chiefly of brachiopoda and acephala. A few species of land plants occur in this formation, belonging to the genera *Sigillaria*, *Stephanopteris*, and *Plumalia*. The other fossils belong to the genera *Orthis*, *Rhynchonella*, *Strophodonta* (*Strophomena*), *Spirifera*, *Athyris*, *Atrypa*, *Aviculapecten*, *Pteronitis*, and *Phacops*.

THE HAMILTON FORMATION.

Hamilton formation. In the western part of Canada, we have not been able to distinguish either the Marcellus shales, or the Tully limestones, from the Hamilton group; and we shall therefore, in describing the rocks of that region, include under the name of the Hamilton formation, all the strata between the Corniferous limestones and the Genesee shales. This formation occupies the lowest portion of the saddle-shaped depression, noticed in the previous chapter, as crossing the peninsula from Lake Erie to Lake Huron, and separating the Corniferous formation into two areas. The space thus occupied is very much covered by drift, and the contact between the Corniferous and Hamilton formations, has not yet been seen; so that it is not easy to assign their precise stratigraphical place to the exposures which are met with.

Bosanquet. On the twenty-third, twenty-sixth, and intermediate lots of the third range of Bosanquet, exposures of the rock are met with, on the banks of a small tributary of the Rivière aux Sables (south). The following section in ascending order was measured on the twenty-fifth lot:—

	Ft.	in.
Grey calcareous shale, imperfectly seen in a slope or talus on the stream,..	25	0
Grey calcareous shale with *Spirifera mucronata* and other fossils,.........	4	0
Grey solid limestone composed of broken remains of encrinites,...........	2	0
Grey soft shales, thinly laminated next the limestone, and filled with fossils, among which *Cystiphyllum Americanum* is very abundant. The upper part has the softness of clay,..................................	20	0
Grey decomposing shale not well exposed,................................	80	0
Grey encrinal limestone, weathering into small lenticular fragments, and holding bivalve shells, corals, and encrinites,........................	2	0
	133	0

This section probably includes the strata of the neighboring exposures. The fossils obtained from the whole of these are *Favosites Gothlandica*, *F. turbinata*, *F. polymorpha*, *Cystiphyllum Americanum*, *Pentremites Roemeri*, *Strophomena ampla*, *S. convexa*, *S. lepida*, *Orthis Vanuxemi*, *O. perversa*, *Rhynchonella Laura*, *Spirifera mucronata*, *Cyrtia Hamiltonensis*, *Athyris concentrica*, *Charionella rostrata*, *Retzia Chloë*, *Atrypa*

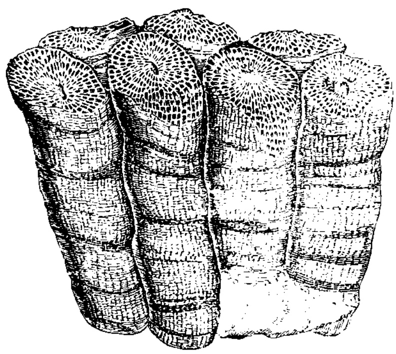
410-414.—ZOOPHYTA.

410

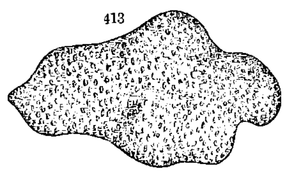
411

a *b* *c* *d*

412



413



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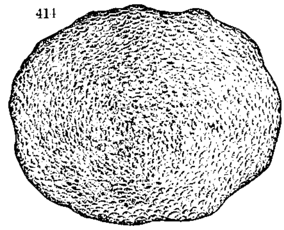


410.—*Striatopora Linnæana* (Billings).
411.—*Trachypora elegantula* (Billings); *a*, *b*, portions of two corallites; *c*, longitudinal section; *d*, portion of a corallite enlarged.
412.—*Diphyphyllum Archiaci* (Billings).
413.—*Alveolites Fischeri* (Billings).
414.—*A.* ——— *Goldfussi* (Billings).

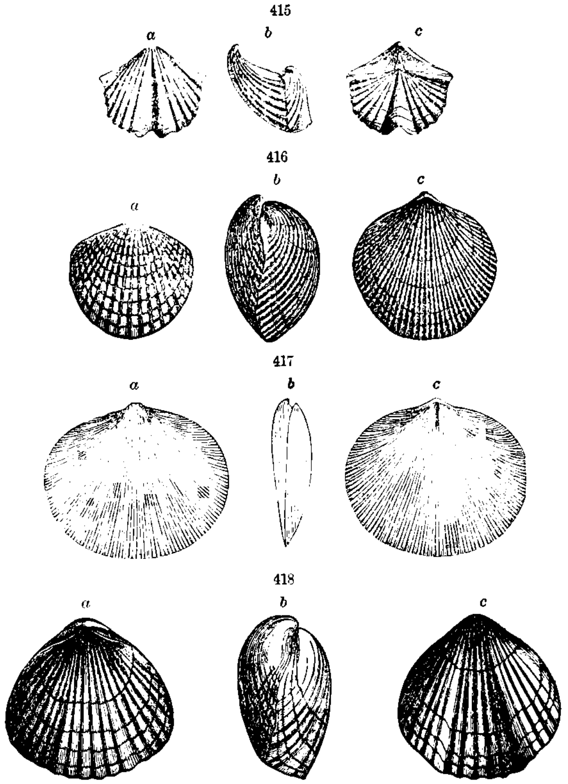
reticularis *Lucina elliptica*, *Pleurotomaria* ———? an undetermined *Orthoceras*, and *Phacops bufo*; with an undetermined *Dalmanites*.

At Jones's mill, on the third lot, upon the south boundary of Bosanquet, on the bank of another small tributary of the Rivière aux Sables (south), the following ascending section is exposed:—

	Ft.	in.
Brownish grey-weathering shales, holding *Spirifera mucronata* in great abundance, and a few other bivalves and corals, ...	25	0
Grey encrinal limestone, ...	2	0
Grey decomposing shale with *Cystiphyllum Americanum*, ...	3	0
	30	0

In addition to the fossils named, which are the most abundant, these strata contain *Favosites Gothlandica*, *Zaphrentis prolifica*, *Heliophyllum Halli*, *Strophomena inæquistriata*, and an undetermined *Chonetes*.

415-418.—BRACHIOPODA.



415.—*Cyrtia Hamiltonensis* (Hall); *a*, ventral, *b*, side, and *c*, dorsal view.

416.—*Atrypa reticularis* (Linnæus); *a*, coarse-ribbed variety; *b*, and *c*, common form.

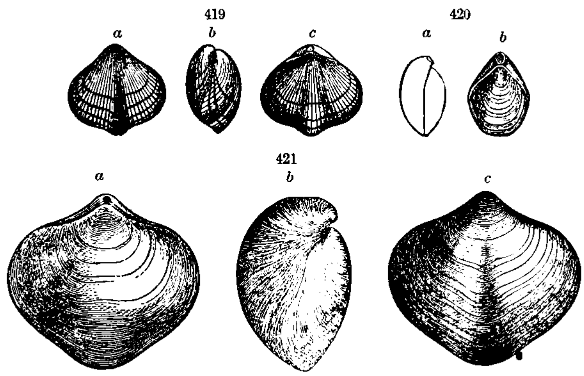
417.—*Orthis Vanuxemi* (Billings); *a*, ventral, *b*, side, and *c*, dorsal view.

418.—*Rhynchonella? Laura* (Billings); *a*, dorsal, *b*, side, and *c*, ventral view.

At Austin's mill on the fourth lot of the first range of the same township, on another small stream, there is a corresponding section, where the grey encrinal limestone which forms the uppermost layer of the exposed strata, is five feet thick. Below this band, the strata are characterized, as before, by a great abundance of *Spirifera mucronata;* and in the bed of the stream, at a level of probably fifty or sixty feet below the encrinal limestone, there is a band of solid arenaceous limestone, about seven inches thick. This is underlaid by black shales, holding *Strophomena inæquistriata*, *Atrypa reticularis*, and an undetermined *Chonetes*. These black shales may possibly indicate the passage, which occurs in New York, between the Marcellus and the Hamilton shales.

A series of beds, which are probably higher than those in the third range, is met with on the twenty-fifth lot of the fifth range of Bosanquet. They consist chiefly of grey decomposing shales, and may have a thickness of thirty feet. The fossils which they contain are *Favosites Gothlandica*, *F. turbinata*, *F. polymorpha*, *F. cervicornis*, *F. hemispherica*, *Alveolites*

419-421.—BRACHIOPODA.



419.—*Retzia Chloë* (Billings) ; *a*, ventral, *b*, side, and *c*, dorsal view.
420.—*Charionella rostrata* (Hall) ; *a*, side, and *b*, dorsal view.
421.—*Spirigera concentrica* (Von Buch) ; *a*, dorsal, *b*, side, and *c*, ventral view.

Roemeri, *A. Fischeri*, *A. Goldfussi*, *Trachypora elegantula*, *T. irregularis*, *Striatopora Linnæana*, *Diphyphyllum Archiaci*, *Zaphrentis prolifica*, *Heliophyllum Halli*, *H. tenuiseptatum*, *Cystiphyllum Americanum*, *Strophomena ampla*, *S. concava*, *S. lepida*, *Spirifera mucronata*, *Athyris concentrica*, and *Phacops bufo*.

In the same township, near the Widder station, a cutting on the Grand Trunk Railway exposes about forty feet of this formation, in horizontal beds. The strata here consist of a soft scarcely indurated marl or clay, with occasional intercalated beds of limestone, a few inches in thickness. The whole of these beds abound in fossils, the chief of which are *Spirifera mucronata*, *Atrypa reticularis*, and *Spirigera concentrica;* with fragments of *Goniatites*. It is not unlikely that these clays, instead of being the Widder.

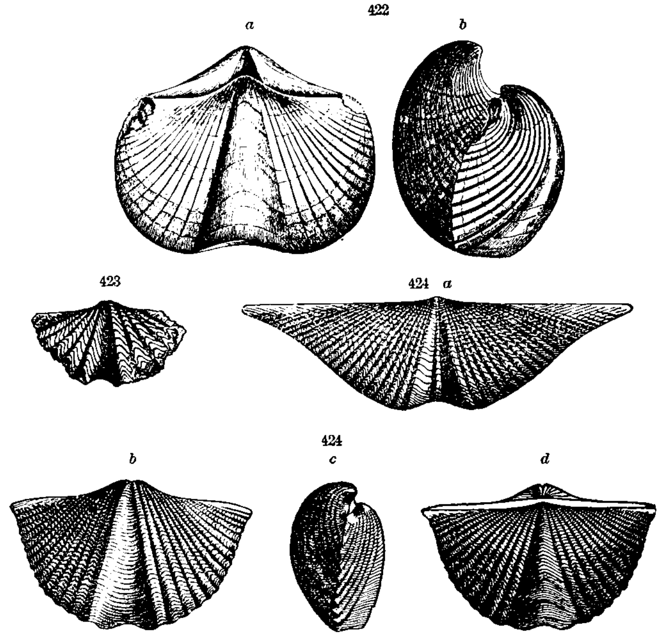
result of a decomposition of the shales, are sediments which have never been hardened. Portions of the Hudson River formation, at Point Rich, and of the Clinton formation, at Dundas, are in a similar condition, and might be confounded with recent clays.

Clay beds.

Enniskillen.

The oil springs of Enniskillen, which are supposed to have their source in the Corniferous limestones, rise through the Hamilton shales, in which

422-424.—BRACHIOPODA.



422.—*Spirifera Parryana* (Hall) ; *a*, dorsal, and *b*, side view.
423.—*S.* ——— *sculptilis* (Hall).
424.—*S.* ——— *mucronata* (Conrad) ; *a*, long-winged variety ; *b*, *c*, and *d*, different views of the short-winged form.

Oil wells.

numerous wells and borings have been sunk, to various depths. These, meeting with fissures, connected probably with anticlinals, bring to the surface large quantities of petroleum; often accompanied by inflammable gas and saline waters. Three of these wells have been sunk in the adjacent corners of the thirteenth and fourteenth lots of the tenth and eleventh ranges of the township, and, after passing through fifty or sixty feet of drift, reach the rock beneath. In one of the borings, according to the account given, there were met with, thirty-eight feet of limestone or sandstone layers, alternating with soft shale or clay; succeeded by 162 feet of similar soft clays, beneath which was a limestone, which may belong to the summit of the Corniferous formation. In two other borings, the soft rock appears to have been met with immediately beneath the drift, and was penetrated to depths of 182 and 190 feet, before reaching the limestone.

A boring on the seventeenth lot of the third range, beneath sixty feet of drift, passes through thirty-eight feet of alternating hard and soft strata, and then 117 feet of soft shale. Below this, a harder bed was met with, which was called by the workmen a sandstone, and may be some arenaceous layer overlying the lower limestone. Another boring, on the thirteenth lot of the sixth range, beneath sixty feet of drift, penetrates 224 feet of soft shale, without meeting with the limestone beneath. It thus appears that there is a great mass of soft shale in the lower part of the Hamilton formation, reaching in some places a thickness of nearly 230 feet; and it would perhaps be quite safe to estimate the whole volume of the formation at about 300 feet. Tttal thickness.

THE PORTAGE AND CHEMUNG GROUP.

Of the higher members of the Devonian series of New York, the Genesee slates are regarded by Mr. Hall, as forming a lower member of the Portage group; the sandstones of which, as we have already said, are interstratified, at their base, with similar black shales. We may, for convenience, unite the Chemung sandstones with those of the Portage series and their underlying black shales, under the name of the Portage and Chemung group. The strata of this group are wanting in Western Canada, with the exception of some portions of black bituminous shale, which are supposed to represent the Genesee slates. These black shales are met with at Cape Ipperwash, or Kettle Point, in Bosanquet, on Lake Huron. Here, in a low cliff, on the west side of the cape, is a section of between twelve and fourteen feet of very fissile black bituminous shales, weathering to a leaden-grey, and often stained brown by oxyd of iron. A yellow earthy coating of oxalate of iron is sometimes found in the surfaces of the shales, which also contain nodules and crystals of iron pyrites; besides peculiar spheroidal concretions, whose fancied resemblance to inverted kettles has probably given its name to the point. They vary in size, from three inches to as many feet in diameter, and are sometimes nearly spherical, and at others somewhat flattened, generally on the under side. Occasionally a smaller spheroidal mass is implanted on the top of a larger one. These concretions are readily broken, and are then seen to be composed of brown crystalline carbonate of lime; which is confusedly aggre- Kettle Point shales.

gated in the centre, and sometimes contains blende. Around this, are arranged slender prismatic crystals, which extend from the nucleus to the circumference; the whole having a radiated columnar structure, which, not less than the terminations of the prisms, at the surface of the spheroidal masses, gives them very much the aspect of fossil corals.

On the east side of the point, the upper beds of the section are concealed; but the lower ones come from beneath the bank, at a little above the water's level, and cover an area of several acres; the whole surface being studded with these spheroidal concretions, which remain when the softer shale around them has been partially worn away.

Fossil plants.

This black shale is fossiliferous, and contains a fucoid resembling a variety of the *Fucoides cauda-galli* of Vanuxem, which is very abundant in the lower beds. Flattened stems of *Calamites inornatus* (Dawson), which are sometimes seven or eight feet long, and three inches wide, occur about the middle of the section, and are occasionally converted into coal. Besides these, according to Dr. Dawson, there occurs here a stem which belongs to *Sagenaria Veltheimiana* (Goeppert). An undetermined *Lingula* is found with these plants, together with numbers of what appear to be microscopic orbicular shells.

These shales contain so much organic matter, as to take fire and burn with flame, after which the color is changed to brick-red. This is observed in the shingle of the beach, which has evidently been subjected to fire; and it is reported by the Indians, to have continued burning for a long time. These black shales have also been observed on a branch of Bear Creek, near Kingston Mills, on the seventh lot of the third range of Warwick. There, as at Kettle Point, the spheroidal concretions of carbonate of lime are met with, but the only fossils observed are some rather obscure scales of fishes. It is probable that this outcrop may have a connection with that on the lake shore: but a third exposure of the shales, with their characteristic concretions, which occurs at Branon's mills, on the twentieth lot of the seventh range of Brooke, in the bed of the east branch of Bear Creek, may perhaps belong to an outlying portion. It is not improbable that another portion of these same shales may underlie the drift, to the south side of the anticlinal, on the shore of Lake Erie; but no exposures of them have as yet been seen in that region.

Devonian in Michigan.

The black color and inflammable properties of these black shales, as in the case of the similar shales of the Utica formation, have suggested to many persons the probability of beds of coal in their vicinity. Between these highest shales, however, and the horizon of the true coal measures, in the southern peninsula of Michigan, where these measures are nearest, there is wanting, in Western Canada, the remaining portion of the Portage and Chemung group; which, in Michigan, according to Prof. Winchell, attains a thickness of 363 feet, and in some parts contains native copper.

Following this, we have there what has been named the Napoleon group, of 123 feet of sandstones, often saliferous; to which succeeds the Michigan Salt group, of 184 feet; consisting, like the Onondaga formation, of marls, dolomites, and beds of gypsum, and yielding brine springs of great strength and purity. To this succeed 66 feet of Carboniferous limestone, and 105 feet of sandstone; making in all 840 feet, before attaining the coal measures of Michigan, on the western side of Lake Huron.* (Report on the Geology of Michigan, 1861.)

To the south of Lake Erie, in New York, the thickness of the strata, from the Genesee slates to the coal measures of Pennsylvania, is vastly greater. The Portage and Chemung sandstones have a thickness of 2000 feet; which increases to 3000, farther to the eastward. These are overlaid by the sandstones, shales, and conglomerates of the Catskill mountains; which, on the west side of the Hudson River, rise to a height of 3800 feet, and correspond to at least 3000 feet of strata, overlying the Devonian series. Above the coarse conglomerate which forms the summit of the Catskill group, we find, along the line of the Appalachians, in Pennsylvania, a series of red shales, with calcareous bands, amounting to 3000 feet more, and succeeded by another conglomerate; which, in that region, lies at the base of the coal measures, and is said to have a thickness of 1400 feet. We have thus, above the Hamilton formation and its overlying black shales, a thickness of more than 10,000 feet of silicious and argillaceous rocks, before reaching the coal measures of the Appalachian field. This great thickness is, as we have seen, represented by less than 800 feet in the Michigan coal field, where it includes 65 feet of what is called the Carboniferous limestone. This calcareous formation is wanting in Northern Pennsylvania, but it appears at the base of the conglomerate farther south; and gradually augmenting to the westward, becomes the great Carboniferous limestone series of the Mississippi valley; where fossiliferous limestones, with occasional sandstones, appear to represent the 7400 feet of sediments, which, in New York and Pennsylvania, overlie the Devonian series. (Hall's Palæontology, Vol. III., Introduction.) We find, in Gaspé, a great series of sandstones and conglomerates, which there succeed to the Upper Silurian limestones, and are supposed to represent the Devonian strata of the New York series. The succeeding Bonaventure formation belongs to the base of the Carboniferous system.

Devonian in New York.

* As a farther illustration of the thinning out of the palæozoic rocks to the westward, so often alluded to, we may mention that Winchell estimates the entire thickness of the series in Michigan, from the top of the coal formation to the base of the Trenton group, at only 2500 feet. The latter rests upon the Ste. Marie sandstones. This, as we have shown, belongs to the Upper Copper-bearing series of Lake Superior, which corresponds to the Quebec (or Calciferous) and Potsdam groups.

CHAPTER XVI.

THE GASPÉ LIMESTONES AND SANDSTONES, AND THE BONAVENTURE FORMATION.

THE GASPÉ LIMESTONES, OF MIDDLE AND UPPER SILURIAN AGE.—THE GASPÉ SANDSTONES, CHIEFLY DEVONIAN.—THE BONAVENTURE SANDSTONES AND CONGLOMERATES, OF THE CARBONIFEROUS SYSTEM.—DISTRIBUTION OF THESE GROUPS IN GASPÉ.—CHATTE AND CASCAPEDIA SECTION; MATANNE SECTION; MATAPEDIA SECTION; METIS AND PATAPEDIA SECTION; LAKE TEMISCOUATA AND MADAWASKA SECTION; SECTION ON THE ST. JOHN, ST. FRANCIS, AND BLACK RIVERS; CHAUDIERE SECTION; SECTION ON THE ST. FRANCIS AND SOME OF ITS TRIBUTARIES.—LAKES AYLMER AND MEGANTIC; LAKE MEMPHRAMAGOG.—DEVONIAN LIMESTONES.—COAST SECTION OF THE BAY OF CHALEURS.—MIDDLE SILURIAN LIMESTONES.—BONAVENTURE FORMATION; ITS RELATION TO THE COAL OF NEW BRUNSWICK.

In describing the Anticosti and Lower Helderberg groups, we have already alluded to their existence in Gaspé, where they appear as a series of limestones. Mention was also made, at the close of the last chapter, of a great mass of Devonian and Carboniferous strata in Gaspé: these, so far as examined, are chiefly sandstones and conglomerates. To the south-west, however, on the Famine River, and on lakes St. Francis and Memphramagog, fossiliferous limestones are met with, apparently of Devonian age. The true relations of these various rocks and their subdivisions, are as yet but very imperfectly made out; but we propose to give, in the present chapter, the facts which, up to the present time, have been observed, with regard to their characters and their distribution, from Gaspé, south-westward, to the boundary of the province.

THE GASPÉ LIMESTONES.

On the south side of the St. Lawrence, in the counties of Gaspé and Rimouski, the rocks of the Quebec group are unconformably overlaid by a series of calcareous strata, which we have been accustomed to call the Gaspé limestones: full details with regard to them have, however, not yet been ascertained. On the Chatte and Matanne Rivers, on Lake Matapedia, and on the rivers Metis and Rimouski, the lower portion of this series of limestones appears to belong to the Anticosti group. It is as yet uncertain how far the strata of this group may extend on the strike, to the east and to the west. They must, however, thin out in some part of the distance of one hundred miles, which intervenes between Cape Chatte and Cape Gaspé, at the extremity of the peninsula, where they are wanting; while to the westward, it is not quite clear that they extend beyond Temiscouata Lake. The limestones met with at Cape Gaspé, appear to be a great development of strata of the age of the Lower Helderberg group. They here rest upon black shales, which are supposed to be those already described as underlying the Quebec group. These limestones present the following series, in ascending order:— Cape Gaspé section.

	Feet.	
1. Grey limestones in layers of from six to eight inches thick, which are separated by bands of greenish calcareo-argillaceous shale, gradually increasing in amount towards the upper part. The limestone beds abound with fossils, and contain, among other species, large crinoidal columns, *Favosites Gothlandica*, *F. basaltica*, *F. cervicornis*, with undetermined species of *Zaphrentis*, *Dictyonema*, and *Fenestella*, two undetermined species each of *Lucina* and *Strophomena*, with *S. rhomboidalis*, *S. punctulifera*, two or three undetermined species of *Orthis*, *Rhynchonella acutiplicata*, two or three species of *Orthis*, *Pentamerus galeatus*, three undetermined species of *Spirifera*, *Athyris lævis*, *Atrypa reticularis*, *Cyrtodonta orbicularis*, *C. lata*, *C. flexuosa*, *Modiolopsis cultrata*, *Avicula Bronni*, *A. naviformis*, *Loxonema Gaspensis*, *L. gracilis*, *Bellerophon Laurenticus*, two undetermined species of *Platyceras*, an undetermined *Conularia*, with several undetermined species of *Orthoceras*, *Dalmanites pleuroptyx*, an undetermined *Phacops*, *Bronteus Canadensis*, and an undetermined species of *Beyrichia*, ...	70	Limestones
2. Greenish calcareo-argillaceous shales, which are interstratified with less calcareous layers, of various shades of red. The only fossils observed, occur about the middle of the deposit, and consist of flattened stems of marine plants, apparently replaced by oxyd of iron, ...	90	Red and green shales.
3. Olive-green calcareo-argillaceous shales, with occasional nodules and layers of compact limestone; the former from an inch to a foot in diameter, and the latter from six inches to two feet thick. Some of the layers are rather arenaceous; remains of fucoids occur at the top, ...	170	
4. Grey limestones in thin beds, separated by grey calcareous shales, of which there are more towards the bottom than the top. The whole mass is interstratified with three or four bands of olive-green calcareo-argillaceous shale. About fifty feet from the bottom, there is a bed of seven feet, made up of several thin layers of limestone and limestone shale, and presenting a singularly wrinkled structure, from which the beds above and below are free. It would appear as if the layers, after their deposit, had been contorted by lateral pressure, the underlying stratum remaining undisturbed; and had then been worn smooth, before the deposition of the next bed. Where the inverted arches of the flexures occur, some of the lower layers are occasionally wanting; as if the corrugated bed had been worn on the under as well as the upper side. The corrugations are precisely in the direction of the dip, and the peculiarity is not con-		Corrugated beds.

Feet.

fined to a small part of the deposit, for the same thing is observed at the Petit Portage and Cape Bon Ami, the only two localities in which these limestones have been observed; these are upwards of a mile asunder. The fossils of these calcareous strata are not so numerous as those of the limestones at the base of the section. Among them however are fucoids or compressed stems of plants, an undetermined species of *Chonetes*, *Leptocœlia concava*, *L. flabellites*, *Spirifera crispata*, with undetermined species of *Conularia* and *Orthoceras*, ... 200

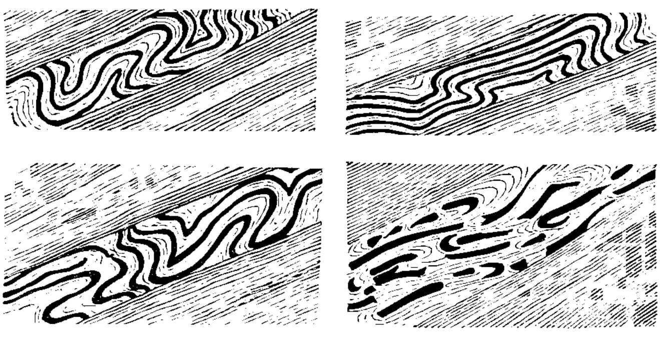
Shales. 5. Grey or slightly greenish calcareous shales, associated with bands of dark grey. Both are interstratified with layers of arenaceous limestone, which are occasionally sufficiently coarse grained to approach the character of a fine conglomerate. Fossils are somewhat abundant; in addition to marine plants, which are chiefly confined to long flattened serpentining stems, the species which prevail are two undetermined species of *Lucina*, and two of *Lingula*, *Strophomena rhomboidalis*, an undetermined *Chonetes*, *Leptocœlia concava*, *L. flabellites*, and *Spirifera crispata*, with two undetermined species of *Orthoceras* and one of *Phacops*,.................... 380

6. Grey calcareous shales or shaly limestones, interstratified, particularly at the top, with thin beds of purer limestone fit for burning. The organic remains of this part, which do not appear to be abundant, are chiefly obscure serpentining fucoids; which are accompanied by species of *Lingula*, *Discina*, a *Conularia* resembling *C. Sowerbyi*, and an undetermined species of *Pterygotus*, ... 300

1210

The accompanying wood-cuts show the characters of the corrugations, in four different parts of the bed of seven feet, which we have just described as interstratified in the thin bedded grey limestones, 4, of the above

425.—CORRUGATED LIMESTONE BEDS AT CAPE GASPÉ.



Scale about $\frac{1}{200}$.

section. The heavy black lines are intended to represent the limestones of the bed; and these, it will be perceived in one instance, are occasionally broken up into fragments.

These strata dip south-west, at an angle of twenty-four degreees, and are beautifully seen in the cliffs; which present a vertical naked face nearly 700 feet in height, on the north-east side of Gaspé promontory. The lowest limestones, 1, constitute the first step in the ascent to the mountains encountered in passing from Cape Rosier to Grand Grève. The second hard calcareous band, 4, forms another step in the same ascent; it makes also Cape Bon Ami, from which the grey calcareous shales, 5, present a steep slope up to the foot of the grey shaly limestones, 6. These rise in a vertical and sometimes overhanging escarpment, up to the edge of the precipice; from which the harder beds that form the summit of the above section, slope down into a valley. This valley divides the hills of the promontory into a double range, and maintains its character with some constancy, farther into the interior.

From this valley, the succeeding members of the series are piled in a second escarpment, and constitute the loftier of the two ranges: these strata, as before, dip S. W. < 24°, and are, in ascending order, as follows:

Feet.

7. Grey nodular shaly limestones, succeeded by grey limestones of a purer nature; these are followed by a second series of beds like the first, on which rest greenish calcareo-arenaceous shales, terminating in a thin layer, which is nearly grass-green. A fossil strongly resembling *Fucoides cauda-galli*, is common throughout the deposit, and some surfaces are almost completely covered by it; the only species observed accompanying it was *Dalmanites pleuroptyx*,.................................. 300 — Limestones.
8. Grey limestones fit for burning, in beds of from six to twelve inches thick, some of them holding chert at the summit. Fossils abound; among the species are *Fucoides cauda-galli*, *Favosites Gothlandica*, *F. basaltica*, *F. cervicornis*, two undetermined species of *Zaphrentis* and one of *Fenestella*, *Orthis oblata*, with two or three undetermined species of this genus, *Strophomena rhomboidalis*, *S. Becki*, *S. perplana*, with two undetermined species of *Strophomena*, three undetermined species of *Chonetes*, and two of *Rhynchonella*, with *R. acutiplicata*, *Leptocœlia concava*, *L. flabellites*, *Eatonia peculiaris*, *Rensselæria ovoides*, two undetermined species of *Spirifera*, with *S. arenosa*, *Atrypa reticularis*, *Athyris lævis*, two undetermined species of *Modiolopsis* and two of *Avicula*, with undetermined species of *Murchisonia*, *Pleurotomaria*, *Loxonema*, *Orthoceras*, *Phacops*, and *Proetus*, with *Dalmanites pleuroptyx*,........................... 500

800

The entire volume of these Upper Silurian limestones would thus be about 2000 feet. They occupy the whole of the promontory of Cape Gaspé, which extends from the mainland for a distance of about seven miles, with a breadth of no more than seven tenths of a mile; except at its junction with the low land extending to Cape Rosier, where it gradually assumes a greater breadth. They skirt the north-east bank of the north-west arm of Gaspé Bay, and the left bank of Dartmouth River; — Distribution.

constituting a range of mountains, some of whose summits, according to Bayfield, are about 1500 feet high. From Little Gaspé, they are flanked by a strip of the succeeding formation, the junction of the two being seen in Little Gaspé Cove. About seventeen miles above Little Gaspé, these limestones cross the north branch of the Dartmouth, upwards of two miles from the mouth of the tributary; on which a partial section, directly across the measures, presents a thickness of 1800 feet. At the bottom of this, there are interstratified layers of chert, which have not yet been observed at Cape Gaspé.

THE GASPÉ SANDSTONES.

Succeeding the calcareous rocks just described, and resting upon them conformably, there occurs an important group of sandstones. The contact of the two series, as already stated, is seen at Little Gaspé; but between the visible base of the sandstone group and the place of its greatest development, there are two considerable undulations, and a probable dislocation, of an uncertain amount. These render it difficult as yet to unite the whole series, with a certainty that no strata are repeated or left out. But though the section which shows the greatest unbroken series of strata, does not reach to the base, it is probably not far removed from it; and it may therefore, for the present, be assumed, probably without much inaccuracy, to represent the whole group. In ascending order, the strata are as follows:—

Shales.

1. Grey arenaceous and argillaceous shales, with beds of grey sandstone, varying in thickness from one to twenty feet, and one of them seventy-five feet. A three-inch band of argillaceous iron ore occurs about a hundred feet from the top. Towards the bottom, the beds weather of a rusty brown color, and contain abundance of plants. One of these, in its arrangement on the surface of the beds, resembles *Fucoides graphica*, but it may be the broken roots or stems of the other species of plants, which have been recognized in this deposit; surfaces thus characterized were met with in more than one locality. Many of the beds abound with the comminuted remains of carbonized plants, most of which are too obscure to be determined. Among them, however, are *Prototaxites Logani*, *Lepidodendron Gaspianum*, *Psilophyton princeps*, *P. robustius*, *Selaginites formosus*, and *Cordaites angustifolia*; all described by Dr. Dawson. Towards the lower part, there is a small seam of coal, with carbonaceous shale, measuring together about three inches; which appears to hold a regular course, having a bed of clay beneath, marked by what seem to be the roots of *Psilophyton*; while the stems and leaflets of the plant are met with in a thin seam of shale above the coal, and in the carbonaceous shale associated with it. On some of the

Fossil plants.

Coal seam.

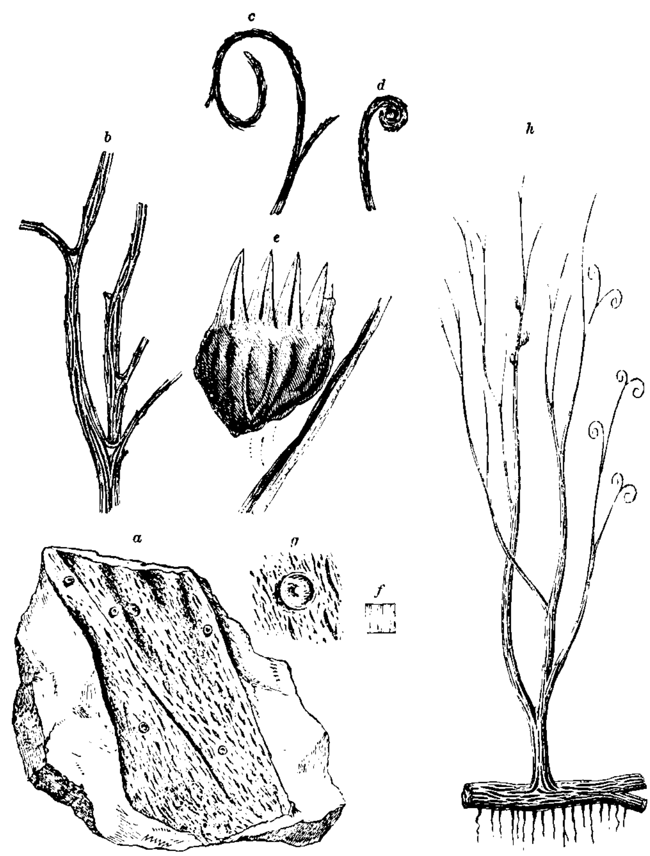
	Feet.	Feet.	
leaflets, small shells of the genus *Spirorbis* are met with. More than 130 feet above the coal seam, there is a hard rough grey bed, looking like fire-clay ; with the fibrous impressions of *Psilophyton* roots penetrating it at right angles. Ripple-mark occurs on some of the surfaces, ...	528		
2. Drab sandstones, many of them with a reddish tinge ; they present spheroidal masses harder than the general character of the rock, and are marked by extensive ferruginous stains. A few scattered pebbles of quartz and jasper occur in some of the beds, which are in general thick, and separated from one another by layers and partings of grey argillaceous and arenaceous shale. Nodules of argillaceous iron ore are contained in some of the layers, and comminuted carbonized plants are frequently seen on the divisional surfaces ; those which have been determined belong to the species already mentioned,....	916		Sandstones. Iron ore.
3. Drab sandstones, inclining to reddish at the bottom and greenish at the top ; with occasional scattered quartz and jasper pebbles, and large spheroidal masses, as above. Ferruginous stains are frequent, and the beds, usually massive, are separated by layers of grey argillo-arenaceous shale, which, as well as the sandstones, sometimes contain nodules of argillaceous iron ore. In the middle and lower part, there are interstratified two conspicuous beds of claret-red, green, and dark grey argillo-arenaceous shale ; in the upper one of which are two, and in the lower, eight bands of a grey tough rock, much like fire-clay, penetrated vertically by the rootlets of *Psilophyton*,..	428		
4. Drab sandstones, inclining to green ; some of which contain quartz and jasper pebbles; many parts have large hard spheroidal masses, as before. The beds are in general very thick, and they are separated by layers of grey argillaceous shale, from which large argillaceous masses occasionally protrude into the superincumbent sandstone, some of these being as much as three feet high and as broad. Comminuted carbonized plants, similar to those already named, occur on the surfaces of the lower beds, ...	2052		
5. Drab sandstone, in massive beds, in only a few of which there are scattered quartz and jasper pebbles. The sandstones are interstratified with five conspicuous bands of claret-red, green, and grey argillo-arenaceous shale, of an aggregate thickness of 140 feet,....	442		
6. Drab strong and coarse conglomerates, in massive beds, one of them 156 feet thick. The pebbles of these consist of white quartz, black chert, yellow, green, and blood-red jaspers, and jasper porphyry ; with which are sometimes found others of feldspar and of limestone, the whole enclosed in a matrix of drab-colored sandstone. In some portions of the deposit, the pebbles diminish in quantity, so that the rock becomes a rather fine-grained sandstone, with only occasional pebbles. The carbonized comminuted remains of plants occur on the surfaces of the beds, and in their oblique elementary layers or false bedding. Among the organic remains of this division, fish-spines or ichthyodorulites occur, of the genera *Onchus* and *Machæracanthum ;* one of them, the *M. sulcatus* of Newberry,..........	856		Conglomerates.
		5222	
7. Red sandstones, sometimes slightly calcareous, with green stripes and spots, many of the beds massive ; associated with occasional drab sandstones, and with two thin bands of conglomerate, holding peb-			Red sandstones.

	Feet.	Feet.
bles of quartz, jasper, and limestone. All of these are interstratified with red argillaceous and arenaceous shales, spotted and striped with green. In many cases, the sandstones exhibit on their under surfaces, highly relieved casts of shrinkage cracks and of rain drops, and on the upper surfaces ripple-marks. The shales are sometimes penetrated by branching plants, in vertical, oblique, and prostrate attitudes; while one or two beds have fibrous root-like impressions, probably of *Psilophyton*, running across them at right angles, ...	1151	
8. Drab massive sandstones, which in the lower part are clouded or mottled with a reddish tinge, and at the bottom exhibit an interstratification with red shales; at the summit the beds are inclined to grey. In many parts, they hold scattered pebbles of white and greenish quartz, and blood-red jasper, with some of limestone; but the pebbles never become so numerous as to constitute a conglomerate. On the surfaces of many of the strata, and in the oblique elementary layers or false bedding of some of them, there occur carbonized comminuted remains of plants; which are too imperfect to be determined,..	663	1814
		7036

Little Gaspé Cove. The lower portions of this great series of sandstones are met with in Little Gaspé Cove; where, in addition to the various species of fossil plants already mentioned, are found the remains of what appears to be a species of *Calamites;* one specimen of which shows a flattened stem four feet long, with a breadth of four inches. Gaspé Bay. The inferior portion of the formation skirts the north-eastward side of Gaspé Bay, and the North-West Arm, from the cove, as far as the north branch of Dartmouth River; where it occupies a breadth of about 9000 feet, across the measures; giving, at an average dip of twenty-six degrees, a thickness of about 4000 feet. On the south-west side of Gaspé Bay, in the neighborhood of Gaspé Basin, the same strata rise with an opposite and more precipitous slope, forming a trough under the bay. The thickness there exposed is again about 4000 feet. The same beds next fold over an anticlinal axis, which comes out upon the bay near Cape Haldimand; then, dipping at a very moderate angle on the south-west side of the axis, beneath the lagoon at the mouth of the river St. John, they re-appear, with a nearly opposite slope, at the south-eastern end of Douglastown village: and exactly face Great Cape Oiseau (Cap Brulé of Bayfield's chart) and Little Gaspé, on the north-east side of the bay. Following the coast, they exhibit a slight sinuosity in Seal Cove (Bréhaut Bay of Bayfield); and at the Tar Point. extremity of Tar Point, between this cove and the next one farther on, they fold over another anticlinal axis; the position of which is indicated by a remarkable greenstone dyke, holding petroleum. The direction of both of these anticlinals is nearly north-west and south-east.

It is from this point to the termination of the series, in the cove immediately northward of Pointe Jaune or Yellow Head, that the strata given in the vertical section are found. The coast cuts them obliquely; and in every step south-eastward from Tar Point, higher strata are met with, in advancing, until Long Cove is reached, where the red sandstones are seen.

426.—PLANTÆ.

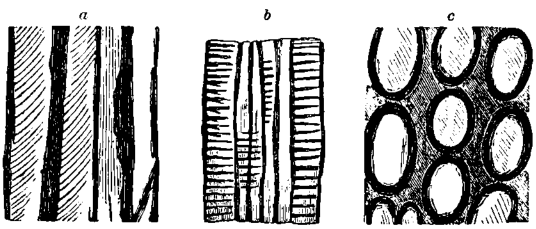


426.—*Psilophyton princeps* (Dawson); *a*, rhizome; *b*, stem; *c*, termination of a branch; *d*, vernation; *e*, fructification; *f*, longitudinal section of stem, — all of natural size; *g*, areole of rhizome enlarged; *h*, restoration of the plant, reduced.

In this cove, the measures have a very moderate inclination, and a slight protrusion in the line of strike causes the coast section of the cliff to present a gentle arch in the centre, repeating a part of the beds. Farther on, the section still gains upon the strata, in the vicinity of Red Head, and beyond it; until they are suddenly cut off by a fault, at the spot already indicated as the termination of the series. Throughout the whole distance, the strata are seldom concealed; and though several small faults occur, the allowance that is to be made for them, may be seen in the cliff, which is generally bold.

Anticlinals. The two anticlinals which have been mentioned, appear to run parallel, as well to the mountain ranges of the neighborhood, as to the calcareous rocks on the north-east side of Gaspé Bay. They may be about three miles asunder in a direct line. The northern one is traceable for seven miles, from the vicinity of Cape Haldimand to the inner basin at Gaspé; which it crosses about 350 yards south-west of the Narrows at the entrance. It brings to the surface, on the north side of the basin, some beds of

427.—PLANTÆ.



427.—*Psilophyton princeps* (Dawson); portions of stem magnified three hundred diameters; *a*, cortical cells; *b*, scalariform tissue of the axis; *c*, parenchyma.

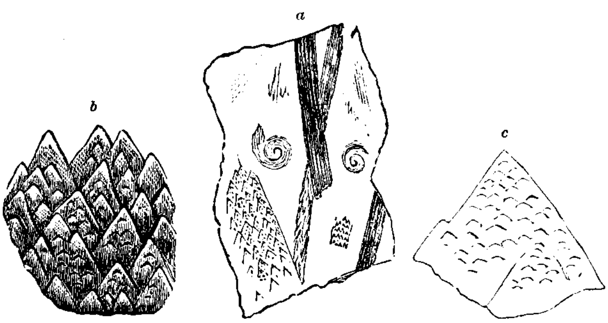
sandstone, which are rendered calcareous by an abundance of fossils. These beds contain comminuted remains of land plants, and impressions that bear a strong resemblance to *Fucoides cauda-galli.* With these are associated, among other species, *Strophomena Blainvilli*, *Rensselæria ovoides*, two undetermined species of *Chonetes*, *Spirifera Gaspensis*, *Leptocælia flabellites*, *Avicula Woodwardi*, and *Grammysia Verneuili.* The beds to the north-east of these, along the south-west side of Gaspé Harbor and Bay, as already indicated, are upwards of 4000 feet higher in the series. They contain a few interstratified bands of a red color near the top, some of them with casts of shrinkage cracks; and along the strike, between Pointe Lourde and Cape Haldimand, some of the best characterized specimens of the land plants of the formation are to be obtained. In the upper 760 feet, eight beds are seen to be marked by the vertical rootlets of *Psilophyton;* and on one of these, two hundred of the rootlets were counted in a square of six inches.

The mark which has been taken as indicating the direction of the southern anticlinal axis, is the course of the greenstone dyke in its vicinity; this, however, has as yet been traced only a short distance, as it soon becomes covered up, after striking into the forest. It is probable that this dyke is connected with a dislocation, throwing down the measures to the north-eastward. It is not easy, however, to say how much higher in the series the beds on that side may be, than those on the south-west. The latter are, as has already been stated, at the base of the 7036 feet of strata given in the vertical section; while on the north-east side, between Tar Point and Douglastown, a section of 3800 feet was observed, after which the summit of the series became concealed. At about 500 feet from the base of this section, there are met with the remains of a coniferous tree,

Dislocation.

Fossil conifer.

428.—PLANTÆ.



428.—*Selaginites formosus* (Dawson); *a*, fragment of shale, with portions of a large and a small specimen of *Selaginites*, showing the imbricating scales; accompanied by three fragments of *Psilophyton princeps*, and two of *Cordaites angustifolia* (Dawson); *b*, small specimen of *Selaginites*, and *c*, scale of larger specimen, both enlarged.

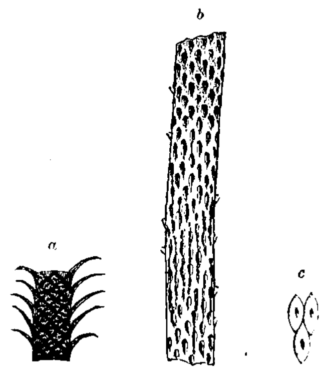
described by Dr. Dawson under the name of *Prototaxites Logani*. The stem of one of these, obtained by Dr. Dawson, must have been twelve inches in diameter, before it became compressed. About 600 feet still higher among these strata, several surfaces in succession are marked by serpentining impressions, about an inch wide, deeply grooved into the stone, marked by small parallel transverse furrows, which are about a quarter of an inch apart. These are perhaps worm-tracks, and are associated with a few bivalve shells of the genus *Rensselaeria*, probably *R. ovoides*. All of these strata, and most of those above them, in which sandstone greatly predominates over shale, are in general drab colored, though some are grey. Many of the surfaces are marked by carbonized comminuted plants, similar to those which have already been mentioned; and argillaceous iron ore occurs in nodules in several beds, about the middle of the mass.

The dips on the north-east side of both of these anticlinal flexures are more precipitous than those on the south-west. In this they accord with the general character of the undulations in the Lower Silurian strata south of the St. Lawrence. The strikes of the anticlinal beds are not precisely parallel, but converge towards the south-east; from which it results that the ridges or crowns of the folds have a slope in that direction.

Veins of galena.

The limestones, in their exposure of four miles, at Cape Gaspé, present numerous dislocations, with dykes, and with veins of calcareous spar, sometimes with galena. One of these localities is in the bight of Little Gaspé Cove, where the limestone is washed by the waters of the bay. Here are several fissures, holding these two minerals, and having a direction of N. 55° E., with an underlie to the northward. Near to these veins, is a dislocation,

429.—PLANTÆ.



429.—*Lepidodendron Gaspianum* (Dawson); *a*, small branch and leaves; *b*, decorticated branch; *c*, areoles of a larger branch; all of natural size.

with a downthrow on the north-west side, by which the limestone is brought against the higher sandstones. It is probable that the mineral veins have some connection with this dislocation. An attempt recently made to work this deposit of galena, has given promise of favorable results.

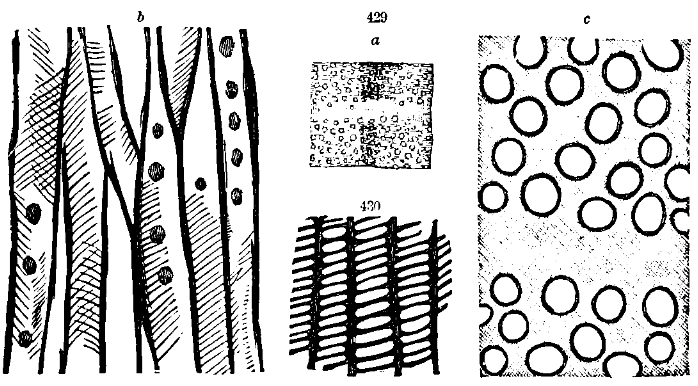
Indian Cove.

The other locality of galena is in Indian Cove. Here is a downthrow to the south-eastward, of at least thirty fathoms, by which the higher sandstone is brought opposite to the limestone. Between these walls, there is a lode about twelve feet wide; composed of the ruins of the two rocks cemented together by calcareous spar, and including numerous small veins of the same mineral, with crystals of galena. The principal one of these veins is about two inches wide in the thickest part: it has an underlie

N. 74° W. < 55°; but the general course of the whole lode, in which the small veins occur, is about N. 18° E., and the underlie appears to be westward. The dislocation in this place points to a transverse valley or depression in the hills behind, which appears to run across to the opposite side of the promontory, in a course nearly N.E. In a dislocation on the north-east side of the promontory, which is supposed to correspond with this fault, and where a continuation of the lodes might be expected, no ore has yet been observed.

Transverse dislocations are of common occurrence in this vicinity. One Dislocations. of them, in a recess about a quarter of a mile above Indian Cove, is filled with white calcareous spar, which has a thickness of nine feet in one part,

429, 430.—PLANTÆ.



429.—*Prototaxites Logani* (Dawson); *a*, cross section magnified forty diameters, showing growth line and medullary ray; *b*, longitudinal section; *c*, transverse section, each magnified three hundred diameters.

430.—Scalariform tissue, probably from the axis of a *Lepidodendron*, magnified three hundred diameters.

and one foot in another. The underlie of the vein is S. 65° E. < 76°, while the dip of the strata at the spot is S. 55° W. < 22°. On the north side of the promontory, seven dislocations, in the space of about a mile and a half, may be seen at one view, from a convenient distance out on the water. The displacements in six of these, compensate one another; and the slope or underlie of the faults, in every instance, is in the direction of the downthrow.

Greenstone dykes, intersecting both the limestones and the sandstones, Dykes. are seen in several places. One of these is found, cutting the strata, without any apparent displacement, a little to the north of the Petit Portage, in Cape Rosier Bay. Its breadth is eight feet, and it traverses a part of the shale which is between the lower two bands of limestone. The rock on each side is a little harder than elsewhere, but it is not otherwise altered. The course of the dyke, which is very nearly vertical, is N. 79° W.

Another of these greenstone dykes intersects the sandstones, about a mile and a quarter above the outside point of Little Gaspé Cove. It is about four yards wide; and its course, as far as seen on the shore, is S. 89° E. There is, however, a turn in the dyke, running for five yards in the direction S. 31° W.; and coinciding with this, is a cross fault, of which the underlie is S. 59° E. $<$ 68°. Here is a space of six or eight inches, filled with a compact feldspar, holding opaque white feldspar crystals, and irregular veins of carbonate of lime. In that part of the dyke which is near, thin veins of iron pyrites occur, which have an irregular parallelism with the cross fault. The dyke is nearly perpendicular; and the strata on each side, which have been indurated, dip S. 49° W. $<$ 28°.

Another dyke occurs about 300 yards below Little Cape Oiseau (Cape James of Bayfield). Its course is about N. 86° E.; and its underlie, which is southward, eighty-eight degrees. There is an angular turn in it, which carries it N. 6° E., for a few yards. The mineral character is much the same as the previous one, and it exhibits a tendency to a transverse columnar structure. Another dyke stands up like a wall, at the mouth of a small brook, about 300 yards above Little Cape Oiseau. Its course is N. 69° E.

Still another greenstone dyke occurs, on the opposite side of Gaspé Bay, in Ance Cousin, close by the mill and brook, about a mile and three quarters above the bluff, on the upper side of the entrance to the South-West Arm. Its course is S. 61° W.; and its underlie, to the southward, seventy-eight degrees. Its breadth is fifteen feet; two feet of which, on the northward side, weather of a more rusty color than the rest, and exhibit an imperfect transversely columnar structure. The sandstone on each side of the dyke, dipping N. 41° E. $<$ 58°, is hardened for a short distance; and it displays a more than usual number of joints, which are parallel with the dyke.

Petroleum. There is still to be described the greenstone dyke, connected with the southern anticlinal, at Tar Point. This dyke, which does not occur in the centre of the fold, but about 200 yards to its north-east or precipitous side, has a breadth of ten or twelve yards, with a direction N. 83° W. Its color is dark grey, weathering to a rusty red, and it is traversed by numerous horizontal and vertical joints, and abounds in large and small druses; which, as well as the joints, are often lined with chalcedony; sometimes, in the case of the druses, presenting botryoidal surfaces, and at others, incrusted with crystals of quartz and calcite. These cavities, as well as others which are not thus lined with chalcedony, are filled with petroleum: this, in some instances, has hardened to the consistency of pitch. The peculiar odor of this substance, which has given the name of Tar Point to the locality, may be perceived at a distance of fifty yards.

Oil springs. Two petroleum springs occur along the line of this anticlinal. One of these is on the south side of the St. John River, about half a mile above Douglastown. Here the oil oozes from the mud and shingle of the beach, and is seen in globules, rising through the water, at high tide. Portions of the oil are said to have been observed, under similar conditions, as far as the extremity of the first marshy island, a distance of three fourths of a mile above; and they may probably extend much farther in the same direction.

The second spring was observed about 200 yards up a small branch of the Silver Brook, which is a tributary of the South-West Arm, falling into it about six or seven miles from Gaspé Basin. The orifice of the spring was not seen; but the oil, which is not observed higher up on the brook, here collects on the surface of quiet pools, as a thick film. These two petroleum springs are nearly in a right line with the bituminous dyke; and in the direction indicated by the bearing of the latter, which is distant about twenty miles from the farthest spring. It is therefore likely that these occur along the line of the undulation, with which, as we have already remarked, the dyke seems to be connected.

The rock adjoining the dyke, and underlying both of these springs, is sandstone; but it is not improbable that here, as in Western Canada, the source of the oil may be in the more fossiliferous rocks beneath; so that we may hope to find other springs of it, not only along the line of twenty miles, just indicated, but still farther along this and other undulations in the same region; where borings and wells may furnish more abundant supplies of petroleum.

Oriskany formation. As has already been stated, the limestones of Cape Gaspé appear, for the most part, to belong to the Lower Helderberg group. The fossils at the summit, however, bear a striking resemblance to those of the Oriskany formation, with which several of them are identical. It appears probable, therefore, that we have here a passage from the Lower Helderberg to the Oriskany, and the latter formation may be more especially represented by the lower part of the Gaspé sandstones. The organic remains discovered in these sandstones are as yet too few to enable us to separate the series into distinct members. We have already mentioned that a species of *Rensselaeria*, identical with or closely resembling *R. ovoides*, which occurs in the upper part of the limestones, is met with at 1100 feet above the base of the sandstone series. This fact, together with the constancy in the lithological characters of the latter, makes it not improbable that at least this lower portion of the sandstones, will ultimately be classed with the Oriskany formation.

In the land plants, there appears to be but little difference from the commencement of the series to the base of the red sandstones: a thickness of over 5000 feet. These strata present analogies with the whole series of formations in New York, from the Marcellus shales to the summit of the Chemung sandstones; in all of which, according to Dr. Dawson, are found several of the species of plants that occur in the Gaspé sandstones. The whole of these 5000 feet resemble, lithologically, the Portage and Chemung sandstones of New York; and it may hereafter be found that in this eastern part of the continent, the Oriskany fauna, which occurs at the base of this Devonian series, merges gradually, towards the summit, into that of the Portage and Chemung group. In lithological characters, the remaining upper 1800 feet of the Gaspé series, resemble the Catskill group of New York, which is regarded by Mr. Hall as the base of the Carboniferous system. As yet however no comparison can be made by fossils; those found in Gaspé being chiefly confined to a few obscure plants.

The Gaspé limestones and sandstones have been traced for a considerable distance to the eastward of the localities just noticed; but before giving what is known of their distribution, it will be convenient to describe the succeeding formation; which is, so far as yet known, the highest member of the palæozoic rocks in Canada.

THE BONAVENTURE FORMATION.

This formation, which is shown by the section on the Bay of Chaleurs, to belong to the base of the Carboniferous series, rests in unconformable stratification upon the rocks hitherto described; and consists of a series of red sandstones, interstratified with beds of a coarse calcareous conglomerate. The island of Bonaventure, opposite to Percé, is entirely composed of this series; for which we have, in consequence, chosen the name of the Bonaventure formation. The best section of it is however seen on Gaspé Bay, extending from a small cove immediately on the upper side of Pointe Jaune (which is the first small cape above what is named White Head on Bayfield's chart), to the extremity of Point Peter.

Bonaventure Island.

Conglomerate.

The pebbles and rounded masses of the conglomerate, which often weigh from seven to fifteen pounds, are chiefly of grey limestone and calcareous sandstone; in some of which are found encrinites, and *Eatonia peculiaris*, belonging to the upper part of the Gaspé limestones. Besides these, are pebbles of red shale and sandstone, with others of red feldspar, syenite, porphyry, and white, yellowish, and greenish quartz. Associated with these, are others of agate, and of red, yellow, and green jaspers, often brilliant in color; which have probably been derived from the conglomerates of the Gaspé sandstones. These jaspers and agates are known among collectors as Gaspé pebbles, and are found in abundance along the sea-shore in this region. The matrix of this conglomerate is usually a red sand, which is often pervaded by a calcareous cement; this, in some parts, is seen as a white calcareous spar among the pebbles. The prevailing color of the conglomerate, arising from this mixture, is a pale red; while the associated sandstone beds are of a deeper red, and sometimes drab-colored or brown, with occasional partings of shale. Ripple-marks and casts of shrinkage-cracks occur in the sandstone; and the remains of plants are found in many of the beds, sometimes carbonized, and sometimes as casts only. The impressions of plants in one bed of red shale, are tinged with a green color. Gaspé pebbles.

The entire volume of this section is 2766 feet; of which a little less than one fourth is made up of conglomerate beds, varying in thickness from one foot to one hundred and eighty-seven feet. The highest part of the section is at the very extremity of Point Peter; where a succession of strong conglomerate beds, plunges, at an angle of fifteen degrees, beneath a rock called Flat Island, lying just half a mile distant, and composed of strata dipping in the same direction as those at the point, but at a less angle. If there be no fault or undulation in the channel, and if we assume for the dip of the intermediate strata an angle of seven or eight degrees, it would give about 300 feet additional, to be added to the vertical thickness; making the volume of the formation at this point, upwards of 3000 feet. It is not improbable that there may be something to be added to the lower, as well as to the upper part; for in the cove above Pointe Jaune, the base of the section is let down against the Gaspé sandstones, by a dislocation of unknown amount. The direction of this fault appears to be S. 18° W.; and the older strata, which, at a distance of 500 yards across the measures, have a dip not exceeding ten degrees, and not more than twenty degrees at half that distance, are gradually bent down to forty, and even to sixty degrees, as they approach the fault. The strata of the Bonaventure formation, on the contrary, are slightly turned up at the junction, where they abut against the Gaspé sandstones, and thence present a moderate dip of from twelve to eighteen degrees, which they preserve with considerable uniformity, to the extremity of Point Peter; the direction of the dip being S. 86° E. From Pointe Jaune to Tickel Inlet, the salient parts of the shore are composed of the conglomerate beds, while the re-entering angles correspond to the softer and less resisting red sandstones. This explains the zigzag line of the coast; the general course of which, on both sides of Point Peter, is oblique to the stratification. Point Peter.

THE DISTRIBUTION OF THE GASPÉ SERIES.

Limestones. The Gaspé limestones are traceable from Little Gaspé Cove, on the north side of the North-West Arm, and its tributary, the Dartmouth River, for twenty-four miles. They appear to preserve a pretty uniform breadth, which, at seven or eight miles above Little Gaspé Cove, is about a mile and a quarter; the inclination of the strata being to the south-west, at an angle of twenty-two degrees. The first exposure on the road from Griffin Cove, occurs at the Ruisseau de la Grande Carrière ; where the base of the series appears as a pure grey limestone, interstratified with some beds, which contain an arenaceous mixture, and, on the weathered surfaces, are converted, to a depth of half an inch, into a porous white earth. Similar beds overlie the limestones, which contain nodules of chert, and abound in fossils: among these are *Favosites Gothlandica*, *Strophomena rhomboidalis*, and *Atrypa reticularis*, with crinoidal stems. These beds dip S. 54° W., at an angle of twenty degrees; and after a mile and a quarter in this direction, an exposure of iron-grey limestone is seen, dipping S. 4° W., at an angle of twenty-two degrees. This is supposed to be at the summit of the series; and would give for the section at this place, a thickness of about 2100 feet. From this point, to the margin of the bay, there is a distance of a mile and a half; in which occurs an exposure of greenish sandstone, dipping S. 29° W., at an angle of thirty-nine degrees. Judging from the outcrops on the coast farther down, it is probable that the whole breadth is occupied by the Gaspé sandstones, which would thus have a thickness of about 4000 feet; and, as already stated, are here dipping down on the north side of a synclinal, to appear with a contrary dip on the opposite side of the bay.

Dartmouth River. At a distance of seventeen miles above Little Gaspé Cove, the limestones are met with about two miles from the Dartmouth; but at the end of the twenty-four miles already mentioned, the upward course of the river is nearly north, and would cross the limestones, if they continued in their north-westward bearing. They are however wanting on the river; while a short distance to the southward, the serpentines of the Quebec group rise into a hill. There must thus be either a transverse dislocation, or a turn in the limestones around a synclinal to the south. This latter would coincide with the synclinal of the North-West Arm, the axis of which would run with the lower part of the Dartmouth River. It is therefore probable that the limestones will present a spur, projecting into the township of Gaspé Bay South, between the Dartmouth and York rivers, on the Haldimand anticlinal.

SECTION FROM THE MAGDALEN TO THE DOUGLASTOWN RIVER.

About three and a half miles west of the turn in the Dartmouth River, just mentioned, the limestones re-appear at the eastern extremity of a trough; which has a length of thirty-six miles, extending to Clear Water Brook, a tributary of the Magdalen, a little west of longitude 65° 30′. It is pretty well ascertained that the limestones surround this trough, in which the included sandstones are divided into two areas, by a transverse undulation bringing up the limestones; the western area of sandstone being more than twice the length of the eastern. The width across this synclinal, including the limestones on each side, is about six miles in the eastern, and seven in the western portion. Along the northern limit of this, the Magdalen River flows for a certain distance; and then turns northward, at a point fourteen miles from the St. Lawrence. Here, at the turn, the whole volume of the limestones is seen in the flank of a mountain, which rises up from the river in successive terraces. The dip of the strata is very regular and uniform, being from S. 5° E. to S. 14° E. $<$ 38°–35°. The formation occupies a breadth of twenty-four chains, and its uppermost beds appear 1375 feet above the base. In going over the mountain, the exposures met with, are at considerable distances. In the section measured, only 210 feet of brownish-grey shaly limestone and calcareous shale were visible, at intervals varying from thirty to nearly 600 feet; while 2072 feet were concealed, making the total volume of the series 2285 feet. No fossils were seen; and only one loose fragment of limestone holding organic remains, was met with. This occurred at the foot of the mountain, near the base of the formation; but the fossils in it resemble some of those which occur at the top of the limestones, near Ship Head, in Gaspé Bay. Among the species are *Strophomena rhomboidalis*, with undetermined species of *Chonetes* and *Platyostoma*.

Magdalen basin.

Limestones.

The crest of the hill and the summit of the limestones, as given above, coincide; and the Gaspé sandstones are supposed to come in on the line of section, some short distance to the southward, on the slope of the hill. The junction of the two formations, however, was not seen; and the first exposure indicating a change in the strata, was met with in a spot, whose place on the line of section would be a mile and a half from the limestones. The rock at this point is a greenish-grey or drab sandstone, having disseminated throughout it small scales of silvery mica. The beds are from two to six inches thick, and abound in comminuted carbonized remains of land plants, and brachiopodous shells; but it is difficult to procure these sufficiently well preserved to be properly identified. The number of species does not appear to exceed two or three; and the most abundant is identical

Sandstones.

with a small *Rensselaeria ovoides?* from the sandstones of Gaspé Bay. The dip of these fossiliferous beds is S. 14° W. < 55°.

About a mile and three quarters southward of this, similar drab sandstones, but without fossils, occur on a small stream: here the dip is N. 1° W. < 14°. Between this stream and the next one, about a mile and a half farther south, a hill is interposed, rising to the height of about 800 feet. On the north side of this hill, the sandstones are very generally seen up to the summit, which is about a quarter of a mile north of the second brook. At the summit, the dip is N. 18° E. < 39°; and the escarpment, down to the brook, is very abrupt. No rock in place was observed, either in the escarpment or on the brook; but numerous large flat fragments of calcareo-arenaceous shale, abundantly marked with carbonized remains of plants, are mingled with others of a very arenaceous limestone: these are accompanied with fragments of chert. The brook is therefore supposed to be the southward limit of the sandstones; which thus lie between it and the crest of the hill above the Magdalen, in the form of a trough, measuring on the line of section about four miles and a half. This, according to the dips observed on the opposite sides of the synclinal, would give for the sandstones a thickness of about 6000 feet.

Crossing the measures southward, towards York River, the only exposure of limestone that has been met with on the south side of the trough is a little over a mile and a half forward. This occurs about half a mile down an escarpment; descending from the summit of a gradual rise, which attains a height of 700 feet. It consists of about thirty feet of dark brownish limestone, without observed fossils; weathering partly white and partly brown, with patches and nodules of chert. The dip of these limestone strata is N. 9° E. < 15°–20°.

York River. The distance from this position to York River, is rather over four miles; and in the interval, no exposures of rock have been observed; but on the river, dark grey calcareous shales occur, showing fine lines of stratification, and breaking into flat fragments of from one to six inches thick; which, like some of the calcareous rocks in the terrace over the Magdalen, weather white. The dip of the strata is S. 1° E. < 43°. About two miles down the stream, not much out of the strike of these beds, a height of 400 feet above the river is capped by 100 feet of calcareous shale, of a somewhat softer character, and weathering brown and white. In this were met with a few fragments of brachiopods, and two small species of *Orthoceras;* one of which strongly resembles an undescribed species from the limestone cliffs of Cape Gaspé.

These calcareous shales, and the limestones four miles to the north, appear, without much doubt, to be equivalent strata on the opposite sides of the Haldimand anticlinal. There is space enough between the two exposures for a portion of the Lower Silurian series. The strike of the York

River beds would carry them to a junction with the supposed limestone spur in the township of Gaspé Bay South; and in their progress they would pass sufficiently near to the northern beds, to make it probable that the two join on the axis of the anticlinal, to the westward of the serpentine.

The course of the York River strata, to the westward, has not yet been ascertained; but fourteen miles south of this band, limestones occur on the Douglastown or St. John River, occupying nearly twenty-five miles of its bed, and reaching to within thirteen miles of its mouth. In these twenty-five miles, the valley of the stream, which is nearly straight, is upon the axis of an anticlinal; and while the limestones dip at pretty high angles northward on the north side and southward on the south, they are followed, usually at no great distances, by sandstones; which compose the flanks of the hills on each side. Some of the limestones are blue, hard, and silicious, while others are blue and grey, in thin beds: they are associated with grey calcareous shales. The thin bedded portions are frequently nodular, and chert accompanies them in some places. Some of the beds may yield good lime, but the great mass appears to be too silicious for such a purpose. The only fossils detected in them were fucoids resembling *Fucoides cauda-galli*, and similar to those which are so abundant at the top of the limestones of Gaspé Bay.

Douglastown River.

Limestones.

The inferior portion of the sandstones is seen at a turn on the Douglastown River, a short distance above the Alexander, which joins it on the right bank. The beds, here resting on the limestones, are dark brown fine grained ferruginous sandstones, abounding with fragments of carbonized plants. They are marked with ferruginous spots from decomposing iron pyrites, and parted by thin layers of black carbonaceous shale. They are succeeded by thick beds of a fine conglomerate, composed chiefly of small pebbles of transparent and translucent whitish quartz, with lumps of black shale, in a hard calcareo-arenaceous matrix. Between the aspect of these beds, and the strata somewhat higher in the series, there appears but little difference; their general character being that of drab coarse grained sandstones, sometimes in massive beds, and at others in thin irregular layers, interstratified with drab arenaceous shale. The sandstones are occasionally separated from one another by thin carbonaceous layers, composed almost entirely of the comminuted remains of plants. Various sized pebbles are frequently scattered irregularly through the sandstones, although nowhere observed in sufficient numbers to constitute a conglomerate. Large loose masses of the sandstone were often found on the banks, and in the bed of the river, holding shells enclosed in an arenaceous matrix. These so strikingly resemble the fossiliferous strata brought up on the Haldimand anticlinal, on the north side of Gaspé Basin, both in the species of shells and in the mode of their occurrence, as to leave little doubt that they are derived from an equivalent bed, situated somewhere on the Douglastown

Sandstones.

River. Among the species are *Strophomena perplana*, *Leptocœlia flabellites*, *Rensselæria ovoides?* and *Spirifera Gaspensis*.

In the thirteen miles of the lowest part of the river, sandstones alone are met with, usually of the character just described. The dip in this part, while it is constantly northward, is reduced to a moderate inclination, sometimes seven degrees, and never exceeding twenty. The axis of the anticlinal would thus appear to leave the river, at a turn to the northward, some five miles above the west side-line of the township of York, and to bear thence towards Point Peter.

Three anticlinals.

Not far from half-way between the Douglastown and Haldimand anticlinals, the distribution of the strata will probably be modified to a certain extent, by the effect of a third anticlinal, which runs from the coast at Tar Point. The axis of this anticlinal would probably coincide with the valley of the York River, for about fifteen miles above the Silver Brook: but no examination of this part of the river having yet been made, it is not known whether the limestones occur upon it. The double trough formed by the three anticlinals, with the effect produced on the strata by the intrusive granite of Table-top Mountain, will almost certainly bring the York River limestones round to those on the Douglastown River, with an eastward spur on the intermediate ridge; but how far westward the band may run before turning, can only be determined by exploration.

What may be the geographical arrangement of the limestones and sandstones, in striking westward from the Douglastown River, on the south side of the anticlinal there, and in passing the southern extremity of the granitic mass, must, for the present, be left mainly to conjecture; there being about fifty miles to the westward in which no facts have yet been collected in respect to any of the rocks, and about seventy miles in which nothing is known of the limestones. The next position along their outcrop to the westward, in which the latter have been examined, is on a traverse made obliquely across the measures, from the Chatte to the Great Cascapedia. The fossil remains obtained on this traverse were a portion of the collections that were lost by shipwreck, and it is only those belonging to the very base of the series that have been renewed.

SECTION OF THE CHATTE AND CASCAPEDIA RIVERS.

Chatte River.

On the south side of the Shickshock mountains, the main tributary sources of the Chatte unite, before entering the deep gorge which there traverses the range. Two of these tributaries flow from opposite directions, in a depression running close along the foot of the mountains; and in this depression, the nearly vertical epidosite rocks of the Quebec group are unconformably overlaid by a yellowish-white fine grained sandstone. This, as far as seen, is about fifty feet thick, and is divided into massive beds. Where the surfaces of these are weathered, the rock loses its yellowish tinge, and has then a somewhat vitreous aspect. This sandstone, which dips southward at an angle of from twenty to twenty-five degrees, is followed by about 200 feet of grey limestone, interstratified with some beds of grey shale, dipping in some places at an angle of from sixteen to twenty-five degrees, which moderates in others to one or two degrees. The lower part of the mass is fossiliferous, and holds, among other species, an undetermined *Ptilodictya*, *Strophomena pecten*, *S. antiquata*, *S. rhomboidalis*, a new species of *Orthis*, *O. Davidsoni*, with *Stricklandia lens*, *S. brevis*, *Atrypa reticularis*, *Calymene Blumenbachii*, *Phacops Orestes*, and an undetermined *Encrinurus*. All of these species are found in the Anticosti group, and appear more especially to belong to the upper part of it. It is probable that the whole 200 feet of limestone may belong to the same group: but before this can be determined, a new collection of its fossils must be procured. Limestones.

In the traverse made from the Chatte to the Cascapedia, after leaving the limestones at the base, calcareous strata, moderately inclining to the southward, were observed at the height of land, and in another position beyond; both included in a direct breadth of six miles across the measures. In this distance, the fragments observed among the roots of overblown trees, were of the same calcareous character; but on reaching the first tributary of the Cascapedia, a short distance beyond, there were met with, in the bed of the brook, flat fragments of drab sandstone, presenting on their surfaces comminuted carbonized remains of plants. Similar fragments, mingled with others of limestone, continued to be occasionally seen in the brooks, and among the roots of trees, to the end of the traverse, equal to five additional miles directly across the measures. Fossiliferous limestones, were again observed in place, on reaching the Cascapedia; but the loss of the specimens makes it impossible to state to what portion of the series they may belong. Limestones.

At the end of the traverse, the strata are disturbed by a mass of intrusive rock, constituting the Conical Mountain. This is a sharp pointed hill, 1910 feet above the sea, situated on the north side of the Great Cascapedia; about thirty miles from the St. Lawrence, and about forty-five miles from the Bay of Chaleurs. The igneous rock of which it is composed is probably of the same character as the masses of trachytic granite to the eastward; but without specimens to institute a comparison, this cannot be stated with confidence. Its breadth on the river is about a mile; and it is probably connected with another mass, which rises to some height on the south side. It may extend altogether, as far as can be judged by the eye, about five miles, in a direction a little west of south. Conical Mountain. Cascapedia.

Sandstones.

In descending the river, grey fine grained slightly micaceous sandstones succeed the trap. They are interstratified with leaden-grey shales, occasionally greenish and reddish, and both the shales and the sandstones hold bivalve shells. These strata are about 230 feet thick. Towards the middle, some of the sandstones are yellowish and rather coarse grained, and the surfaces of a few grey beds among them are studded with the carbonized comminuted remains of plants. Some of the sandstones, which are pyritiferous, show dark brown stains, and disintegrate readily under the influence of the weather. The beds lean against the trap, their dip being S. 52° E. < 50°–44°.

Red sandstones.

After an interval of concealment of about three quarters of a mile, directly across the measures (including probably about 3000 feet of strata), red sandstones and shales make their appearance, dipping S. 53° E. < 60°–40°, and occupying such a breadth as shows them to be about 900 feet thick. Many of the beds present casts of shrinkage-cracks on the under surfaces, and ripple-marks on the upper. Vertical upward-branching plants penetrate some of the red beds, which contain a few drab colored interstratified layers, abounding in carbonized comminuted vegetable remains. Still farther down the stream, the red rocks continue; but the dip gradually moderates to an inclination of nine degrees; and 900 feet additional of strata similar to those just described, are met with.

Where all these beds occur, the river runs southward across the measures; but it then turns eastward, and continues in a valley worn out in the strike of the red rocks, for ten miles. In this, the strata present a very regular dip to the east of south, for the first half of the distance, and south for the remainder, never exceeding about ten degrees of inclination. To the southward of this valley, and parallel with it, at the distance of about a mile, there rises a range of hills; some of the summits of which are about 1000 feet over the river. These hills appear to be composed of greenish-grey sandstone, consisting of grains of quartz and opaque white feldspar, with a little mica. The rock holds occasional pebbles of white quartz, blackish and greenish silicious slate, soft greenish shale, and blood-red jasper, and the surfaces of some of the beds are covered with carbonized comminuted plants. These strata may be 1000 feet thick: they dip to the southward, and no doubt overlie the red sandstone and shales already noticed, but between the two there may be some strata wanting.

Turning southward, the Cascapedia twice intersects the strata of these hills, in the distance of about ten miles, on the opposite sides of a synclinal. The intermediate dips prove a gradual sweep in the stratification; rendering it probable that a considerable portion, if not the whole mass of sandstones, will crop out on the axis, not very far to the eastward; a result very likely to arise from the effect of the intrusive mass of Table-top Mountain on the distribution of the strata.

SECTION OF THE MATANNE RIVER.

From the Chatte, the limestones strike along the south foot of the Shickshock mountains to the Matanne. Here, the white quartzose sandstone at the base, is speckled with small red ferruginous spots, and weathers of a rusty yellowish color. It shows an occasional outcrop on the Matanne, between its tributaries the Trout and the Tawagadie, and attains a thickness of seventy feet at the mouth of the latter. In the eight and a half miles between the gorge leading from Lake Matanne and the Trout, the limestone escarpment rises boldly over the south bank of the Matanne, to a height of between 500 and 600 feet. In this, the lower members of the series consist of blue limestones and grey calcareous shales, with thin bands of blue limestone interstratified. A few fossils are met with in the limestones, but none as yet sufficiently well defined to be recognized. The upper part of the ridge is composed of massive beds of blue and grey limestone holding numerous fossils. These have usually been much distorted by molecular movements, and thus rendered somewhat obscure. Among them are an undetermined species of *Stenopora*, and a large undetermined species of *Fenestella*, *Strophomena rhomboidalis*, *S. radiata?* *S. perplana?* *Spirifera perlamellosa?* *S. pleiopleura?* undetermined species of *Athyris* and *Modiolopsis?* several undetermined species of *Platyceras* and *Platyostoma*, and one of *Conularia*. While the sandstones at the base of the series would seem to ally this portion to the Anticosti group, the beds at the summit have more the aspect of the Lower Helderberg; but better specimens of the organic remains will be required to establish their equivalency with certainty. Sandstones. Limestones.

The sandstones at the base, and the limestones at the summit, might become serviceable for building purposes; but it appears doubtful whether the latter are not generally too silicious to be burned for lime. The Trout River, intersecting the measures at right angles, exhibits a section of the lower portion of the limestones, in which the lowest beds dip S. 38° E. $< 54°$; but at the end of the section, the inclination diminishes to twenty-eight degrees, and the measures probably become nearly horizontal to the southward, corresponding with the level character of the country: in which, however, no examination has yet been made, before reaching the Matapedia.

SECTION OF THE MATAPEDIA LAKE AND RIVER.

The north-east side of Lake Matapedia appears to be occupied by rocks of the Quebec group. For four and a half miles from the upper or north-western end, they consist of dark grey soft clay slates, enclosing, about Lake Matapedia.

Quebec group. half-way down, a mass of conglomerate nearly a hundred feet thick, composed of limestone pebbles, in a matrix of whitish sandstone; bands of which, without pebbles, separate the layers of conglomerate. The dip of the conglomerate, with that of the slates to the north-westward of it, is northward; but the slates to the south-eastward have a contrary slope. In the latter direction, they are followed by sandstones, which probably represent the Sillery series. A promontory about a mile and a half below the mouth of the Awaggan, displays a section of these, in which upwards of 700 feet of the usual greenish colored sandstones are interstratified with occasional red layers. Similar sandstones, with red slates, appear still farther down the lake, and are intersected by trap dykes. Associated with these strata, is a large body of a peculiar dioritic rock, often concretionary, and similar to masses which are met with among the altered strata of the Quebec group in the Eastern Townships. This rock abounds in epidote, which occurs among the concretions, and in veins. Upwards of three miles of the lower part of the coast, and three or four islands near, are occupied by these rocks: the lowest of the islands, called Makwash, being about a mile above the narrows leading to the lower lake.

Sillery formation.

Epidotic rock.

The strike of the rocks on the north-east side of the lake is about W. S. W., and from the conglomerate downwards, the dip is southward; the inclination of the strata varying from thirty to eighty degrees. It is very probable that in some parts they present overturn dips. On the opposite side of the lake, the general strike is about N. N. W., with the trend of the lake, and the dip is always to the westward. In only one or two isolated instances, does the slope exceed ten degrees, and it is often not greater than three or four. The lowest strata on this side belong to the band of sandstone which we have just described on the Matanne; and from its attitude in relation to the rocks on the north-east side of the lake, there is little doubt that it overlies them unconformably. This sandstone on Lake Matapedia is generally white, sometimes speckled with small red spots: it frequently assumes a pinkish tinge, and occasionally presents a band or two of a red color. Its thickness is computed to be from sixty to seventy feet, but its contact with the rocks beneath it has not been observed. It must come upon the lake somewhere near the outlet, and it appears to occupy the south-west margin to within about four miles of the upper end; leaving the remainder, with the exception of a point half-way, which is tipped with it, for the succeeding limestones. The sandstones would afford very good material for building purposes; and Mr. Brochues, who is settled on the lake, has obtained from them good millstones, which are used in his mill in the neighborhood. Loose blocks, undoubtedly derived from some of the beds near, are occasionally met with, holding fossils; the whole of which are obscure, with the exception of a cast of *Pentamerus*, strongly resembling *P. oblongus*.

Gaspé sandstones.

Limestones. The calcareous rocks which succeed to this band of sandstone, have been examined only at their base; where they occupy the upper part of the south-west side of the lake, and are seen in contact with the underlying beds. In this part, which may have a thickness of 150 or 160 feet, they consist of dark brownish-grey somewhat arenaceous limestones, weathering to a lighter grey. They enclose nodules of a purer limestone than the mass, which is made up of irregular and uneven surfaced beds. The fossils of these strata are *Favosites polymorpha*, *Halysites catenulatus*, *Diphyphyllum* ——— ? *Strophomena rhomboidalis*, *S.* ——— ? a variety of *Pentamerus galeatus*, *Spirifera crispa*, *S. radiata*, *Atrypa reticularis*, and an undescribed *Pleurotomaria*; all of Middle Silurian age.

Matapedia River. On the Matapedia River, between the lake and the Devil's Elbow, a bend about three miles beyond the Causapscal, the whole of the Gaspé and limestones are met with; but the absence of observed fossils makes it difficult to compare the different portions with the section of Cape Gaspé. The entire distance is about seventeen or eighteen miles; in the first part of which, to the Umpui, there are no exposures. In the remainder of the distance, there are many intervals of concealment; but, judging by the strata which are visible, the masses, in succession, seem to be dark grey calcareous shales, occasionally nearly black, terminated by dark grey limestones, weathering to a rusty yellowish-brown. This mass is succeeded by a grey hard, compact, and somewhat gritty calcareous slate, weathering to a yellowish-white. The slate has a cleavage independent of the bedding; and the thinness and closeness of the strata, with their slight differences of color, often give to the planes of cleavage a ribbon-like aspect. Following these, black soft calcareous slates occupy the river for two and a half miles above the Causapscal; succeeded below it, by dark grey calcareous slates, weathering whitish and yellowish, with occasional beds of black limestone.

About a mile and a half south from the Causapscal, on the Campbelltown road, the calcareous series is followed by grey argillaceous slate, weathering to olive-green, and sometimes to opaque white, perhaps where affected by fire. The mass, which does not appear to be calcareous, occupies a mile and a half on the road, and then gives place to a succession of arenaceous strata, representing the Gaspé sandstones. These occupy the road for about six miles, and consist of greenish-grey or drab sandstones and arenaceous shales, with occasional layers of red and purplish-grey. Some of the surfaces are ripple-marked, but no carbonized remains of plants have been observed upon them. On the Matapedia, which is a short distance to the westward of the road, the breadth of the sandstones is somewhat less than six miles. The dips at the opposite extremes of the distance, indicate that the strata lie in a synclinal form; on the axis of which, it seems probable that they will be found to crop out to the westward, at no very great distance. They do not reach the Patapedia, which is distant about twenty miles in that direction. Sandstones.

SECTION OF THE GREAT METIS AND PATAPEDIA RIVERS.

Great Metis River.

From the upper end of Lake Matapedia, the base of the Gaspé limestones turns southward of west, following the valley of one of the tributaries of the lake for five or six miles; and thence reaches the Great Metis River, which it crosses at a distance of fifteen miles from the St. Lawrence. On this river, a little below the mouth of its tributary, the Musquegegish, large loose angular blocks of fine grained white sandstone are abundant; but the beds from which these are derived are concealed. At the mouth of the tributary, however, the overlying calcareous rocks make their appearance. With a dip of S. 66° E. < 45°, they present an escarpment of about twenty feet high, and consist of grey nodular limestone, divided into beds of two and three feet. The rock is fossiliferous, but the fossils are difficult to extract. In one of the fragments, at the foot of the escarpment, were however obtained a *Pentamerus* resembling *P. Knightii*, a *Strophomena* resembling *S. inæquistriata*, and another species, which is resupinate and resembles *S. punctulifera*.

Limestone.

Farther up the Great Metis, at a distance of about 850 yards at right angles to the strike, another exposure occurs. Here the beds consist of limestones of the same character as before, interstratified with greenish shale; the dip being S. 65° E. < 30°. About fifty chains farther up, strata are again met with; but here the dip is N. 75° E. < 2°-6°. These beds consist of dark grey argillo-calcareous shale, interstratified with greenish layers. At the base, a bed of about three feet thick, consists of greenish arenaceous limestone, and contains obscure fossils, one of which resembles *Pentamerus oblongus*. These three exposures are supposed to overlie one another; and the total thickness, with what is concealed, is computed to be about 2000 feet.

River Rouge.

For two miles above this, no exposures occur; but in the succeeding two and a half miles, to its tributary, the Rouge, several are met with. The first one consists of greenish arenaceo-calcareous shales, and the others of grey micaceo-arenaceous limestones or strongly calcareous sandstones, well fitted for flagging stones, interstratified with purplish-brown arenaceo-calcareous shale. Masses of similar characters constitute the rocks of the falls between the Rouge and the Metis lakes, and near the lowest lake. Both above and below the Rouge, they show various and sometimes opposite dips, occasionally with very high angles. In a part of the distance, the rocks exhibit a cleavage independent of the bedding, and it is often difficult to distinguish the one from the other. It has, in consequence, as yet been found impossible to compute their thickness; but from the amount of calcareous matter which they contain, these strata are supposed still to belong to the Gaspé limestones, and to represent a higher portion than those mentioned above.

No rocks have been seen on Lower Metis Lake; but strata are met with in several places in the upper half of the middle lake; consisting of grey granular limestones, weathering brownish-yellow, and containing obscure fossils. The beds are from six to twelve inches thick, and are interstratified with less calcareous layers, greenish-grey in color and weathering brown. An obscure cleavage exists in the less calcareous layers, and they separate with difficulty in the direction of the beds. These strata, with several minor undulations, appear to preserve a general horizontality, and they are supposed to be a repetition of the lower part of the Gaspé limestone series. Metis lakes.

The shores of Upper Metis Lake are strewed with many large flat fragments of calcareo-arenaceous shale, mixed with sandstone; and in one place, the bottom of the lake is paved with a greenish sandstone, interstratified with greenish shale: the beds appear to be horizontal. After passing the water-shed, an exposure, about half-way down the Awaganasees, consists of greenish calcareous sandstones, in beds of from six to eight inches, dipping N. 3° W. $< 24°$. Below this, to within a mile of the Patapedia, there appear flagstones, very similar in character to those below the Lower Metis Lake, and near the Rouge, except that they are more even and regular in their divisional planes. In some parts, the thicker slabs are separated by calcareous slates, which split into large and remarkably even plates, no more than the eighth of an inch thick; of a dark grey internally, but changing rapidly in the weather to a greyish-yellow or light drab. Rocks of a similar character, but not so evenly bedded, prevail for the remainder of the distance to the Patapedia. They are considered to be a repetition of the upper part of the Gaspé limestone series, to which we here assign a total breadth of between fourteen and fifteen miles.

Between the mouth of the Awaganasees and Indian Rivers, and half a mile below the latter, the rocks are dark grey compact thin-bedded limestones, interstratified with blackish calcareous slates. These recur twice, and on each occasion are followed by dark grey calcareous slates. Below this, for seven miles, as far as Pollard's Brook, there prevails a greenish-grey arenaceous slate, which weathers yellowish-brown, and is sometimes calcareous. At this brook, and for a short distance below it, there is a recurrence of dark grey calcareo-argillaceous finely laminated slates, splitting into large slabs about the thickness of roofing slates, and weathering to a greyish-yellow or drab, like those of the Awaganasees. With the exception of these drab-weathering strata, the prevailing rocks, for five miles below Pollard's Brook, are dark grey argillaceous slates, interstratified with occasional non-calcareous layers. For six miles farther, the rock is a dark grey calcareous slate, interstratified, in the last two miles, with more calcareous bands. For a mile and a half farther, thin-bedded black limestones occur a third time, interstratified with black and dark grey Patapedia River.

argillaceous slates; beyond which, the only rocks, for two miles, to the junction of the Patapedia with the Restigouche, are dark-grey calcareous slates, interstratified with arenaceous and greenish sandstones.

In all of these rocks on the Patapedia, there is a cleavage independent of the bedding, and it is often very difficult to distinguish the one from the other. Occasionally the strata are much contorted; and it has been found impossible, up to the present time, to determine what may be their thickness, or the number of repetitions of equivalent groups of strata. No fossils have been found in these rocks; and it is difficult at present to establish their age; but they are not supposed to be older than the Gaspé limestones.

SECTION ON THE RIMOUSKI RIVER.

From the Metis River, the base of the Gaspé limestones continues its course south of west, parallel with the margin of the St. Lawrence, at the distance of fifteen miles; then sweeping around the western extremity of Mont Commis, it approaches to within ten miles of the St. Lawrence. At this distance, it again runs parallel with it for about five miles, across one half of the township of Neigette, and then makes another sweep forward, towards the front of Macpes; reaching the Rimouski River at a point about nine miles, in a straight line, from its mouth. The base of the Gaspé limestones are, however, not more than seven miles from the coast, between Rimouski and Bic.

Rimouski River.

On the right bank of the Rimouski, the rocks of this series rise in a well-marked escarpment, over a hundred feet high. The rock at the base is a whitish-grey calcareous sandstone, of which between twenty and thirty feet are seen, dipping S. 39° E. $<$ 7°-9°. This is succeeded by beds of bluish argillaceous limestone from six inches to two feet thick, which constitute the remainder of the escarpment. Limestones of a similar character are met with at intervals, for about five miles up the Rimouski, to a large marsh, on the fourteenth lot of the third range of the township of Duquesne; which would be about two and a quarter miles across the measures. The dip is here S. 60° E. $<$ 45°, and the rock is a dark grey calcareo-argillaceous slate, interstratified with greenish calcareous sandstones, in beds of from one to two inches thick. To the south of the marsh, a ridge rises to the height of about 150 feet, having at its southern base a valley; which on the east side of the river contains Lake Macpes and its discharging stream, and on the west, the river Touradiff. This depression is over half a mile from that of the marsh, and the rocks seen in it are much the same as those just described, with perhaps a somewhat smaller quantity of slate: the dip is S. 59° E. $<$ 30°.

A mile and a quarter above this, there is another depression, occupied, on the west side, by the Rivière France; and two and a half miles farther up, we have the fall of the Rimouski, on the twenty-fourth lot of the sixth range of Duquesne. The rock at the fall is a greenish-grey calcareous sandstone, in beds of two or three inches, separated by grey calcareous shale; the shale and the sandstone being about equal in amount, but irregularly interstratified. The dip at the fall is S. 44° E. < 60°; but just below it, there occurs a small undulation, by which the same beds are kept at the surface for a distance of about forty-five yards across the measures. The Rimouski, for a considerable distance below the fall, flows in a very deep and inaccessible chasm. The strata, in consequence, have been examined only at considerable intervals; and if there should be many undulations similar to that at the fall, these would materially diminish the thickness to be deduced from the ascertained dips.

Rimouski Fall.

About a hundred yards below the fall, the rock is very evenly divided into beds of from one to four inches thick, and would yield excellent flagstones, two to three feet wide, and from four to six feet long. They very much resemble the flagstones already described on the Metis, and their stratigraphical place may very probably be the same. Fossils have been observed in several parts of the series, but the only one that can be identified is a pear-shaped variety of *Favosites basaltica*.

No exploration has yet been made farther up the Rimouski, nor has the base of this series of limestones been consecutively traced, with accuracy, farther west. After crossing the Rimouski, the base appears to keep on the south side of its tributary, the Little Rimouski, very nearly to the water-shed between it and the eastern tributaries of the Trois Pistoles River. Here, turning more southward, it runs a course about parallel to the Tuladie, and comes upon Lake Temiscouata.

SECTION OF LAKE TEMISCOUATA AND THE MADAWASKA RIVER.

That part of Lake Temiscouata which is above Fort Ingall, extends to the north-eastward, with the strike of the rocks, and at right angles to its lower part. This lower portion, with the Madawaska River, to Little Falls, and the St. John in continuation, to the vicinity of Woodstock, afford a transverse section of the strata.

The upper part of the lake, on the north-west side, gives a fuller development of certain strata, which occupy the last two and a half miles on the Temiscouata Portage road, and which, at the time of examination, in 1849, it was supposed might possibly belong to the Devonian series. As seen above Sandy Point, which is four and a half miles from Fort Ingall, they consist

Shales and limestones.

of grey slaty limestones, splitting into thin firm laminæ, apparently in the direction of the beds; which are nearly vertical, and would yield excellent tiles and flagstones. Lower down the lake, grey clay slates are interstratified with calcareous sandstones, which weather to a yellow earth or rotten-stone: in some parts, nodules of a similar character occur. In addition to these strata, clay slates, sometimes lead-grey, or of a darker hue, are found, interstratified with thin bands and lenticular masses of a fibrous or columnar limestone; the fibrous structure running at right angles to the beds, and quite across them. These slates and limestones prevail, not only on the north-west side of the lake and for a mile above, to the mill on Mill Brook; but they are seen extending along the south-east side of the lake, from its head, to a point immediately opposite Mill Brook. Here, there is some irregularity in the structure, and the grey slates are associated with beds of grey calcareous sandstone and of arenaceous limestone, with dark banded green slates.

Beds similar to these, occur to the north-west of the Shickshock mountains, on the Chatte River; and the peculiarity of the fibrous structure of the limestones in both places is so striking, as to induce the supposition that the rocks in the two localities must be equivalent. The strata on Temiscouata Lake having been classed with the Devonian series, those on the Chatte were placed in the same horizon; and they were so represented on a small map published in Paris, in 1855, to illustrate a sketch of the geology of Canada. The light recently thrown on the Quebec group by the fossils discovered at Point Lévis, however, leads us to suppose that these strata on the Chatte, and on Lake Temiscouata, belong to the base of this group.

Quebec group.

Mount Wissick.

After proceeding for three fourths of a mile to the south-east, transverse to the strike from these lower rocks, we come upon the higher strata which constitute Mount Wissick or Mount Lennox. This mountain rises on the north-east side of Lake Temiscouata, and consists of the following strata in ascending order:—

		Feet.
	Whitish massive sandstone, of a moderately fine grain,....................	45
Conglomerates.	Grey coarse calcareous conglomerate; the matrix is a greenish sand, and holds a large amount of angular fragments, and some rounded masses of grey limestone, with a much smaller number of quartz pebbles. No fossils have been observed in the enclosed portions of limestone,.........	20
	Measures concealed,..	90
Red and green shales.	Green sandstone, with a few conglomerate bands similar to the previous one,	20
	Red and green shale in alternating bands, none of which were observed to be calcareous. There are three successive exposures of this shale, with fossiliferous limestones between them; but two of these are supposed, from differences in the strike, and from one observed anticlinal, to be repetitions; the shale being subjacent to the limestones,.............	125

Limestones.

	Feet.
Grey nodular limestone, abounding with fossils; among which are *Favosites Gothlandica*, *Atrypa reticularis*, and an undescribed species of *Pentamerus*. The limestone presents a vertical columnar structure, due to two sets of joints, which divide the beds into irregular rhombic prisms,...........	50
Grey hard sandstone, without observed fossils,.........................	10
Grey fossiliferous limestone with a columnar structure,..................	20
Grey arenaceous limestones and sandstones, with fossils at the base and summit, and probably throughout. Some of the beds have very little carbonate of lime, and many have none at all. This constitutes the main body of Mount Wissick, and its thickness is estimated from the height of the mountain, which is 550 feet. No rocks were seen for a considerable distance, across the measures, from the band of grey sandstone above mentioned,.......................................	500
	880

The dip of these strata is S. 50° E. $<$ 13°; and to the middle of the valley between Mount Wissick and the next ridge running to Black Point, there would, if the dip remains constant, be room for 1000 feet above them. No exposures of strata however appear on either side of the lake, to tell of what the interval may be composed; and between the middle of the valley and the rock of Black Point, there is another concealed interval, whose breadth, directly across the measures, would be 400 yards, equal to 276 feet more in thickness.

Black Point conglomerate.

Black Point, and Burnt Point, which is opposite, consist of a very coarse conglomerate, composed chiefly of pebbles of quartzite and limestone, the former prevailing. The colors of the quartzite pebbles, which occasionally hold a few spangles of mica, are green and grey, but principally green, and some of them are from six to eight inches, and even a foot in diameter. The calcareous pebbles generally weather to a yellowish tint; but many of them remain grey, while some of the pebbles consist of red slate. The matrix of the rock is a sandstone of a dark grey color, which appears to be slightly calcareous. The first or lowest band of this conglomerate is about 400 feet thick; and it is followed by others, varying from one to sixty feet, which are separated by beds of sandstone of from one to fifteen feet thick. The whole breadth of these coarse rocks is about 400 yards, and the dip remains very uniformly S. 63° E. $<$ 51° - 56°; which would give a total thickness of very nearly 1000 feet.

This conglomerate rock constitutes a sharp and prominent ridge, which can be traced, as viewed from the summit of Mount Wissick, running far into the country north-east of the lake, on the north-west side of the Tuladie River; whose course is very probably guided by it for ten or twelve miles. From the same height, the fossiliferous range to which the mountain itself belongs, can be seen extending in a parallel line for upwards of ten miles; the last visible eminence in the range bearing N. 23° E.

On the west side of the lake, the fossiliferous band is not so conspicuous, nor so clearly traceable, but it is supposed to direct its course to a hill to the north of the Cabineau River, in the bearing S. 23° W.; while the conglomerate will probably be found in a better marked ridge, which occupies the south side.

Cabineau River.

In the lowest four miles of the Cabineau River, where strata intermediate between the conglomerate and the fossiliferous limestone might be expected, there appear to be only two exposures of rock. The first, nearly three miles from the mouth, consists of grey thin-bedded contorted limestones, without fossils; and the second, half a mile beyond, of green slate, banded with black, and interstratified with pure limestone bands, also without fossils. Except that these limestones are not fibrous, the measures resemble the lower strata on the north-west side of the lake.

Beyond the conglomerates of Black Point, the next rock exposed is a grey soft scaly argillaceous slate, becoming a little lighter in color under the action of the weather, which splits it into small flat fragments. On the west side of the lake, it occupies about three quarters of a mile, in the distance of a mile and a half, across the measures, and it probably forms the bed of the Tuladie, a few miles up from its mouth. This slate may be much contorted, and it is for the present impossible to state its thickness.

The rocks which immediately succeed this slate on the west side of the lake, are given in the following horizontal section, whose distances correspond to a line at right angles to the general strike :—

Slates and sandstones.

	Yds.	*Yds.*
Grey argillaceous scaly slates, of the same kind as described above, interstratified with bands of sandstone, varying in thickness from an eighth of an inch to one inch. Some of the beds are partially calcareous, and they are generally cut by veins of quartz, not exceeding the thickness of paper,	31	
Measures concealed,	14	
Grey argillaceous slates, with sandstones as before,	69	
Measures concealed, but supposed to be the same,	13	
Measures concealed, but so thickly covered with large angular blocks of a light grey sandstone with a greenish tinge, that there is little doubt that this rock is present beneath, in thick beds,	24	
Light grey sandstone slightly tinged with green, of the same character as before, but in thick beds. It is hard and fine grained, approaching a granular quartzite, and is in a slight degree calcareous. The dip is S. 63° E. $< 83°$,	7	
Measures concealed, but probably the same description of sandstone,	38	
Light grey sandstone of the same character as before, with a few beds of slate separating the layers,	9	
Measures concealed,	7	
Light grey sandstone as before, weathering of a lighter grey than the interior color,	10	
Grey argillaceous slate, becoming green, and crumbling under the influence of the weather,	1	223

	Yds.	*Yds.*	
Dark grey hard argillaceous sandstone, slightly calcareous. It has a greenish hue within, and weathers more green externally; there are a few quartz pebbles at the bottom of the bed. Fragments of the rock held in a proper light, show a peculiar reflection, from the symmetrical arrangement of crystalline grains of calcite or of dolomite,...	10		
Dark grey tough argillaceous sandstone, like the last, without any calcareous matter; alternating with beds of jasper, the color of which in some layers is a uniform purplish black,.....................	10		
Measures concealed, probably beds of a similar kind to the last, and constituting Pointe aux Trembles,............................	30		Pointe aux Trembles.
Greenish tough argillaceous sandstone, alternating with beds of a uniform purplish brown jasper. The sandstone beds have grains of red in them, but their general tint is green,.....................	25		Jasper beds.
Measures concealed,..	86	161	
Greenish tough argillaceous sandstone; in some parts it holds a few red pebbles, and others of grey and greenish hues. The pebbles are very obscure, and tightly soldered into the matrix; fractures go through both without deflection,......................................	18		
Measures concealed,..	18		
Greenish tough sandstone as above; the occasional presence of pebbles is more observable than before, and they sometimes stand up in relief on the surface; the rock towards the top partakes of a conglomerate character. Some of the pebbles are from five to six inches in diameter, and they are all highly crystalline, appearing in general to be from metamorphic rocks. The matrix, which is not very fine, continues to be a mixture of red and green grains, giving a green tinge in the aggregate. Some of the interstratified bands are of a darker hue than the general mass, approaching to an iron-grey, but weathering to a yellowish-white By these bands, and by others of a deep purplish-red slate, the dip, which is S. 56° E. < 76°, can be readily distinguished. There are thin vertical transverse veins of epidote cutting some parts, and the same mineral seems to exist also as a constituent of portions of the rock. There is a very regular set of joints in the rock, of which the underlie is N. 85° W. < 22½°,	96	132	Epidotic rock.
		516	

These rocks constitute two points on the west side of the lake. The upper one, called Pointe aux Trembles, just opposite the Tuladie River, is very conspicuous. The second point is of no importance in the configuration of the coast, but it runs back into a ridge, with a valley on each side of it, which marks well the course of the sandstone composing it. It is probable that the conglomerate of Black Point, and the chief part of the strata included between it and Pointe aux Trembles, may belong to the Quebec group. These, from their highly inclined attitude, as contrasted with the moderate dip of the rocks of Mount Wissick, would appear to underlie the Gaspé limestones unconformably; but not having yet been traced out to any distance on the strike, it will require further investigation before their relations can be completely understood. Quebec group.

The rocks of the second point would come upon the section about five hundred and forty yards, at right angles to the strike, from the last described sandstones. The intervening strata, judging by the first rocks seen on the south side of the Tuladic, at a corresponding point, would probably be calcareous slates of a bluish-grey color and fine texture, with some thin bands and patches of a coarser grain. The stratigraphical divisions of these slates are obliterated by cementation, and it is only by slight differences of color that the beds can be distinguished. These strata are followed by grey slates, which are not calcareous, and appear to be slightly micaceous. They weather to a dull dark olive-green, and cleave into very thin leaves. These alternate with, and pass into a grey tough, feebly calcareous sandstone, which is fine grained, slightly micaceous, and has a dull granular earthy fracture. They all weather greenish, where washed by the water and spray of the lake ; but surfaces removed from the lake, and denuded of moss and trees, are often of a dull white, with a reddish-yellow tinge, perhaps the result of the action of fire. The beds succeeding the calcareous slates, have a transverse measure of 290 yards: their dip, where it could be determined, was S. 55° E. $<$ 50°.

The next five miles across the measures, are occupied, on the west side of the lake, by calcareo-argillaceous slates, occasionally interstratified with non-calcareous bands, which are more or less arenaceous. The colors are dark bluish-grey, light grey, and black ; and the divisions of the original bedding have become very much obscured ; so that in fresh fractures, it is only by different shades of color, that the stratification can be made out. The action of the weather and water on the ice-rounded surfaces upon the lake, however, distinctly shows the bedding, by the unequal wearing of the more and less calcareous layers. The beds are almost always thin, and the surfaces display a great variety of the most complicated contortions ; sometimes in folds, to the north-west, and sometimes in involutions, which it is impossible to understand, without a larger exposure than usually occurs. Combined with these contortions, there are often disruptions or dislocations ; which, however, show no veins of foreign matter. The torn and twisted mass has been apparently compressed together, and cemented in such a way, that, except for the colors or the unequal weathering, it would never be suspected that it had been disturbed. In some parts, however, the contorted rocks are cut up by a multitude of small veins of calcareous spar. The figure on the next page represents the contortions and dislocations upon a surface on which no veins, whatever, appear.

Contorted beds.

In the vicinity of Little Island, which stands opposite to Grand Bay, in a section of three quarters of a mile across the measures, including the island, no calcareous matter is found in the slates, which weather of a greener color than the beds farther up. There is a small amount of carbonate of lime in the hard bands, which are very thin sandstones. The calcareo-argillaceous slates then appear again, and continue for a mile and a half farther. The remaining distance, to the exit of the lake, another mile and a half, transverse to the general strike, shows occasional thicker beds of sandstone; with grey calcareo-argillaceous slates, holding thin calcareous sandstones, and black and dark grey non-calcareous beds. The last exposure, just at the exit, on the right bank of the Madawaska, consists of non-calcareous sandstones and slates: which are grey internally, but weather to a dull olive-green, resembling those near the Tuladie River. The beds are all slightly micaceous; the slates more so than the sandstones.

About half a mile down the Madawaska, where the rock comes close upon the river, the same grey, greenish-weathering slate is seen, with thin Madawaska River.

431.—SECTION OF SLATES ON LAKE TEMISCOUATA.

Scale about $\frac{1}{30}$.

light colored slightly calcareous bands marking the bedding. The exposures on the river, all the way to Little Falls, at its junction with the St. John, are not numerous. They consist pretty uniformly of the same slates and sandstones as before, the slates greatly predominating, and occasionally holding a small amount of calcareous matter. At Little Falls, Little Falls. the color of the rock is grey internally, weathering generally to a dull obscure olive-green, sometimes so dark as to give it a chloritic aspect. The slate, which is micaceous, is interstratified with occasional hard compact bands, cleaving with difficulty, and possessed of sufficient grit to entitle them to the name of sandstones.

ROCKS ON THE WALLOOSTOOK OR ST. JOHN RIVER, AND SOME OF ITS TRIBUTARIES.

Slates and sandstones, similar to those at Little Falls, are seen farther down on the St. John, near its tributary, the Squesibish; where there is a transverse exposure of 200 or 300 yards. Here the slate, internally grey, weathers greenish, and is interstratified with bands of feebly calcareous sandstone, some of which are from four to twelve inches thick. The bedding is well displayed at this place, and a few contortions in the stratification are visible.

Shiguash. Still lower down, and about a mile and a quarter above the mouth of another tributary, the Shiguash, a band of coarse conglomerate, which crosses the road, bears a strong resemblance to that of Black Point, on Lake Temiscouata, and holds a great amount of large pebbles and small boulders of black limestone, weathering to an ash-grey. Some of the calcareous boulders are themselves of a conglomerate character, holding pebbles of a stratified rock, while their matrix includes organic remains. With the calcareous portions of this conglomerate band, are mingled others of black jasper and of chalcedonic quartz: with these, were observed several pebbles of a blackish-green serpentine. The matrix is a hard calcareous sandstone, with grains of white and colored quartz: it is grey internally, and weathers to a yellowish tinge. Vertical beds of the conglomerate, running N. 30° E., alternate with beds of a sandstone similar in character to the matrix: a breadth of seventy-five yards is visible, giving a thickness of 225 feet. As the strata above and below are concealed, the volume may be greater, particularly to the south-east; where the ground rises in a small hill, for a quarter of a mile. At this distance, the conglomerates are followed by calcareous slates, which at first are interstratified with a few bands of sandstone, resembling that associated with the conglomerate, but, farther on, display strongly calcareous beds, weathering to a rotten-stone. Sometimes the slates, without being themselves calcareous, are interstratified with slightly calcareous sandstones. These alternations are occasionally visible for about 500 yards; between which and the Shiguash, there are no exposures on the road. The examination in this vicinity has not been carried farther.

Conglomerate.

Serpentine pebbles.

Rocks similar to those of the lower part of the Madawaska and the Squebish, prevail along the St. John, as far as the St. Francis, and even to the Black River, twenty miles higher. Both the slates and the sandstones are in general micaceous, and occasionally calcareous. On the St. Francis, no traces have been found of the Black Point conglomerates, or of the jasper rocks of Pointe aux Trembles; nor have we been successful in meeting with the fossiliferous limestones of Mount Wissick, though the distance from Temiscouata is scarcely more than twenty-two miles. The lowest exposure belonging to the Quebec group, on this river, consists of a coarse greenish chloritic sandstone, associated with green slates. It occurs just to the north of the province line, at the foot of a lake called by the Indians, Wollenabégeg: below this, the country appears to consist chiefly of clay slate. The most calcareous ridge met with, occurs about three miles above another lake, which is called by the Indians, Battéwich-

St. Francis River.

câgameg. The rocks of this ridge, however, shew no fossils, and they do not hold a sufficient quantity of carbonate of lime to entitle them to the name of limestones. A mountain on the north-east side of this lake, displays some strong beds of sandstone, associated with bluish-black or dark grey slates, both slightly micaceous; but the sandstones alone are somewhat calcareous. Similar micaceous sandstones, sometimes holding a little carbonate of lime, prevail to the mouth of the lake.

On the Black River, twenty miles above the St. Francis, there occur the same grey micaceous slates and sandstones, occasionally calcareous. The sandstones weather greenish, and, where washed by the water, acquire a slightly reddish tinge. Large angular blocks of a calcareous conglomerate are occasionally met with; but the rock, *in situ*, does not occur below the province line. Both below and half a mile above this line, calcareous slates occur, with black or dark grey coarse limestone bands; and half a mile above this, there is seen a conglomerate, of which three exposures occur in a breadth of 300 yards. It holds boulders of a fine silicious conglomerate and of grey quartzite, with blackish vitreous quartz grains and fragments of green slate. The matrix appears to be composed of this green rock in a comminuted state, with a fine grey slate. The fact that this conglomerate itself contains pebbles of an older conglomerate rock, resembling some portions of the Sillery series, connects it with the conglomerate of Black Point, on Lake Temiscouata, and with that near the Shiguash; which last encloses pebbles of serpentine. These characters suggest the probability, that all of these conglomerates may be newer than the Quebec group, the sandstones of which were seen between three and four hundred yards farther up the Black River. They were examined for a distance of about a mile and a quarter, and resemble those of the Sillery series; being greenish, massive, and coarse grained, with scales of mica and of graphite, and interstratified with occasional bands of red slate.

Black River.

Conglomerate.

Sillery series.

SECTION OF THE CHAUDIÈRE RIVER.

We have already stated that in the valley of the Chaudière River, the Quebec group is limited to the south, by a series of Upper Silurian strata. These appear in the parish of St. Francis, a few miles above the Guillaume River, and consist of dark grey and black clay slates, interstratified with a few beds of sandstone. Similar beds prevail as far as the vicinity of St. Francis church, in the seigniory of Vaudreuil, Beauce; and at the turn in the river, some distance above, there is met with a light grey calcareous bed, overlaid by a massive feldspathic sandstone. This is followed, higher up, by dark grey clay slates, with quartzite bands of the same color, fol-

Vaudreuil, Beauce.

lowed by impure blackish limestones. Three hundred yards farther, occurs another band of feldspathic rock similar to that just mentioned, and having the aspect of a fine conglomerate. Beyond this band, which is about a mile and a half above the church, the prevailing rock is clay slate.

On the Touffe des Pins, about a mile above its mouth, these clay slates are bluish-black, striped with a lighter color. They are occasionally slightly calcareous, while the somewhat feldspathic interstratified sandstones, are strongly so. These slates preserve the same character up to the river Famine, where, with a dip S. 37° E. < 65°, they plunge beneath a grey slaty micaceous limestone without fossils, succeeded, about fifty yards to the southward, by dark fossiliferous limestones, not exceeding from ten to twenty yards in breadth; which form a low short ridge, overlooking the Famine. The fossils have a Devonian aspect: among them are *Favosites Gothlandica*, *F. basaltica*, *Syringopora Hisingeri*, *Diphyphyllum arundinaceum*, an undetermined *Zaphrentis*, *Heliophyllum Oneidaense*, *Orthis striatula*, *Strophomena rhomboidalis*, two undetermined species of *Chonetes*, a small *Productus*, like an undescribed one occurring in the Corniferous formation; *Spirifera duodenaria*, *S. gregaria*, *S. acuminata*, *Atrypa reticularis*, and a *Cyrtia* like *C. rostrata*.

Famine River.

Approaching the mouth of the Rivière du Loup, the proportion of sandstones somewhat increases, and continues to do so for three miles up this tributary, as well as up the Chaudière to the Great or Jersey Fall. At this fall, there is a considerable exposure, measuring about 150 yards across the strata, which appear to dip S. 37° E. < 62°. The beds consist chiefly of grey sandstones, some of which are schistose, and approach to a coarse mica slate, while others are massive. They weather to a greenish tinge when above the water-line; but where washed by occasional floods, they have a reddish cast. These sandstones are interstratified with calcareous beds, which are harsh and gritty to the touch, and contain a great proportion of sand; none of them would burn to lime. Other and thinner bands are blackish on the exterior; and these, which are smoother than the rest, are soft and wear into grooves; while the sandstones stand out in relief. The black bands are finely laminated, and split into brittle plates, with glossy surfaces. The sandstones weather to a lighter grey than the calcareous beds, some of which approach to a pale olive-green color on the exterior. A quarter of a mile below the fall, there is another exposure of similar strata, with some more highly calcareous beds.

Jersey Fall.

Rivière du Loup.

Rocks related in character to those given above, consisting of fine and coarse grey micaceous clay slates, with grey micaceo-argillaceous sandstones, which weather greenish in the air, and become reddish and very smooth where exposed to running water, occur much farther up the Rivière du Loup and the Chaudière; reaching near to the province line on the one hand, and to Lake Megantic on the other. The information collected in regard to these rocks is not yet sufficiently detailed to enable us to give a connected description of them. Both above and below the junction of the two rivers just named, the clay slates are often observed to have a cleavage independent of the bedding; and they will, in some places, very probably yield material fit for roofing. On the Rivière du Loup, about half a mile above its mouth, a band of the rock, exceeding half a mile in breadth, would in several parts afford both roofing and writing slates, as well as excellent flagstones. Of the latter, good even slabs may be obtained of five and six feet in length, by three or four in width, with a thickness of from two to three inches. Clay slates.

ROCKS OF THE ST. FRANCIS AND SOME OF ITS TRIBUTARY LAKES AND RIVERS.

From Vaudreuil, Beauce, on the Chaudière, the base of the Upper Silurian clay slates, in its course south-westward, reaches the north or lower end of Lake St. Francis. Here the lower part of these slates occupies from one half to three quarters of a mile, between the water's edge and the magnesian and epidotic rocks of the Quebec group, and stretches away to the east corner of the Augmentation of Ham. Higher beds occupy both sides of Lake St. Francis, farther up; first becoming interstratified with occasional layers of an argillaceous sandstone, and then assuming a slightly calcareous character. A few beds, more arenaceous than others, contain a considerable proportion of carbonate of lime. Lake St. Francis.

Ten miles up the lake, two opposite points project, and form the Narrows. That on the right side, consists of very quartzose talcoid slates, showing a breadth of about 300 yards. These are immediately succeeded, to the southward, by two or three layers of fossiliferous limestone, in which the species, chiefly corals, are rendered too obscure by crystallization, to be identified. These fossiliferous beds, whose total breadth does not exceed ten feet, dip N. 28° W. $< 84°$, very probably showing an inversion of the strata, and are followed by a light grey thin bedded limestone, weathering to a yellowish red. Beyond these, occur coarser and more arenaceous limestones, mixed with micaceo-calcareous sandstones. These latter become interstratified with other sandstones, which contain little or no carbonate of lime, clay slates often separating the beds. Limestones.

The fossiliferous limestones just mentioned, are not much out of the position which the general strike would give to a continuation of the fossiliferous strata of the Famine. Ten miles farther in the same direction, towards the south-west, limestones of a similar aspect, though not fossiliferous, occur two and a quarter miles south of Lake Aylmer, on the forty-fifth lot of the road through Stratford. The interval between this lime- Lake Aylmer.

Quebec group.

stone and the margin of the lake, is occupied by strata resembling some of those belonging to the Quebec group; consisting of green chloritic slates and sandstones, with a serpentine-like rock on the thirty-ninth lot, and nacreous slates nearer the lake; besides a band of dolomite about twenty-five yards wide, on the twenty-eighth lot.

Ward's Bay.

On Lake Aylmer, beds of limestone, supposed to belong to the higher rocks, are seen at the upper point, separating Ward's Bay from the body of the lake. Within the bay, there is a small point composed of hard sandstones and very coarse conglomerate beds: some of the rounded masses in which are a foot in diameter, most of them being very feldspathic, and apparently of intrusive rocks. These sandstones and conglomerates, interstratified with hard fine green slates, dip S. 38° E. $<$ 80°. They have a breadth of about 110 yards, and are followed to the northward by 140 yards of the same green slates, without sandstones. These strata may belong to the Quebec group; but clay slates, supposed to be of the upper series, succeed, and have a transverse breadth of four miles and a half, to Lake Coulombe, on the road to Wolfestown, near the east corner of the Augmentation of Ham; where they reach a band of calcareous serpentine, which has been previously mentioned. The bed of the St. Francis River, between Lakes Aylmer and St. Francis, consists of clay slates, often holding flattened nodules of grey yellow-weathering limestone.

Intrusive granite.

About seven miles up Lake St. Francis, a little way above the mouth of the Blueberry River, an intrusive mass of granite, composed of white quartz and feldspar, with black or brown mica, forms opposite points, nearly east and west of one another. The breadth of the granite appears to be about 400 yards; and where the strata come in contact with it, on the north side, the effect of the igneous rock on them is plainly discernible, in the presence of an abundance of small crystals of a dark colored mica, and

Andalusite slates.

of reddish translucent andalusite, in the argillaceous beds. The sandstones appear as a dark grey quartzite, with disseminated grains of pyrites. On the worn surfaces of loose fragments of slate, found in several parts around the lake, are seen slender raised forms, which are due to the presence of imperfect crystals of andalusite.

The same intrusive granite occurs in two small hills on the Felton River, which falls into Lake St. Francis on the left side; one of them about half a mile, and the other three miles, from its mouth. It also occurs in a hill upwards of three miles long, in Winslow, about five miles to the south-east of Lake Aylmer, and in another hill about a mile to the south-east of Lake Louisa. It is very probable that most of the abrupt isolated eminences of the district, are composed of the same rock.

Between Lake St. Francis and Lake Megantic, the few exposures of stratified rock which have been observed, are composed of clay slates and sandstones, such as have been just described; but on the western side, and at the southern end of Lake Megantic, chloritic and epidotic rocks, with nacreous slates and quartzite, again make their appearance, and probably belong to the Quebec group. A granite dyke intersects these strata, about a mile and a half from the upper end of Lake Megantic; and in the region between this lake and the river St. Francis, there are intrusive mountain masses of granite, which very probably produce considerable disturbances in the stratification. The largest mass constitutes the Great Megantic Mountain, at the united corners of Hampden, Marston, and Ditton. This, with a length of six miles, and a maximum breadth of three, may cover an area of twelve square miles. It has not yet been visited by any of the officers of the Survey; but we have been assured by a competent person, that the rock is of the same lithological character as the intrusions farther west. Another large granitic mass occurs in the Little Megantic Mountain, which may cover an area of six square miles, not more than one to two miles to the south-west of the line between Aylmer and Grayhurst townships. The bold and pointed form of Gosford Mountain, at the head of the Arnold River, flowing in at the upper extremity of Lake Megantic, makes it probable that it, also, is composed of this rock. Granite appears on the Kennebec road, a short distance south of the boundary line of the state of Maine. It there rises into bold mountains on each side of the road; and it will probably be found to form the range of elevations described as running thence, north-eastwardly, to Bathurst, on the Bay of Chaleurs. Lake Megantic. Megantic Mountain. Granite hills.

The base of the clay slates, at the east corner of the Augmentation of Ham, is five miles north-westward from the limestone which forms the upper horn of Ward's Bay in Lake Aylmer: but in tracing the outcrops of the two, to the south-westward, the distance between them gradually diminishes, and, after crossing Weedon, they are scarcely more than a mile apart, on the line between that township and Dudswell. On the Gosford road, in Dudswell, the clay slates become concealed, and the limestones rest upon the altered strata of the Quebec group, which form the Stoke Mountain range. With the exception of a few points, where the clay slates appear along the southern flank of this range, the limestones are seen in contact with the rocks of this group, all the way to the eastern shore of Lake Memphramagog, a little north of the province line; where they both cross the lake, and are continued southward into the state of Vermont. Clay slates. Dudswell.

In this part of their distribution, from Dudswell to the province line, these upper strata become of much more importance than before. They occupy a breadth of about fifteen or sixteen miles, and consist of crystalline micaceous limestones, interstratified with fine and coarse mica slates. The limestones are much more abundant in the first three miles of the breadth than in the remainder; and in this portion they are usually of a Fossiliferous limestones.

dark grey color, and often of a dull earthy black. These black beds are frequently separated by thin black brittle calcareous carbonaceous slates, which have a silky lustre in fresh fractures, resulting probably from the presence of very fine scales of graphite. The black limestones weather to a deep brown, and the slates to a brownish-black; and it often happens that a thickness of from six to twelve inches, at the surface, is found in a friable, disintegrating state.

The light grey limestones, which are of a rather more durable character, sometimes exhibit 300 feet of vertical thickness, in a single exposure. The color of the rock, from light grey, becomes, in some layers, of a uniform yellowish-white or cream color. The beds of this color seem to be more compact than other portions of the rock, and some of them will probably yield excellent marble. Both these beds, and others near them, of a mottled dark and light grey, are penetrated by a multitude of reticulating veins of yellow dolomite. On the surface of cut slabs, portions of the grey limestone occasionally approach to black. If any of these beds should be found to give a more uniform and darker grey, or a black, they would yield a marble approaching in character to the celebrated Portor, or black and gold marble. In this, also, the black ground is a pure limestone, while the yellow reticulating veins are of dolomite.

Marbles.

In some parts, considerable masses of the limestone are striped with grey and white, running in the strike; and the rock appears to be fissile in the direction of the colors, from the presence of mica between the layers. The light colored varieties are not so easily discolored or disintegrated by the influence of the weather, as the brown-weathering black limestones. The latter usually hold a considerable quantity of iron pyrites, disseminated in isolated cubes of various sizes, up to half an inch; which are often thinly encased in white quartz.

The upper end of Massawippi Lake affords examples of the black limestones; while the vicinity of the bridge over the Burrows River, on the Stanstead and Sherbrooke road, displays the grey variety. The striped limestones are seen at Magoon's Point, on Lake Memphramagog; and the white and mottled varieties occur at Dudswell.

Magoon's Point.

In the latter two localities, organic remains are met with. At Magoon's Point, they consist of encrinites, which are plainly visible in relief, on weathered surfaces of the rock, and are also perceptible in fresh fractures, notwithstanding the metamorphic condition of the rock; which is crystalline and finely granular, with mica running, as already stated, in parallel planes. The sections of the encrinal stems appear as oval rings, with smooth surfaces, resulting from a cleavage oblique to the axis. These rings are surrounded by the finely granular limestone, and show a spot of the same in the centre.

At Dudswell, in addition to encrinal columns and disks, there is a great abundance of corals; which occur chiefly in the light grey beds, and are readily distinguished by their whiter color. The whole rock is highly crystalline; but the corals appear more evenly and finely grained than the enveloping matrix, and are free from mica. Their structure is often plainly discernible on the weathered surfaces, where deeply-worn lines mark the divisions of the cells, columns, and concentric layers. Some of the species appear to be *Favosites Gothlandica*, *F. cervicornis*, *F. polymorpha*, *Halysites catenulatus*, *Heliolites Murchisonia*, *Syringopora compacta*, a *Diphyphyllum* like *D. arundinaceum*, undetermined species of *Zaphrentis* and *Heliophyllum*, *Stromatopora concentrica*, and an undetermined *Platyostoma*. Dudswell.

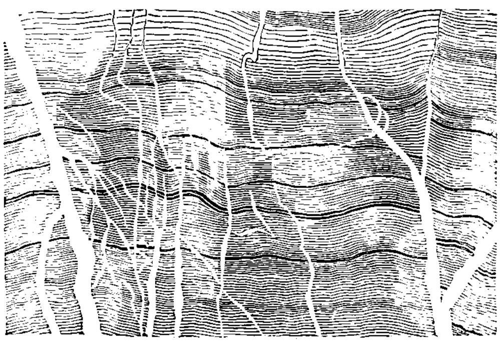
The mica slates, which are interstratified with the calcareous portions of the formation, are usually of a soft and fine texture, resembling clay slates, with the addition of mica. In the following seventeen miles of the section, as seen on the Coaticook road, across Compton, Barford, and Hereford, the calcareous beds diminish in frequency, while the mica slates become stronger and more quartzose, and finally form very thick bands. The usual color of these beds is grey, the limestones sometimes very dark grey, and often silicious. They almost all weather brown, and usually exhibit a thick disintegrated coating; while their ruins constitute a considerable portion of the soil. Among the fine mica slates, a few black beds with waved surfaces, are sometimes met with, displaying small crystals of chiastolite in cross fractures. The whole formation is very pyritiferous; isolated cubes of sulphuret of iron being often thickly disseminated throughout all the beds. There is but little doubt that these strata are much affected, both by large undulations and by minute corrugations; but in the majority of cases, the dips are towards the north-west, and usually at high angles. By one of these undulations, the serpentine of the Quebec group is brought to the surface, on the fourteenth lot of the eighth range of Eaton, the property of Mr. Farnsworth; where, as usual, it holds traces of chromium and of nickel. Mica slates.

The most south-eastern bed of limestone observed, is on the sixth lot of the eighth range of Barford. In the remainder of the distance to Canaan in Vermont, which may be of about twelve miles, mica slates prevail, in alternating black and grey bands, the black holding more mica, the grey more quartz. Bands of light grey or whitish quartzite, weathering to an ochre yellow, are interstratified with the slates, and, about three miles forward on the road, constitute the ridge of a hill. In the immediate vicinity of Canaan, some of the strata exhibit a large amount of crystallized black hornblende, with small imbedded garnets. Cubes of iron pyrites are met with in all the beds. The prevailing dip appears to be to the north-west, though there are probably many undu- Hornblende and garnets.

lations. This part of the formation gives a bold, rugged country, and appears to constitute the range of hills, which furnish the main sources of the Connecticut and St. Francis rivers.

Intrusive granite. The strata in the region between the Massawippi River and Canaan, are, in many parts, pierced by considerable masses of a beautiful granite, which consists of white quartz and feldspar, with a rather sparing amount of black mica very uniformly mixed. It is precisely similar to the granites of lakes St. Francis and Megantic, and the intrusive nature of the masses is clearly shown by the granite dykes which proceed from them in various directions. Stanstead. One of the largest masses of this region, measuring about six square miles, occurs between Stanstead Plain and Lake Memphramagog,

432.—GRANITE DYKES, CUTTING DEVONIAN LIMESTONES, AT STANSTEAD.



Dip of the strata, N. N. E. < 30°. Scale, about $\frac{1}{300}$.

occupying from the first to the sixth lot of the fourth, fifth, and sixth ranges of the township. It appears to displace the calcareous strata, which it penetrates, as these are observed to dip from it in several places. On the fifth lot of the fifth range, on the east side of the road, within a short distance of the edge of the granitic nucleus, a great number of dykes of the granite are seen, cutting the basset edges of the limestone beds; the whole having been worn down to a horizontal surface. Some of the main dykes are from two to three feet in breadth, and divide into a multitude of irregular and reticulating branches, many of which are no more than the eighth of an inch wide. In the face of an escarpment, which rises from the granite nucleus to this horizontal surface, a large dyke, of which all the others are probably ramifications, can be traced down towards its source.

Intrusive masses of the same description of granite are met with on the south side of Barnston and Barford, and farther north in Hereford, in six different localities; in addition to several dykes of a few feet in width, which are traceable for short distances. In the immediate vicinity of Stanstead Plain, there is a granite dyke of from seventy to a hundred feet in breadth; which has been traced for a distance of nearly four miles, from the fourth lot of the ninth range, to the north side of the thirteenth lot of the eleventh range of the township. It appears to cut the stratification in the direction of the strike, which runs north or a little east of north; and it is traversed and broken by transverse faults in two places, in each of which it is heaved to the eastward, on the north side, upwards of 600 yards. The direction of these important dislocations seems to bear for the vicinity of Owl's Head Mountain; and they serve, in conjunction with the intrusive granite masses and dykes, together with the tilted and occasionally inverted attitude, and the contorted condition of the strata, to illustrate the violent disturbances which the rocks of this region have suffered at different epochs.

The Stoke Mountain range, as we have already described it (page 252), is a narrow belt of rocks of the Quebec group; which crosses the southern part of Lake Memphramagog, and extends north-eastwardly, through Stoke, to Weedon. The upper slates and limestones are traced along its south-eastern base, and around its northern extremity, into another synclinal area, which is occupied by the same higher strata. This area is of a narrow and irregular form, with a length of sixty miles, extending from the Owl's Head Mountain, on Lake Memphramagog, to Ham Mountain; and with a breadth of from five to fifteen miles, between the Stoke Mountains and the Shipton Pinnacle ridge. In the south-western extremity of the area, there are two narrow belts of grey fossiliferous limestone, interstratified with clay slates; the space between them being occupied by dark grey clay slates, with several bands of a yellow-weathering rock, which is probably magnesian. The belts run in the longer direction of the area, the western one being about three quarters of a mile, and the eastern about a mile and a half wide. To the south-west, they are united or nearly so, beneath the waters of the lake; while in the opposite direction, they diverge a little, the least measure across them both being two miles, and the greatest, including the intermediate space, four miles and a quarter. The eastern belt is somewhat longer than the western, as the latter does not reach the Granby and Outlet road, while the former crosses it; the distance to this road from the Owl's Head being about sixteen miles. The eastern belt underlies the northern half of the lake, while the western passes to the west of it, crossing only the western bay, near Potton Ferry.

Stoke Mountains.

Western synclinal.

Fossiliferous limestones.

There is little doubt that these two belts of limestone, which contain the same fossils, are equivalent rocks; and they are supposed to be in the form of two distinct long parallel-sided troughs. The dips of the strata, however, do not assist in making out the structure; for while the beds on both sides of the western trough, are as nearly as possible vertical, those of the eastern, dip to the southward at a high angle. These dips might induce the supposition that the two belts of limestone are arranged in the form of a single trough; but in that case the belts should come to a junction to the northward, which they do not. The fossils common to these belts are *Favosites Gothlandica*, *F. basaltica*, *F. polymorpha*, *Syringopora Hisingeri*, with undetermined species of *Zaphrentis* and *Heliophyllum*, a *Diphyphyllum* like *D. arundinaceum*, crinoidal columns, and *Stromatopora concentrica*. The schistose plumbaginous limestones, at the Owl's Head, abound in obscure fossils, among which a species of *Zaphrentis* may be recognized.

Clay slates. Grey clay slates, banded with black, both with glossy surfaces, flank these limestones on each side. On the west side of the western belt, their breadth is pretty uniform, being probably from a quarter to half a mile; but on the east side of the eastern belt, beginning near Lake Memphramagog, close upon the edge of the limestone, the breadth occupied by them, gradually increases to the north-east, and, opposite the outlet, may be about five miles. Beyond the termination of the limestones, these slates appear to have a breadth of about ten miles; reaching from the Sherbrooke and Montreal road in the fourteenth range of Orford, to the Sherbrooke and Massawippi road in the fifth range of Hatley. Farther to the north-eastward, their distribution is affected by two undulations, which bring the strata of the Quebec group to the surface, on their anticlinals, in the neighborhood of Sherbrooke. On the St. Francis, these slates occupy nearly the whole front of Brompton, and include the rocks of Brompton Falls; where they are nearly flat, and where the distinction between cleavage and bedding is well marked. They underlie the Windsor River and all its tributaries; and in the upper part of this river, in Stoke, there rests upon them a third synclinal portion of fossiliferous limestone; in which, however, the species are rather obscure. This limestone appears to occupy part of the eleventh, twelfth, and thirteenth lots, of the eighth and three sequent ranges; where it is about a mile and a half removed from the north-western flank of the Stoke Mountains.

Brompton.

The fossils from the limestones of the western area, are, like those of the Famine, Devonian; and the species from the extension of the eastern area on Lake Memphramagog, in Vermont, are of the same age. Those of Dudswell are so altered by crystallization, that some little doubt attaches to the determination of their species. Most of them, however, appear to be Devonian; but *Halysites catenulatus* and *Syringopora compacta*, which are supposed to be found there, have not been hitherto recognized higher than the Lower Helderberg group. These facts seem to indicate that a portion of these fossiliferous strata may belong to the summit of the Gaspé limestones, or perhaps represent the base of the Gaspé sandstones. Nothing, however, having the lithological characters of these sandstones, as they appear at the eastern extremity of the province, has been seen in Lower Canada to the west of the Matapedia River. There is not much doubt that the clay slates which underlie the limestones represent some part of the Gaspé limestones, though the want of fossils makes it, for the present, difficult to say which part. The lower portion of the Gaspé series, to the westward, gradually becomes less calcareous and more argillaceous; and to the west of Temiscouata Lake, no considerable mass of it can be recognized as a limestone.

These upper clay slates, on the Chaudière and the St. Francis, are intersected, in several places, by white quartz veins, generally running with the strike. Some of these, on the Chaudière, hold a little blende and argentiferous galena, with small portions of native gold; but they are not yet with certainty known to be the source of the drift gold of the Eastern townships. The heaviest masses of gold that have there been met with, weighing from ten to a hundred and twenty-six pennyweights, have been found resting on this slate formation. One of these, in the Museum of the Geological Survey, weighing four ounces, has a considerable portion of quartz adhering to it, and penetrating it; so that there is little doubt that gold-bearing quartz veins exist in the region, but whether they belong to the Lower or the Upper Silurian series, or to both, has yet to be determined. Gold veins.

The micaceous slates and quartzites of the third and fourth lots of the sixth range of Barford, are cut by several quartz veins nearly transverse to the stratification. One of these, which is three or four feet wide, contains dendritic native copper, and yellow sulphuret of copper, associated with magnetic pyrites, white or pale green apatite, and crystals of silvery white mica. Copper lodes.

COAST SECTION FROM GASPÉ BAY TO THE BAY OF CHALEURS.

The strata of the Bonaventure formation, between Yellow Head and Point Peter, have a general dip to the south-eastward. They strike across the land, forming the south horn of Gaspé Bay, and run along the coast, all the way to Tickel Inlet. From this inlet to Beach Corner, they are covered up, for about five miles, by the barrier of sand and gravel, which separates the lagoon at the mouth of Malbay River, from Malbay itself. One hundred and seventy yards beyond the brook at Beach Corner, the strata of the formation again make their appearance; not however with the moderate southern dip of the inlet, but bent up to a high angle, with a northern dip, and occasionally presenting a perpendicular face. One of the conglomerate beds shields the cliff for some distance; but pursuing the strike, transverse openings, and the channels of one or two brooks, show Gaspé Bay.

red shales, fine grained sandstones, and other conglomerate layers beneath it; and on reaching a gap called the Little Blow-hole, a mass of limestone, belonging to an older series, makes its appearance. This however becomes again covered up, farther on, by conglomerate beds, which are nearly vertical at the base, but present a curved face, diminishing in slope at the top. By these, the lower rocks are concealed, until near the Great Blow-hole; where they are once more exposed, and run out in vertical or highly inclined strata, into Les Murailles and Barry Cape. This cape is the extremity of a sharp narrow ridge of mottled reddish and yellowish limestone, standing between the bay and Barry Brook. The highest point of the ridge, called the Peak, is 660 feet above the water, and is crowned with the conglomerate; which lies in a horizontal attitude upon the edges of the unconformable beds beneath.

Barry Cape.

Split Rock of Percé.

The pierced or Split Rock, from which the village of Percé takes its name, is an isolated, almost inaccessible mass of the same mottled yellowish and reddish limestone, which stands like a wall, in continuation of Barry Cape. It overhangs the perpendicular, ten degrees north-eastwardly, with a length of 1500 feet, a breadth of 300, and a height of 290 feet; and presents two arched openings, which have been pierced through it by the action of the waves. Mount Joli and Battery Point are parallel strata, consisting of grey thin bedded limestones and calcareous shales, whose strike eastward would carry them south of the pierced rock. It is plain from their strike in the opposite direction, that they run under the Percé Mountains; the whole of the summits of which, are composed of the Bonaventure conglomerate.

Percé Mountains.

The flat top of the pierced rock, and that of Les Murailles, extending to the cone of that portion of them termed the Peak, are probably portions of the ancient surface, on a continuation of which the conglomerate is based. The height of this surface being about 300 feet above the sea level, while that of the most elevated summit of the Percé Mountains is 1230 feet, according to Bayfield's chart; it would appear that a vertical thickness of not less than 900 feet of the conglomerate is present in these mountains. Lofty perpendicular precipices of it are seen on several sides of the Table Roulante, and of Mount St. Anne, and its base may be traced along the eastern flank of the latter, descending as it proceeds southward; though where it probably reaches the shore, at Robin's Brook, about three fifths of a mile from Mount Joli, it is concealed from view by the gravel of the beach. Percé Reef, however, is composed of this rock, and probably marks the direction of its submarine connection with Bonaventure Island, which is wholly formed of the conglomerate. Here its massive beds rise up, at a moderate inclination to the north-east side; where they form vertical cliffs of several hundred feet in height, which give shelter to myriads of gannets,

Bonaventure Island.

cormorants, gulls, and other sea fowl. It is from this island that the name of the Bonaventure formation is derived.

Proceeding southward along the main shore, from Robin's Brook, the base of the Bonaventure formation again makes its appearance near Lafestie's Brook, upwards of a mile from Mount Joli. Here it gradually rises up, at an angle increasing from two to seven degrees, and once more exposes lower unconformable strata in White Head; which is composed of a limestone fit for burning, tilted up at an angle of seventy degrees. The two formations are seen in juxtaposition for between 500 and 600 yards; the lowest member of the upper formation being a ten-feet bed of whitish-grey hard calcareous rock, greenish at the bottom, with many small veins of red and white chert. White Head.

In the White Head limestones there are a few fossils: the limestones of the pierced rock and of Barry Cape abound with them, though the species do not appear to be numerous. Among them, in addition to fucoids, are *Strophomena perplana*, two undescribed species of *Chonetes*, different from those of Cape Gaspé, *Leptocælia concava*, *L. flabellites*, *Rensselaeria ovoides*, two undetermined species of *Spirifera*, *S. arenosa*, undetermined species of *Athyris*, *Platyostoma* and *Platyceras*, *Dalmanites pleuroptyx*, and an undetermined *Phacops*. Among the species of Mount Joli are *Favosites Gothlandica*, *F. basaltica*, *F. cervicornis*, with an undetermined *Zaphrentis*, and fragments of a *Rhynchonella*. These older rocks, which all present high angles of inclination, are affected by undulations, and broken by transverse faults, and their precise relation to one another has not been finally determined. The strata at Battery Point and Mount Joli have a breadth of about 500 yards. After a small interval of concealment, those of the pierced rock, Barry's Cape, and Les Murailles, follow, with a breadth of about 400 yards. These appear to be succeeded to the northward, by yellowish-white fine grained calcareous sandstones, which may have a transverse measure of 120 yards. The only fossil found in these strata is a worm-track, very much resembling that of the Gaspé sandstones near Tar Point. There comes in contact with them, on the north side, a band of greenish-black soft argillaceous fossiliferous shale, in which were observed the following genera: *Chonetes*, *Nucula*, *Pleurotomaria*, *Bellerophon*, *Acidaspis*, and *Ampyx*, with the pygydia of two other trilobites, and *Serpulites*. A thin bed of limestone, near the black shale, contains *Halysites catenulatus*. The geographical sequence of these rocks, from south to north, in connection with their fossils, would appear to bring them into comparison with the Gaspé limestones, and the lower part of the Gaspé sandstones; and to place them, with the exception of the black shales, on the horizon of the Lower Helderberg and Oriskany formations. The shales can scarcely be higher, and may be lower than the Niagara formation; in which case there must exist in these older rocks, on the south side of Fossiliferous limestones. Age of the strata.

Malbay, a considerable longitudinal dislocation, which, with all the undulations and transverse faults that have been mentioned, is covered over by the Bonaventure rocks. The white sandstones would afford a beautiful material for building purposes. In one of the numerous veins of calcspar, with which the mural precipices of the reddish and yellowish limestones are traversed, there are traces of galena; the occurrence of which still farther assimilates these rocks to the series on the north side of Gaspé Bay.

Fault.

Continuing to trace out the geographical distribution of the rocks, along the coast; a dislocation occurs, about 500 yards westward of White Head, letting down the edge of the Bonaventure rocks against the fossiliferous limestones. These are here seen in a transverse section, with a dip S. 7° E. < 58°; showing the direction of the fault to be S. 67° W. The upper rocks, consisting chiefly of red sandstone, with only a few conglomerate layers, slope in towards the limestones, maintaining an eastern dip for about a mile. They begin with an inclination of twenty degrees, but gradually diminish to four, and at length become horizontal on the crown of a flat arch. This causes a repetition of some of the beds in ascending order, farther on, and brings the general strike of the measures to coincide pretty nearly with the coast, as far as Beaufils Bay, with a gentle slope to the south-eastward.

FAULTS IN THE BONAVENTURE SANDSTONES.

Bearing and inclination of the undertie.

Number.	Bearing.	Inclination.	Downthrow.	Upthrow.	Number.	Bearing.	Inclination.	Downthrow.	Upthrow.
1	227°	80°	7	..	13	187°	65°	8	..
2	202°	58°	90	..	14	187°	65°	100+	..
3	352°	65°	6	..	15	235°	90°	1	..
4	177°	68°	6	..	16	352°	83°	30	..
5	172°	61°	8	..	17	?	?	..	30
6	187°	56°	1	..	18	192°	75°	12	..
7	187°	65°	2	..	19	7°	75°	30	..
8	2°	75°	..	1	20	187°	75°	..	50+
9	187°	65°	7	..	21	187°	60°	30	..
10	187°	65°	4	..	22	177°	70°	5	..
11	197°	65°	2	..	23	352°	75°	10	..
12	192°	65°	1	..	24	352°	65°	5	..

The red sandstones between White Head and Beaufils Bay, are exposed for nearly four miles, in a cliff. This varies from twenty to one hundred feet in height, and displays in that distance, not less than twenty-four dislocations; the extent of nearly the whole of which, may be seen in the cliff. On the preceding page is a list of them, with the bearing and inclination of the underlie of each, so far as it could be determined by the evidences on the beach, and in the cliff; together with the number of feet of upthrow or downthrow, proceeding westwardly along the coast. The bearings are given in degrees, numbering eastwardly from north as zero. The underlie of one of the faults, 17, could not be ascertained. Dislocations.

After an interval of about three quarters of a mile, covered over by the sandy beach of Beaufils, or Upper Cape Cove village, another mile and a half of red sandstone cliffs occurs, presenting a second flat arch, with a sweep in the strike, keeping it with the trend of the coast; which has more of southing in it. Here, eleven dislocations, of a similar character with the preceding, occur. Another interval of sandy beach, occupied by Lower Cape Cove village, brings us to Cape d'Espoir, where 110 feet, composed chiefly of conglomerate beds, with a dip S. 17° E. $< 4°$, are presented in a vertical cliff. The coast continues on the strike of these, for nearly three miles, to Little River; where lower unconformable strata once more break through. Cape d'Espoir.

These lower rocks consist of hard arenaceous limestones, in beds of from one to ten inches thick, separated by layers of fine bluish-grey argillaceous and slightly calcareous slate, dipping N. N. W. $< 73°$. These, after appearing at intervals, for half a mile, at the base of the conglomerates, and in contact with them, again become hidden for three quarters of a mile, in which the conglomerates alone occupy the cliff. A layer of trap becomes intercalated with these beds, at a spot called Les Roches Noires. Its thickness is from ten to fifteen feet, and, occupying the upper part of the precipice, which varies from sixty to a hundred feet in height, it maintains a constant position for about a mile. In the latter part of this distance, the lower strata, in a disturbed attitude, are again seen underlying the conglomerates. The three rocks are visible at once in the cliff section. This is composed of ten feet of conglomerate at the top, succeeded below by the same thickness of trap, and by thirty feet of conglomerate; which are underlaid by ten feet of the inclined calcareous strata. Interstratified trap.

In the interval between this and the Grand River, the cliff is divided between the horizontal conglomerate, and the tilted strata beneath it, each occupying about one half of the height. Ravines, occupied by brooks, however, cut the cliff down to the base of the conglomerate. Approaching the Grand River, after a distance occupied by the conglomerate, in a low cliff, there is a space covered with sand and gravel. Another bed of trap, perhaps a continuation of the previous layer, paves the beach at the Grand River.

extremity of Green Point, and the conglomerate coming from below it, crops out and forms a narrow flat strip on each side of the mouth of the river.

It is probable that in the whole distance from Little River, the conglomerate beds, which have a gentle dip to the south, have but little breadth, and are nothing more than portions of the rim of the formation, saved from the wearing action of the sea, which has carried off the other parts, by the presence of the harder tilted strata at high water mark. It may be seen that wherever the flat conglomerate alone occupies the cliff, the waves, dashing against its base, wear deep horizontal caverns beneath. Great portions being thus deprived of support, are cracked off vertically, and fall in huge fragments, forming a temporary talus; which it is probable the ice of winter, with other causes, may aid in removing.

With the exception of the narrow strip at the mouth of the stream, none of the conglomerate is seen on the Grand River, for six miles up. Its banks are composed of dark grey slates, with a cleavage independent of the bedding, associated with dark grey limestones and occasional arenaceous layers. The age of these strata, for want of fossils, has not been determined. The coast line westward, however, with the exception of those parts covered by sand, and particularly of the barrier to the lagoon of Little Pabos, is wholly occupied by the conglomerate; which is displayed in cliffs, varying from ten to forty feet, and not exceeding sixty feet in height. They belong to a narrow belt of the deposit, which is continuous, until reaching a brook about a mile and a quarter eastward of Grand Pabos beach, 400 yards beyond which it terminates. Between this termination and the rock of Grand Pabos beach, there is only one thin small patch of the conglomerate, at the Pointe du Portage, extending about half a mile; where it is seen resting on the lower rocks, now changed in their characters from calcareous to arenaceous.

Grand Pabos.

From the rock of Grand Pabos lagoon, none of the upper formation occurs, with the exception of a small patch at a point called Jardin à Naveau, until attaining the south side of Point Maquereau. The interval along the coast is thirteen miles, and, as has already been stated in describing the distribution of the Quebec group, it is occupied by these lower rocks. The vertical strata of this group extend along the coast towards Anse à la Vieille, where they are overlaid by the inclined strata of the Gaspé limestones, which, in their turn, support the Bonaventure conglomerates; the three series being unconformable with each other.

Anse à la Vieille.

Discordance of three formations.

The proofs of this double discordance lie within a space of half a mile, a little less than two miles westward of the line between the counties of Gaspé and Bonaventure; and as there is no concealment of strata, the whole is readily apparent to the eye. The smoothly worn edges of the vertical strata of the Quebec group, here support an even layer of four feet of hard greyish-white strong silicious conglomerate, which divides into layers of a foot or two, and would make good millstones. It dips S. 4° W. < 38°, and is conformably overlaid by a great series of fossiliferous limestones and shales. At a point about 230 yards, along the beach, from the millstone layer, these calcareous strata dip S. 3° E. < 45°, in a cliff from 100 to 120 feet high. Upon the basset edges of these, the beds of the upper conglomerate are seen to repose, with a dip S. 42° E. < 20°. These stretch along for 200 yards, presenting a perpendicular precipice in front; while the underlying calcareous series forms a talus, and occupies sometimes more and sometimes less than one half of the height of the cliff.

The conglomerate is here of a deep red color, and holds many boulders, as well as pebbles of various kinds. Those of a red sandstone are the most numerous, and some of them may attain a weight of one hundred pounds, while others of a silicious conglomerate would not be less than seventy pounds. Pebbles of fossiliferous limestone, of ten pounds weight, were met with, and others of a compact limestone were equal to two hundred pounds, and, in one instance, to half a ton weight.

In the next ten miles along the shore, two small areas only of the Bonaventure formation are met with; but the underlying calcareous strata are conspicuously displayed in the coast cliff. The base of the series is the four feet of millstone conglomerate already described; and the section presents, in ascending order, the following rocks :— Port Daniel section.

	Feet.	Feet.	
1. Reddish-grey micaceo-arenaceous limestone, weathering to a dull ochre-yellow, interstratified with six bands of silicious conglomerate; (of which the four-feet millstone bed at the base, is one;) and abounding in fossils, ...	140		Silicious conglomerates.
2. Greenish calcareous shale, including a few beds of yellow-weathering limestone, with many nodules of the same, and holding many fossils, ...	200		Green shales.
There is here a break in the succession, occasioned by a fault, which creates an interval of great confusion. The cliff shows many of the details of the disturbance, but is not high enough to afford evidence of the amount of displacement. Judging however, by the different color of the strata on the west side, it appears probable that there is a downthrow to the west, which would cause no repetition, to exaggerate the apparent volume of the formation. On the west side of the dislocation, the following is the succession :—			
3. Grey hard limestone, in beds of from six inches to a foot, ...	50		Limestones and red shales.
4. Red micaceo-arenaceous shale, with very few fossils, ...	200		
5. Grey limestone shale, inclining to green, with many corals, ...	900		
6. Grey or greenish limestone, partly of a slaty character, and full of organic remains. It includes a band of yellowish-grey calcareous sandstone in the middle, equal to about half the amount, yielding excellent tilestones and flagstones, ...	150		
7. Greenish calcareous shale, with *Fucoides* like *F. cauda-galli*, ...	500	2140	

		Feet.	Feet.
	Among the organic remains of all the preceding beds, are the fucoid just mentioned, *Palæocyclas porpita*, *Heliolites interstincta*, *H. Murchisonia*, *H. inordinata*, *Favosites Gothlandica*, *F. Hisingeri*, *Stenopora pulchella*, *Halysites catenulatus*, an undetermined species of *Syringopora*, two species of *Cyathophyllum*, and two of *Zaphrentis*, two of *Diphyphyllum*, and one of *Cystiphyllum*, *Stromatopora concentrica*, an undetermined species of *Strophomena*, *S. rhomboidalis*, *Orthis elegantula*, *O. Davidsoni*, *Rhynchonella neglecta*, *R. cuneata*, *R. nodostriata*, *Stricklandia Gaspensis*, *Pentamerus Knightii ? Athyris intermedia*, and *Euomphalus rugosus*.		
Red shales.	8. Light red shale with green streaks and spots, ...	500	
Grey limestones.	9. Grey limestones, in beds of from six to eight inches, with fossils. Among the species are *Heliolites interstincta*, *H. Murchisonia*, *H. inordinata*, *Favosites Gothlandica*, *Halysites catenulatus*, undetermined species of *Diphyphyllum* and *Fenestella*, *Stromatopora concentrica*, *Strophomena funiculata*, with a new species of the last genus, and one of *Orthis*, *Spirifera crispata*, and an undetermined *Illænus*,................	200	
	10. Light grey compact limestone, indistinctly bedded, and filled with corals, broken encrinites, and other fossils. Here and there, a portion of red arenaceous limestone runs for a short distance in the supposed direction of the strata; which are interrupted by shapeless lumps of compact limestone. The red layers contain white broken encrinal columns, and are pierced by white cylindrical corals. Among the fossils are *Favosites Gothlandica*, two undetermined species of *Strophomena*, with *S. rhomboidalis*, *S. funiculata*, two undetermined species of *Rhynchonella*, with *R. Stricklandi*, *R. Wilsoni*, *R. cuneata*, an undetermined species of *Spirifera*, *S. crispata*, *S. radiata*, three undetermined species of *Athyris*, *Atrypa reticularis*, three undetermined species of *Pleurotomaria*, and one of *Orthoceras*, *Bronteus Canadensis*, *Lichas Canadensis*, with undetermined species of *Acidaspis* and *Chierurus*, ...	500	1200
			3340

Anticosti group.

The fossils of this series would appear to place it at the summit of the Anticosti group, about the horizon of the Niagara formation. We may expect in future explorations of the interior of Gaspé to find this series, in some part of its distribution, between the equivalents of the white sandstones of the Chatte, with their immediately succeeding limestones, and the calcareous strata of Cape Gaspé.

Between Cape Maquereau and Port Daniel, the lower members of the section, to the sixth division inclusive, form the eastern part of Anse à la Vieille, up to the brook. The seventh and eighth constitute the remainder of the cove, and also Anse au Gascon; while the ninth, and about seventy feet of the tenth or upper division, compose Pointe aux Bouleaux, which separates these two coves. The Gros Morbe, between Anse au Gascon and Anse à la Barbe, displays the whole thickness of the two higher members.

These two also constitute the coast, nearly the whole way to Port Daniel, by Harrington Cove. The two conspicuous points on the east side of Port Daniel Bay, of which the northern one is called the Devil's Cape, exhibit the uppermost limestone in a nearly vertical attitude, with its encrinal character well marked; and it is again seen on the front of Mr. Carter's land, between the great and little lagoons. Following up the West River, it is found to cross it several times, first with a south-west, and then with a north-west dip. Though it does not again occur in the five miles of this stream which have been examined, there is not much doubt that it will be found higher up, with a final southward dipping outcrop. Port Daniel Bay.

Following round Port Daniel Bay, from the exit of the little lagoon, the strata are covered over by sand and gravel for upwards of a mile; beyond which, the green calcareous shales, 7, are seen dipping northwardly, then southwardly, and finally resting upon the red shales, 8. The upper limestones are again displayed in South-West Point, and from this, run along the coast, for two miles, to the neighborbood of Indian Point; where they are once more concealed, at the water-line, by the overlying unconformable red sandstone and conglomerate.

The base of this calcareous series, in the vicinity of Port Daniel, is probably near to the junction of the Middle River with the great lagoon. From beneath these strata, higher up on the stream, beds of black bituminous graptolitic shales come to the surface, and are seen, at intervals, for several miles. The position of these shales is between the calcareous series, and the strata of the Quebec group, at Cape Maquereau. Their absence in the coast section is explained by the unconformability of the overlying formation; while their relations to the rocks above and below, would assimilate them to the black shales which underlie the Gaspé limestones near Cape Rosier, and which are supposed to be near the base of the Quebec group. Graptolitic shales.

Some portions of these black shales hold hydrocarbonaceous matters in sufficient quantity to burn with flame, when subjected to heat. This property, in connection with their color, has in this, as in other instances, led persons to suppose these shales to be indications of the presence of workable coal seams. The structure of the neighborhood, however, places these strata at a much lower geological horizon than that of the coal formation, and renders the discovery of profitable coal seams in them, contrary to present geological experience.

The Port Daniel limestone is of an excellent description for burning, and is well fitted for mortar or for agricultural purposes. Very beautiful flag and tile stones might be obtained from some calcareo-arenaceous strata, which occur a little westward of the brook, in Anse à la Vieille, and split readily into large and very even plates of almost any required thickness from a quarter of an inch to three or four inches, from the presence of a small quantity of mica in the divisional planes. The bed of silicious conglomerate at the base of the limestone series, as well as others of similar character, and of greater amount, on the West River, would yield good millstones.

Bonaventure formation.

Returning to the unconformable Bonaventure formation, there are between Anse à la Vieille and Indian Point, two localities where portions of the conglomerate rest upon the limestones. One of these is in Harrington Cove, where a breadth about forty yards of it is seen, and where its enclosed masses are angular, and are derived from the immediately underlying strata. The fragments are large, and one, which protrudes from the red sandstone matrix, cannot be much under eight tons in weight. The other portion occupies the banks of a small brook flowing into Port Daniel Bay, a little to the east of the great lagoon. From the mouth of the brook, it runs up the dingle, and crosses the road about a mile east of the sand beach. It is a strip, which occupies a valley in the surface where it was originally deposited, and has been protected from erosion by the defences of older rocks on each side of it.

New Carlisle.

From Indian Point, a great stretch of this formation, with only such concealment as arises from the sand beach of Nouvelle, and that of Paspebiac (to the landward of which there is a precipitous bank clearly marking the presence of the rock), carries us to New Carlisle. In this distance of twenty miles, its prevailing character is that of a red sandstone, with but few conglomerate layers. The rocks upon which it rests, are seen, at high-water mark, only in the first part, as far as Cape Loup Marin, and again at Mashigoweech.

Less than a mile and a half from the town-lot of New Carlisle, the older strata again appear, presenting at the same time a new feature in the coast section. Proceeding westward, the upper rocks, consisting chiefly of red sandstone, have a gentle dip, not exceeding one or two degrees, to the eastward; and repose upon the truncated extremities of a group of trap dykes, not much less than fifty in number, and from eighteen inches to twenty feet in breadth. These cut through the lower formation, which here consists of red calcareo-arenaceous shale, with a few thin bands of limestone. The intrusive rock is sometimes a greenstone porphyry, containing tabular crystals of greenish-white feldspar, which have their flat faces turned to the walls of the dyke towards each side, but are occasionally transverse to the dyke, in the middle. On reaching the town-lot, the overlying red sandstones cease, and crystalline rocks cover nearly the whole of the area. These appear to be of different characters in different parts: a ledge running N. N. E. and S. S. W., consists, in one part, of greenish-white feldspar, with black hornblende and a small quantity of black mica. In another part, to the south of this, the feldspar assumes, when weathered, a light flesh-red tint, and the rock is nearly made up of it. This is on the

Trap dykes.

Crystalline rocks.

thirty seventh lot, where it appears to hold a small vein of the specular oxyd of iron, which, from the decomposed condition of the rock, it was found impossible to trace to a distance; but it is said, that for a considerable distance around, lumps of micaceous iron ore are frequently turned up by the plough.

The breadth inland, of the Bonaventure rocks, in the neighborhood of New Carlisle and Paspebiac, is a little over two miles. They extend to the foot of a hill, composed of the upper Port Daniel limestones, which rises rather boldly to the height of about 300 feet, and runs in a direction to join the limestone on Mr. Carter's land. From New Carlisle to Red Cape, and a little beyond it, in the township of New Richmond, a distance of about twenty-three miles, the coast displays the upper red sandstones; with the exception of about five miles at the mouth of the Bonaventure or Wagamet River, where they are covered over by drift clay. They occur about five miles up the Bonaventure, and have probably a breadth of four miles in the township of Hamilton. Red Cape

At Capeling River, the Bonaventure formation is a conglomerate, with limestone pebbles, and the beds lie nearly flat; but at Red Cape they dip S. S. E. $< 20°$, and, about five furlongs farther, suddenly turning down to a dip S. 35° W. $< 55°$, they abut against a great mass of trap; which extends about a mile along the coast, and at its termination, constitutes Black Cape. The direction of the dislocation is N. 55° W., and, at the junction of the two rocks, the conglomerate contains boulders and great fragments of trap, in the usual matrix of red sandstone; together with large calcareous pebbles holding organic remains, which are like those of the upper limestones of Port Daniel. Black Cape.

In the coast section, this mass of trap, in its eastern part, is homogeneous in appearance, and has a uniform dark green color, with occasional red iron stains. On the western side, it forms a breccia, which is interstratified with several beds of reddish limestone, similar to the upper rocks of Port Daniel; forming together a cliff of about fifty feet, with a dip S. S. E. $< 46°-68°$. Much of the trap in this portion weathers of a rusty purple, but is of a dingy bottle-green within. It encloses large angular masses, which differ but little in color, but are harder than the matrix, and stand out in bold relief on the weathered surfaces; sometimes with smooth faces, resembling huge crystals. With these, are also found large angular amygdaloidal masses, holding carbonate of lime: these, also, sometimes weather in relief. Fragments of indurated red shale, and others of limestone, like that of the adjacent beds, are also common in this trappean breccia. The limestones retain their reddish-white color, and often exhibit corals and encrinites on their weathered surface, though these are not apparent in recent fractures. The limestone fragments are chiefly met with in the paste or matrix of the breccia; and though they occasionally Trap breccia.

occur in the amygdaloid, are entirely absent from the harder angular masses.

This lower part of the trap has much the aspect of having resulted from a flow of viscid matter, which had rolled over on its own crust, enclosing fragments of this, and of everything met with in its progress. Another portion seems to be arranged in beds, holding a collection of trap boulders, pebbles, and fragments enclosed in a trappean cement. All these characters accord with the relation which the trap bears to the strata to the west: and it may have been poured over them, at different times, when they were in a horizontal position. The thickness of this mass, including the interstratified beds of limestone, appears, from the data obtained on the coast, to be 650 feet.

The strata to the westward, along the bay, have the same general characters as those of the Port Daniel section. At the summit, there is a limestone like the upper divisions there, and another at the base, resembling that of Anse à la Vieille; while the intermediate strata, as a whole, are very similar to those of the last named locality, and of Anse au Gascon. The total thickness in this vicinity, as exposed in the two miles succeeding Black Cape, is more than three times that of the other, owing to the augmentation of the middle portion of the series.

Cascapedia Rivers.

This great exposure terminates just one mile east of the cove at the mouth of the Little Cascapedia River, where the limestones run inland, with a strike S. 5° E. The whole coast, from this to the mouth of the Great Cascapedia River, is occupied by drift clays, with their usual accompaniment of marine shells. On the west side of the Great Cascapedia, the Bonaventure conglomerates again make their appearance. They are seen in a conspicuous hill, in which the strata gradually rise from Indian Point, attaining an elevation of 378 feet; and they compose not only the hill, but the flat valley beyond. From Indian Point, their transverse stretch up the Great Cascapedia may be about four miles; at the end of which distance, they reach the base of the mountain slope running for the Peak of Tracadigash. Westward from the Great Cascapedia, they skirt Cascapedia Bay, up to the dividing line between the townships of Maria and Carleton; where they may have a breadth of a mile and upwards, though they are not seen on the coast; being covered, along the water-line from Indian Point, by the drift clays.

Mountain flank.

The mountain flank, which runs nearly parallel with the coast, from the Cascapedia towards the Restigouche, is a part of the southern boundary of the table-land which composes the general surface of the Gaspé peninsula. As far as the Peak of Tracadigash, it appears to run about southward, in the strike of the measures, and to be composed of a coarse silicious conglomerate, standing in a vertical attitude, and presenting several remarkable precipices. Between it, and the comparatively flat Bonaventure con-

Trap hills.

glomerates in front, there occur several isolated hills of trap, with conical summits, occasionally resting in part upon the mountain flank. The breadth occupied by these, indicates that the range of trap with which they are connected, is of some importance.

From the Peak of Tracadigash, the flank of the table-land changes its direction, still running parallel with the coast, a little to the north of west, and makes a partial section obliquely across the measures. These consist of dark colored slates, with several masses of trap, and finally a great calcareous formation; which seems to run inland, to the north of the silicious conglomerate. It is probable, however, that the strike of the strata and the mountain flank, again coincide, farther on; for at the foot of the latter, trap is found, associated with limestone beds, at the bridge, five miles up from the mouth of the Nouvelle River; and again, on the bridge over the Scaumenac, a mile from its mouth. Trap also appears at the junction of the Little River with the Restigouche; from which it is separated, between the mouths of the Scaumenac and Little Rivers, by a margin of silicious conglomerate, very like that of Tracadigash. This latter rock is seen in vertical or highly tilted southward-dipping strata, below Mungo's Brook, as well as at Points Lagarde and Bordeau; comprehending a distance of thirteen miles. Scaumenac River.

The valley of the Little River makes a section across the range of trappean hills. These, on the Kempt or Metis road, which runs along this valley, have a breadth of more than two miles, extending to the bridge across the river; close by which, fossiliferous limestones appear, succeeded by calcareo-argillaceous and arenaceous shales, and, farther back, by thin-bedded limestones, with dark shales. Not far below the bridge, a tributary from the west joins the Little River, and, in the latter part of its course, runs through a valley; which corresponds with that in which another stream flows westward, joining the Restigouche, about five miles below the mouth of the Matapedia. The fossiliferous limestones, which probably extend along these valleys, here come upon the Restigouche. Little River.

Mountains of trap occupy the whole of the triangle between the valleys and the main river; and just at the termination of the mountain, at the apex of the triangle, the intrusive rock is seen interstratified with the limestones. Some of the fossiliferous strata are exposed near the mill on Andrew's Brook, a little over two miles below the Matapedia; and again about half a mile farther up, below the mouth of Seller's Brook. The thin bedded limestones, in which no fossils have been observed, come upon the Restigouche at and below the mouth of the Matapedia. Trap hills.

Returning down the Restigouche, on the opposite side, in New Brunswick, the trap range is again met with. The Sugar-loaf, near Campbelltown, is a hill of trap; and this rock occupies the greater part of the area between the brook at its base, and the Restigouche. On the margin of the river, however, a silicious conglomerate appears; and at Mission Point, just in front, a greenish-grey sandstone, probably belonging to the same formation, is met with. The strata in both localities dip northward. Lower down, between Shaw's Brook and Point La Lime, intrusive rocks again appear. They are composed of red feldspar and black mica, and are interstratified with the conglomerate; which is composed almost altogether of pebbles of crystalline rocks, and runs along the beach for some distance, to Point La Lime.

A little below the point, there occurs, associated with the conglomerate, a thin seam of carbonaceous shale, with a bed of clay beneath it. The same seam is again seen at Point Pin Sec, resting on the clay bed, and overlaid by a mass of intrusive rock; which has changed it to a hard black stone. A conglomerate bed again occurs farther on, from beneath which, towards Point Peuplier, there appears a red slate, employed by the Indians for the manufacture of their calumets. The rocks seen along the shore, between this and Dalhousie, are nearly all of trap. In a beautiful transverse section of the trap series, which occurs in the vicinity of Cape Bon Ami, and continues for a mile, the layers of igneous rock are interstratified with limestones and calcareous shales, abounding in fossils. Among the species are *Favosites Gothlandica*, *F. basaltica*, *F. polymorpha*, with two undetermined species of *Zaphrentis*, *Strophomena rhomboidalis*, *S. punctulifera?* two undetermined species of *Orthis*, and two of *Spirifera*, *Atrypa reticularis*, an undetermined species each of *Athyris* and *Orthoceras*, with *Calymene Blumenbachii*.

Cape Bon Ami.

Restigouche basin.

The inference to be drawn from these details is, that the lower rocks in the valley of the Restigouche, from the mouth of the Matapedia downwards, constitute a trough, containing a calcareous and a silicious series. These are probably contemporaneous with the Gaspé limestones, and their overlying conglomerates and sandstones. The intrusive rocks, which are so abundant in this basin, mark a period of disturbance, whose influence has not unlikely been powerful in this part of the continent.

Bonaventure rocks.

On this trough of lower rocks, the Bonaventure conglomerates repose unconformably. Their northward limit is the mountain flank of the Gaspé table-land, which they follow in the line that has been described; turning sharply up to a nearly vertical attitude, for a short distance, as they approach the intrusive rocks, and generally leaving a geographical depression between their basset edges and the mountain flank. Between Tracadigash and the Nouvelle River, the strip occupied by the Bonaventure conglomerates on the coast, is flat and narrow, the width not being a mile; but between the Nouvelle and the Scaumenac, though their dip is gentle, these rocks rise into hills, which occupy a breadth of four miles, and form the coast from Maguasha Point to High Cape. This is their western limit in the district which has come under the examination of the Survey.

On the New Brunswick side of the Restigouche, a small portion of the Bonaventure formation is seen lying unconformably on the trap and lower conglomerate of Point La Lime, on the south side of the Campbelltown road, just in the rear of the point. None of it has been observed at Dalhousie; between which place and Jacket River, the coast has not been examined. Huron Island is however supposed to belong to this formation; and between Jacket River and Bathurst, it is displayed, in many places, resting in a nearly horizontal attitude upon fossiliferous limestones, trap, and silicious conglomerates. These are repeated several times in the distance, through the effect of undulations.

Dalhousie.

The flat red rocks in the vicinity of Bathurst belong to this formation; and on the left bank of the Nipisiguit, about a mile above the town, they are found to contain fossil plants, which are partly converted into coal, and partly replaced by vitreous sulphuret of copper, in a manner similar to those at the Joggins in Nova Scotia, on the Bay of Fundy. At this spot, on the Nipisiguit, an attempt was made about twenty years since, by the Gloucester Mining Company, to work the deposit for copper ore; but the irregular distribution of the organic remains rendered the operations uncertain, and induced the abandonment of the adventure. The strata are very nearly horizontal; and they present the following section, in descending order:—

Bathurst.

Copper ore.

	Ft.	*in.*
Chocolate-red micaceo-arenaceous shale, with casts of shrinkage cracks,..	30	0
White quartzose conglomerate, the thickest part of which is two feet, diminishing in one direction to two inches, in the space of fifteen yards. The bottom is very white, and contains quartz pebbles, some of which are an inch in diameter,................................	1	0
Whitish-red argillo-arenaceous shale, forming a passage to the next bed below,...	0	6
Bluish-grey argillo-arenaceous shale in parallel layers; the bed thins out in about thirty yards up the stream. It is charged with the remains of broken plants, some of which are replaced by vitreous sulphuret of copper, coated with a thin covering of green carbonate. Some are in part replaced by the copper ore, and partly converted into coal. Small nodules of the sulphuret of copper also occur, chiefly in the lower part, and traces of nickel are said to have been found in some of them. The greatest thickness of the bed is four feet; its average,..	2	0
White quartzose conglomerate, similar to that of the summit. This does not thin out in the distance examined, about fifty yards,............	4	0
Red sandstone conglomerate, with white quartz pebbles; of which some would weigh three ounces,.....................................	6	0
Red shale,..	6	0
Red sandstone conglomerate, with quartz pebbles, some weighing a pound and a half, ...	10	0
	59	6

At Rough Waters, three miles up the Nipisiguit from Bathurst Harbour, the Bonaventure rocks are found lying in a nearly horizontal attitude upon

Nipisiguit River. a mass of granite, and filling the inequalities of its surface. The granite is fine grained, and is composed of white feldspar, colorless translucent quartz, and black mica. At the immediate junction of the two rocks, the red sandstones seem slightly harder than in other parts, while the granite Granite. is softer. The feldspar is very white and opaque; and two or three feet of the surface have a schistose structure, as if from the stratification and solidification of a layer of disintegrated granite. In some places, the lowest of the red strata terminate abruptly against a vertical granite ledge, and present the semblance of a dislocation at the spot; but the even continuity of the overlying beds plainly shows this to be the result of original deposit upon an uneven surface.

Where the junction of the sandstones and the granite is first seen, the former are thirty feet thick; but as the surface of the granite gradually rises, up the river, while the sandstones maintain their nearly horizontal attitude, these gradually thin out and disappear. At Rough Waters, there is a porphyritic dyke, consisting of reddish compact feldspar inclosing red crystals of the same mineral: it has an underlie S. $< 60^\circ$. Granite of the same character as that of Rough Waters, is seen up the Middle River, 250 Age of the granites. yards from its junction with Bathurst Harbour. The resemblance of this granite to that of the Eastern Townships, and the distribution of a similar granite, from the state of Vermont, through Maine, to New Brunswick, leave little doubt that they are all of the same age. The intruded masses of this rock in the Eastern Townships, as we have seen, intersect the Devonian strata, and those of Bathurst are here shown to underlie the Bonaventure formation, which belongs to the Carboniferous period; so that the eruption of the white granites of this part of North America, appears to have taken place, at or near the close of the Devonian period.

Proceeding along the coast of New Brunswick, to the north-east of Bathurst, after an interval concealed by sand, red sandstones again occur, at Salmon Beach, four miles from the entrance to the Harbour. They are exposed for 156 yards across the measures, and their dip appears to be N. 40° E. $< 9^\circ$. Five miles farther, after another interval of sand, a succession of greenish-grey or drab sandstones, no doubt overlying the former, make their appearance, dipping N. 20° E. $< 1^\circ - 2^\circ$. These commence at Ellis Brook, west of Cranberry Cape; and the measures to the eastward are not again concealed for a very considerable distance along the coast. Point Dumai. As far as Point Dumai, twelve miles from Cranberry Cape, the succession of beds, that can be seen and followed in the cliffs, which vary from twenty to a hundred feet in height, amounts to very nearly 400 feet.

Coal seams. In this section, two regular coal seams occur, within 132 feet of each other, the upper one eight inches, and the lower six inches thick. Each of these is underlaid by the argillaceous root-bed, or under-clay, which supported the plants of whose ruins they are composed. These under-clays are thickly penetrated by *Stigmaria ficoides*, and studded with occasional nodules of argillaceous carbonate of iron. The roof of the upper coal seam, consists of a dark bluish-grey argillaceous shale, and contains an abundance of ferns and other plants. Among them are *Pecopteris Serlii*, *P. nervosa*, an undetermined *Sphenopteris*, *S. latifolia*, an undetermined species of *Asterophyllites*, with *A. galioides*, *Cordaites borassifolia*, *Sphenophyllum Schlotheimi*, *Næggerathia flabellata*, with undetermined species of *Bechera*, *Lepidodendron*, *Calamites*, and *Cyperites*.

By thus tracing the Bonaventure conglomerates and sandstones round the Bay of Chaleurs, to Bathurst, their relation to the nearest coal seams of New Brunswick, is made out with a considerable degree of certainty. The general dip of the Bonaventure formation in Canada accords with the result thus arrived at. Its slope towards the bay, would carry it beneath the coal-bearing strata on the south side; where no rock of a similar character is seen to overlie the coal measures. The only fossils which have been met with in this formation, are certain large plants, converted into coal, which occur in the vertical beds on the south side of Malbay; and although the external markings of these fossils give nothing by which to determine their species, they offer no contradiction to the stratigraphical evidence. Bonaventure formation.

The Bonaventure formation appears to be the very base of the coal series, in so far as Gaspé is concerned; and its distribution in Canada shows that a narrow margin on the north shore of the Bay of Chaleurs may be considered as the limit, in that direction, of the great eastern coal field of North America. Coal formation.

We here conclude the general description of the rock formations of the province, and of their distribution, so far as yet examined; with the exception of the diluvium or drift formation, which is reserved for a subsequent chapter. The mineralogical and chemical history of these rocks will now be given in successive chapters, on their mineral species, the composition of the stratified and unstratified rocks, and the mineral waters. These will be followed by particular descriptions of the economic rocks and minerals of the province; reserving for the Appendix a complete list of the organic remains, with a large number of figures in addition to those already given.

CHAPTER XVII.

MINERAL SPECIES.

ARRANGEMENT. — CARBONATES. — SULPHATES. — PHOSPHATES. — FLUORIDS. — SILICATES. — METALLIC ORES AND METALS. — CARBONACEOUS MINERALS. — SULPHUR.

In the preceding chapters, we have, in describing the different rock formations, made mention of the greater number of the mineral species which these contain. It is now proposed, as preliminary to a chemical and mineralogical description of these rocks, to notice in succession the various minerals, which have, up to the present time, been observed in the province. Under each species, will be given the most interesting facts in its history, so far as regards its occurrence in Canada, its associations, and

Classification.

its chemical composition. Without attempting to follow a rigidly scientific classification, we shall first notice the carbonates, sulphates, phosphates, and fluorids, and then proceed to the silicates; reserving for the last, the metallic ores and combustible minerals. The history of the mineral substances which are found dissolved in our natural waters, will be given in the chapter on the mineral waters of Canada.

CARBONATES OF LIME AND MAGNESIA.

CALCITE.

Calcareous spar.

Finely crystallized forms of calcareous spar are abundant in many of the mineral veins on Lake Superior, and on Lake Huron; some of these have afforded transparent cleavable varieties like Iceland spar. At Harrison's location on St. Ignace Island, a calcite of this kind is found, some portions of which are filled with small brilliant crystals of native copper, giving it the aspect of aventurine. At the Bruce Mines, large scalenohedrons occur, with pearl-spar and quartz. Large semi-transparent very obtuse rhombohedrons have been found in veins, in the Trenton limestone group, near Lachine; and similar varieties are met with in various other localities in the same formation. Huntingdon, in Hastings county, is cited by Professor Chapman as affording remarkable crystals. Crystals of the primary rhombohedron occur in the dolomites of Point Lévis, on the walls of fissures, which are filled with crystals of quartz and a bituminous matter; sometimes with pyrites. The variety known as dog-tooth spar, is abundant, lining cavities in the dolomites of the Niagara formation: the crystals are generally implanted on those of pearl-spar. Mention has already been made of the concentric masses of carbonate of lime, with a concretionary fibrous structure, which are found in the limestones of the Quebec group, and are abundant at Point Lévis, Orleans Island, and at Acton. These masses have sometimes been mistaken for fossil corals, but Travertine. resemble still more the travertines formed by certain mineral waters of the present day; with which they are probably identical. Masses of crystalline travertine occur in fissures in the gypsiferous rocks, at Oneida and elsewhere. Recent deposits of a similar nature, from calcareous springs, are abundant in many parts of Western Canada: as at Dundas, Niagara, Woodstock, and near Toronto. These travertines are sometimes solid and crystalline, like alabaster; and at others, porous and tufaceous. They often enclose or incrust mosses, leaves, and branches of trees. In the township of York, on a small tributary of the Don, beds of tufa occur, from twelve to fifteen feet in thickness, and are overlaid by sand and clay. Deposits of this substance are abundant in many places, along the base of the escarpment formed by the Niagara formation, in the counties of Grey and Simcoe. They are constantly in process of formation. We may also in this connection mention the fresh-water marls, which are nearly pure carbonate of lime: these are abundant in our lakes and marshes.

The particular history of the great masses of carbonate of lime which constitute the various limestone formations, will be given in a subsequent chapter. We may here, however, notice a peculiar variety of fetid carbonate of lime, which forms a large bed in the Laurentian series, in Grenville. It is a very coarse-grained cleavable, milk-white, and Fetid calcite. apparently pure calcite, which, when struck or very slightly scratched, evolves a most powerful and unpleasant odor, recalling somewhat that of phosphuretted hydrogen. It dissolves without residue in dilute acids; and the carbonic acid gas evolved does not affect solutions of lead or silver-salts, so that it is difficult to say to what the peculiar smell of this singular rock can be due. It is entirely distinct from the bituminous odor, which is evolved by percussion from a great many of the limestones of the palæozoic series, or from that produced by striking some silicious rocks.

ARRAGONITE.

Arragonite. This species has been observed forming stalactites and delicate fibrous masses, in a calcareous rock, in the township of Tring. A similar variety, according to Dr. Bigsby, was found in a vein in the limestone of Lachine.

DOLOMITE.

Dolomite. Crystallized dolomite, which is often known by the names of pearl-spar and bitter-spar, is abundant in cavities and geodes in the dolomites of the Niagara formation in Western Canada; where it is generally associated with calcite, in the form of dog-tooth spar, and with gypsum. Anhydrite, the sulphates of baryta and strontia, quartz, and fluor-spar, more rarely occur crystallized in these geodes. The dolomites of the Calciferous formation, which resemble those of the Niagara, in like manner contain geodes of pearl-spar, with calcite, gypsum, heavy-spar, and quartz, in many localities.

Pearl-spar.

In the copper-bearing quartz veins at the Bruce mines, crystallized pearl-spar is also found with calcite. In one instance, a crystalline massive variety forms a veritable wall of dolomite, varying from a few inches to two feet in thickness, and running through the middle of a metalliferous quartz vein, which traverses diorite.

Among the altered rocks of the Quebec group, dolomite is often intimately mixed with serpentine, forming a variety of ophiolite; or, in the form of crystals of bitter-spar, is disseminated in steatite, in which it sometimes forms veins, as at Leeds; where a ferruginous bitter-spar is the gangue of copper-glance, specular iron, and native gold. It is also abundant in many of the quartz veins of this mineral region.

Magnesian limestones. Dolomites, or magnesian limestones, which consist of variable mixtures of dolomite with pure carbonate of lime, are developed to a very great extent in Canada. Besides forming great beds among the Laurentian limestones, and rendering those of the Huronian series more or less magnesian, dolomites make up the chief part of the so-called Calciferous formation, which was formerly known as the Calciferous sandrock; and are developed on a great scale in its geological equivalent, the Quebec group; where they present varieties remarkable for containing large portions of carbonates of iron and manganese. The so-called limestones of the whole Middle and Upper Silurian series in Western Canada, are, with few exceptions, dolomites; including the Clinton, Niagara, Guelph, and Onondaga formations. The Devonian limestones of that region are not generally magnesian; but in Eastern Canada, the fossiliferous limestones of that age, at Dudswell, are curiously penetrated by veins of dolomite, constituting a sort of breccia. Conglomerates or breccias, with a magnesian cement, also occur in the Quebec group, in many places, and in the Chazy formation

Conglomerates.

at Montreal. A much more recent dolomitic conglomerate, which encloses fragments of fossiliferous limestone of the Lower Helderberg formation, occurs on the Island of St. Helen. Dolomite also occurs, replacing the remains of great numbers of fossils in the Trenton limestone, at Ottawa. Corals, brachiopods, gasteropods, cephalopods, and crustacea, are alike replaced by a white, translucent, crystalline, reddish-weathering dolomite. This also forms small seams in the bluish-grey compact limestone, which contains 3·9 per cent. of clay, with a little oxyd of iron, but no magnesia. A fragment of an *Orthoceras* from this rock was nearly solid, but had drusy cavities filled with pearl-spar and quartz. Its analysis gave: carbonate of lime 56·00, carbonate of magnesia 37·80, carbonate of iron 5·95 = 99·75. Similar dolomitic casts of orthoceratites are found in a grey earthy, non-magnesian limestone, of the Chazy formation, near Montreal, and at the Mingan Islands. We reserve for another place some inquiries into the origin of dolomite, and likewise a series of analyses of dolomites and various limestones, from different formations. Fossils replaced by dolomite.

MAGNESITE.

Carbonate of magnesia has hitherto but rarely been recognized as forming rock masses; but it is probably much more abundant than has been supposed, and may have often been mistaken for dolomite, which it resembles. Beds of a rock, consisting chiefly of carbonate of magnesia, with variable proportions of carbonate of iron, occur in several places among the strata of the Quebec group, associated with serpentine, dolomite, and steatite. On the twelfth lot of the seventh range of Sutton, it forms a bed a foot thick, associated with the latter two rocks, in grey micaceous schists. Magnesite rock. Sutton.

It is mingled with grains of a feldspathic mineral, and with small scales of green mica; giving the whole the aspect of a bright green, very micaceous gneiss, weathering rusty-red. The proportion of soluble carbonates in the rock is variable; a pure, slightly colored fragment gave carbonate of magnesia 83·35, carbonate of iron 9·02, insoluble 8·03 = 100·40. Another portion gave carbonate of magnesia 33·00, carbonate of iron 19·35, alumina 0·50, insoluble 45·90 = 98·70. The specimens contained small grains of nickeliferous pyrites; but the insoluble residue, after the action of nitric acid, still retains a portion of nickel as an insoluble silicate, and has a bright green color, apparently due to a small amount of oxyd of chromium, which it also contains. It is essentially a silicate of alumina and alkalies, chiefly soda, with traces only of magnesia and of iron; and is apparently a mixture of feldspar with a green chromiferous mica.

The magnesite rock of the seventeenth lot of the ninth range of Bolton forms a bed many yards wide; interstratified between steatite on one side, and an impure serpentine, passing into diorite, on the other. It resembles Bolton.

a crystalline limestone, and is made up of strongly coherent cleavable grains of magnesian spar, whitish or bluish-grey in color, and weathering rusty red; with grains and small irregular veins of hyaline quartz. It is stained here and there with a yellowish-green hydrocarbonate of nickel, which incrusts the joints of the rock. It also contains small grains of pyrites, small portions of some green chromiferous silicate, and occasionally a little carbonate of lime. Analyses of two different portions gave carbonate of magnesia 59·13, carbonate of iron 8·32, insoluble 32·20 = 99·65; and carbonate of magnesia 59·72, carbonate of iron 10·31, insoluble 29·90 = 99·93. The insoluble matter was nearly pure quartz, yielding 93·6 per cent. of silica, with a little alumina, alkali, and oxyd of chrome.

Magnesite also occurs on the twenty-fourth lot of the ninth range of Bolton, where it forms beds in argillite. It here appears as a compact rock, with a conchoidal fracture, bluish-grey within, but weathering reddish-brown. It contains, like the others, a mixture of silicious matter, and a portion of carbonate of iron. This variety can scarcely be distinguished, by its external characters, from the magnesian limestones so common in the same region.

SULPHATES, PHOSPHATES, AND FLUORIDS.

HEAVY-SPAR.

Heavy-spar. Heavy-spar, or sulphate of baryta, is found in many localities in Canada. In the Laurentian series several veins of this mineral have been observed. One of these, on the second lot of the eighth concession of Lansdowne, intersects the crystalline limestone, and is in some parts mixed with calcite and galena. In other parts, the whole vein consists of nearly pure heavy-spar, forming large tabular crystalline masses, which are semi-transparent, and bluish or rarely reddish in color. Well defined crystals are met with in cavities in the vein. The township of Dummer is also cited as a locality by Prof. Chapman.

On the fourth lot of the sixth range of Bathurst, a vein of opaque white lamellar heavy-spar, said to be about a foot wide, is found in gneiss. It contains small grains of copper pyrites. Heavy-spar is also met with in MacNab, at the mouth of the Dochart; and a red variety is associated with purple fluor-spar in cavities in the Laurentian limestone near the hematite of Iron Island, Lake Nipissing.

Sulphate of baryta is abundant in many of the veins on the north shore of Lake Superior, and sometimes makes up a great proportion of the vein. An interesting locality, according to Dr. Bigsby, is on a large and lofty island, three miles east of Gravelly Point, and sixty-three cast of Fort William. Here the mineral occurs lining fissures in a porphyry, with green octahedral fluor-spar. It is also occasionally met with in the copper veins of the Bruce mines. Small veins of massive white heavy-spar are met with intersecting the serpentines of the Bras, a tributary of the Chaudière. The same mineral occurs crystallized in geodes, in the dolomites of the Calciferous formation, and is said to be occasionally found in those of the Niagara formation at Niagara Falls. Small almond-shaped masses of a reddish cleavable variety of heavy-spar are found, with gypsum, imbedded in shales of the Hudson River formation, at Cape Rich.

CELESTINE.

Sulphate of strontia.

Celestine, or sulphate of strontia, abounds in the limestones of the Trenton group, at Kingston, and in its vicinity. Dr. Thompson gave the name of baryto-celestine to specimens from this region, which, according to him, contained thirty-five per cent. of sulphate of baryta. The specimens from Kingston in the collection of the Geological Survey, were, however, found to be pure sulphate of strontia, without a trace of baryta, and to have a specific gravity of 3·96. It occurs in white translucent crystalline foliated masses, which are sometimes radiated, and often several inches in diameter. These are generally associated with calcite, blende, and iron pyrites. Sulphate of strontia, according to Dr. Bigsby, occurs in sky-blue prismatic crystals, in a similar limestone on the right bank of the Ottawa, near the head of the Long Sault. A fibrous variety occurs also in limestone, at the narrows of Lake Simcoe, near the Severn, with selenite, on the Grand Manitoulin, and at Niagara Falls.

GYPSUM.

Gypsum.

Gypsum, or hydrous sulphate of lime, has already been mentioned as occurring with pearl-spar, in the dolomites of the Niagara formation. It is abundant in these, not only in a lamellar form (selenite), but in compact snow-white masses, sometimes several inches in diameter; filling rounded cavities in the dolomite, which are often lined with crystals of quartz. It is met with in similar conditions in some of the dolomites of the Clinton and the Calciferous formations. Cavities in the latter, at Beauharnois, and elsewhere, are lined with calcite and quartz crystals, and filled with compact and lamellar gypsum. Small almond-shaped masses of reddish gypsum occur in the Hudson River shales at Point Rich, along with heavy-spar; and a bed of soft bluish shale in the Medina formation, at St. Vincent, contains an abundance of isolated crystals of gypsum, an inch or more in length. Large masses of transparent selenite, according to Dr. Bigsby, occur in the limestones of Hudson's Bay. The great workable deposits of gypsum in Canada, are interstratified with the magnesian limestones and shales of the Onondaga formation, under which head they have already been described.

ANHYDRITE.

Anhydrite. This species is not yet known to occur in Canada; but the Niagara formation in western New York has afforded a foliated transparent variety, which occurs in the geodes, common to the dolomites of that series.

EPSOM SALT.

Sulphate of magnesia. Epsom salt, or sulphate of magnesia, besides predominating in the waters of some mineral springs, is found upon the dolomites of the Clinton formation, at various points along their outcrop from Niagara Falls to Lake Huron. It generally occurs as a crystalline incrustation upon sheltered surfaces of the rock, and, in such cases, evidently results from the evaporation of exuding waters. These crusts, at Dundas, are sometimes an inch in thickness. Near Niagara, however, it is said to be found with gypsum, in geodes in the rock. Sulphate of magnesia has been observed in other countries, associated with gypsum, apparently as a contemporaneous deposit; and it is probable, that here in the Clinton formation, also, it is derived from an original impregnation of these gypsum-bearing dolomites with the salt; instead of being, as some have supposed, the result of a subsequent reaction between the gypsum and the dolomite.

Sulphate of magnesia has also been observed as an efflorescence on a serpentine rock, near the iron-ore bed of Crow Lake, in Marmora; where it may arise from the action of sulphuric acid from oxydizing pyrites, upon the magnesian silicate. An abundant efflorescence of the same salt has been observed in the black shales of the Utica formation, along the line of the aqueduct, near Montreal, when these are first quarried and exposed to the weather; and it is also seen upon the black shales of Quebec.

APATITE.

Phosphate of lime. Apatite, or phosphate of lime, is a common mineral in the limestones of the Laurentian series, sometimes disseminated in minute and rare blue or green crystals; but at other times so abundant, as to make up a great proportion of the rock, and in some cases to form beds of a nearly pure crystalline apatite. The most remarkable localities known in Canada, are in North Elmsley and in South Burgess. In the former township, the mineral has been traced across the lots twenty-four, twenty-five, and twenty-six of the eighth range, for about a mile in a south-west direction; and it appears to be continued into South Burgess, on the second lot of the seventh, and from the seventh to the tenth lot of the fifth range. It has been quarried to a small extent on the twenty-fifth lot of the eighth range of North Elmsley, where it seems to form an irregular bed, having a breadth of about ten feet; of which three feet are nearly pure crystalline sea-green apatite, with only a small admixture of black mica. In the remaining portion, it is mingled with the limestone, the phosphate largely predominating, and sometimes forming prisms a foot or more in length, and four inches in diameter. These are generally rough, but often terminated, and, as well as the smaller ones, have always their angles rounded. Large prisms of it are also found in a bed of quartzite near the limestone. The apatite is sometimes associated with large crystals of pyroxene, and of phlogopite: in one of the latter, about four inches in diameter, a crystal of apatite, a quarter of an inch thick and two inches long, was found imbedded, the axis of the prism being parallel with the cleavage of the mica. Rounded masses of calcite are often enclosed in the apatite; which, in its turn, is frequently in rounded pale-green crystalline masses, imbedded in the coarse-grained limestone. The phosphate of lime of Burgess belongs to the variety called fluor-apatite, and contains only about 0·5 per cent. of chlorine. **Fluor-apatite.**

A similar locality of apatite occurs in the township of Ross, where large olive-green terminated crystals, with rounded angles, are imbedded in a yellowish crystalline limestone, which at the same time contains a considerable proportion of cleavable grains of purple fluor-spar, and crystals of black spinel. In some bands of this limestone, small crystals of the apatite, with grains of fluor-spar, make up more than one half of the mass. Another locality is at the foot of the Calumet Falls; where crystals of blue apatite, and of quartz, are imbedded in a coarsely cleavable sky-blue calcareous spar. Apatite is also met with in some abundance, in crystalline limestone, near Blaisdell's mill, on the Gatineau.

At St. Roch, on the Achigan River, there occurs an intrusive mass of fine grained grey dolerite, in which, besides crystals of augite, small hexagonal prisms of apatite are rather abundantly disseminated. These are transparent, pink or purple in color, and sometimes an inch in length, and one or two lines in diameter: their surfaces are often dull, and their angles are rounded.

Nodules, composed in great part of phosphate of lime, occur in many localities in the Lower Silurian rocks, and appear to be coprolites. In some cases, at least, they exhibit imbedded fragments of the shells of *Lingula*, which was probably the source of the phosphate of lime. We have shown that the horny translucent shells of *Lingula* and *Orbicula*, both of recent and fossil species, together with *Conularia* and *Serpulites*, differ entirely from those of other mollusks, and, like the bones of vertebrate animals, consist for the greater part of phosphate of lime. The shell of *Lingula ovalis* (Reeve), a recent species, left, by calcination, 61·00 per cent. of fixed residue; which consisted of phosphate of lime 85·70, carbonate of lime 11·75, magnesia 2·80 = 100·34. **Coprolites.** **Phosphatic shells.**

Among the localities of these phosphatic nodules, we may mention the Chazy formation at Allumette Island, where they are abundant in a coarse grained sandstone. Not only does the phosphatic paste enclose fragments of *Lingula*, but it is found filling the moulds of *Pleurotomaria* or *Holopea.* These masses, which are sometimes an inch thick and two inches long, are chocolate-colored, and contain imbedded grains of white silicious sand. When heated, they disengage a strongly ammoniacal water, with an odor of burnt horn. Smaller fragments of a similar phosphatic material are found at Grenville, in sandstone beds, which belong to the same formation as the last. The Chazy limestone at Hawkesbury and Lochiel also encloses phosphatic nodules, from one fourth of an inch to an inch in diameter, blackish-brown without, but yellowish-brown within, and giving off abundance of ammonia when heated. Fine examples of similar coprolites have been found in the graptolitic shales of Point Lévis, and at Rivière Ouelle in a calcareous conglomerate, both of the Quebec group. At the latter locality, the phosphatic masses are very abundant, and often assume curious imitative shapes.

A specimen from Allumette Island had a specific gravity of 2·875, and gave as follows: phosphate of lime (bone earth) 36·38, carbonate of lime, with some fluorid, 5·00, magnesia and peroxyd of iron, by difference, 7·02, insoluble 49·90, volatile matter 1·70 = 100·00. The insoluble matter, which consists of silicious sand, equalled 38·00 per cent. in another fragment. A specimen from Hawkesbury gave phosphate of lime 44·70, carbonate of lime 6·60, carbonate of magnesia 4·76, peroxyd of iron and a trace of alumina 8·60, insoluble sand 27·90, volatile 5·00 = 97·56.

One from Rivière Ouelle, with a specific gravity of 3·15, afforded phosphate of lime 40·34, carbonate of lime, with some fluorid, 5·14, carbonate of magnesia 9·70, peroxyd of iron, with traces of manganese, and a little alumina, 12·62, insoluble silicious residue 25·44, volatile 2·13 = 95·37. In the latter specimen, the microscope shows, besides grains of quartz, small cylindrical bodies, resembling the spiculæ of sponges. The large amount of iron in the nodules from Rivière Ouelle, appears to exist as a carbonate of the protoxyd; and is evidently connected with the presence of an abundance of iron pyrites, which surrounds the phosphatic masses, and points to the action of organic matters on a solution of sulphate of iron; whose reduction must yield an atom of protoxyd of iron for each one of bisulphuret: $2\,(FeO, SO_3) = FeS_2 + FeO + O_7$. Small hollow cylindrical masses, found in the sandstones in that locality, resemble bones. They appear to be homogeneous under the microscope, and are only

Serpulites. incrusted with silicious sand. These, which are supposed to be *Serpulites*, differ in their composition from the soluble portion of the nodules, in containing a much less proportion of iron. An analysis gave phosphate of lime 67·53, carbonate of lime 4·35, magnesia 1·65, protoxyd of iron 2·95, volatile 2·15, adhering sand 21·10 = 99·73. All of these bodies give evidences of the presence of fluorine; and of azotized organic matters, which evolve ammonia, with an animal odor, when heated. (American Journal of Science, July 1854, [2,] XVII, 235.)

FLUOR-SPAR.

This mineral has been met with in several localities in Canada, but is rarely found in great abundance. Green and purple fluor-spar frequently occur in the mineral veins on Lake Superior: a purple variety is found on the main land opposite Pic Island, filling veins in syenite; and also with calcite in amygdaloid, three miles east of Point Gargantua. Another locality of green octahedral crystals, with heavy-spar, in porphyry on an island near Gravelly Point, has been mentioned under the latter species. The above localities were long since described by Dr. Bigsby. Green cubes of fluor-spar also occur at Prince's mine, associated with quartz and calcite. Fluor-spar.

In the Laurentian rocks, purple fluor occurs, both granular, and in small cubic crystals with heavy-spar, in fissures in the limestone on Iron Island, Lake Nipissing. The same mineral is found disseminated in purple cleavable grains, associated with green apatite, in a yellowish crystalline limestone in Ross: the fluor-spar makes up from five to ten per cent. of the rock. A small vein of the mineral is also met with in the vicinity. A specimen of galena, said to be brought from the Gatineau, is imbedded in a crystalline lilac-colored fluor-spar. A green compact variety occurs in considerable proportion, in veins of milk-white calcite, with galena, cutting the Potsdam sandstone at Bay St. Paul and Murray Bay; and a dark purple cleavable fluor-spar, with white calcite, forming very fine specimens, is found in veins, among the black slates, near the citadel of Quebec. A small vein of compact purple fluor-spar has been observed in the grey fossiliferous limestone of Montreal: its color is at once destroyed by heat. This mineral is also occasionally found crystallized, with various other spars, in the geodes of the dolomites of the Niagara formation.

SILICATES.

In describing the silicated minerals, it will be convenient to group them into two classes: 1st, Non-aluminous silicates, chiefly of protoxyds, such as lime, magnesia, and ferrous oxyd. 2nd, Aluminous silicates, which, with the exception of a limited number of simple silicates of alumina, may be represented as double silicates of alumina, and an alkaline or earthy protoxyd. These two classes are connected, through the aluminous pyroxenes and hornblendes.

OLIVINE, OR CHRYSOLITE.

Olivine. This species has hitherto been recognized in but few localities in North America. A nearly colorless transparent variety, the boltonite of Prof. C. U. Shepard, occurs in the crystalline magnesian limestone of Bolton, in Massachusetts, with asbestus, mica, and magnetic iron. It has a density of 3·21; and its analysis gave to Prof. Brush, silica 42·82, magnesia 54·44, protoxyd of iron 1·47, lime 0·85, volatile 0·76 = 100·34. A curious granitoid dolerite, which is found in boulders at Thetford, in Vermont, contains masses of green olivine, sometimes an inch in diameter. This gave by analysis, according to Mr. Manice (Am. Jour. of Science [2,] XXXI, 359), silica 40·75, magnesia 50·28, protoxyd of iron 9·36 = 100·36. Many of the dolerites in the vicinity of Montreal abound in olivine. At Rougemont, dykes of a fine grained greenish-black basalt, enclose numerous well defined crystals of green olivine, which appear in strong relief on the weathered surfaces. A granitoid dolerite, with a white feldspathic base, which forms a large portion of the same mountain, contains, besides black augite, small honey-yellow grains of olivine in abundance; and a similar rock is found in Mounts Royal and Montarville. In a portion of the latter, olivine is the predominant mineral, and occurs in olive or amber-colored imperfect crystals, sometimes half an inch in diameter, forming 45·0 per cent. of the rock. The powdered olivine gelatinizes with hydrochloric acid in the cold, and is almost instantly decomposed when warmed with sulphuric acid diluted with an equal volume of water; the silica separating chiefly in a flocculent form, and enclosing small grains of the undecomposed mineral, which are left after dissolving the ignited silica. A little silica is however retained in solution, and is precipitated by ammonia, with the oxyd of iron. Two analyses of separate portions of this olivine gave as follows, after deducting the undecomposed mineral:—

				Oxygen.
Silica, ...	37·13	37·17	=	19·82
Magnesia, ...	39·36	39·68	=	15·87
Protoxyd of iron, ...	22·57	22·54	=	5·10
	99·06	99·39		

Olivine has not yet been noticed among the magnesian rocks of the Silurian period in Eastern Canada; but it occurs in the same geological formation in the United States. Dr. Genth has lately described it in disseminated grains in a talc slate from Webster, Jackson county, North Carolina; where it is associated with serpentine, pyrosclerite, quartz, and chromic iron. The olivine from this locality, like the accompanying magnesian minerals, contains traces of oxyd of nickel. Grains of olivine also occur with the chromic iron of Loudon county, Virginia. (Am. Jour. of Science, [2,] XXXII, 199.)

CHONDRODITE.

This fluosilicate of magnesia is much more common than chrysolite in crystalline limestones, and is often met with in those of the Laurentian series, in Canada. The grains of chondrodite are sometimes so arranged as to mark the stratification of the rock. In a specimen, the locality of which is unknown, the contact of two beds of limestone, one marked by grains of chondrodite, and the other by those of serpentine, is distinctly seen. A similar association occurs in the limestones of St. Jerome. Fine specimens of chondrodite are found, with small scales of graphite, in a white crystalline limestone, from near Newborough. Chondrodite.

LIEVRITE OR YENITE.

To this rare species is to be referred a silicate of iron, which probably forms a bed in the Laurentian series, since a boulder of it nearly a foot in diameter, was found in the vicinity of Ottawa. It contains some black mica, and portions of red granular garnet; but it consists, for the greater part, of a mineral having a hardness of 5·5 and a density of 4·15 – 4·16. It weathers of a rusty red; but within, its lustre is sub-metallic, shining, and sometimes iridescent. Its color is velvet-black, but its powder is yellowish ash-grey. The mineral is slightly translucent on the edges, and is strongly magnetic. It is brittle, with an uneven fracture, and cleaves imperfectly in two directions, oblique to one another. Before the blowpipe, it intumesces, and yields a black magnetic slag. The mineral gelatinizes with hydrochloric acid, and is completely decomposed. Its analysis gave, silica 27·80, protoxyd of iron 56·52, peroxyd of iron 10·80, magnesia 2·59, lime 0·64, oxyd of manganese, a trace, volatile 1·20 = 99·55. Another trial gave 28·20 of silica, and 9·93 of peroxyd of iron. From its composition, not less than its physical characters, this substance is regarded as a variety of lievrite. The rock from which the mass was derived, has not been observed in place. Lievrite.

WOLLASTONITE OR TABULAR-SPAR.

This silicate of lime is often found with the Laurentian limestones, in which it sometimes forms beds, occasionally mingled with carbonate of lime or with quartz. At Grenville, it is associated with a dark green pyroxene and a white feldspar; forming a rock in which garnet, idocrase, sphene, pyroxene, and graphite occur. Beautifully white fibrous masses of wollastonite, several inches in length, are obtained in this locality. Its specific gravity is 2·89–2·92, and its analysis gave to Mr. Bunce: silica 53·05, lime 45·74, protoxyd of iron 1·20 = 99·99. In Bastard, a pale green variety also forms a rock, with quartz and small scales of brown mica. Other localities of tabular-spar are St. Jerome and Morin. Wollastonite.

HORNBLENDE OR AMPHIBOLE.

Hornblende. The variety of hornblende called tremolite is abundant in the Laurentian limestones at the Calumet Falls, and in Blythfield and Dalhousie. Short thick and highly modified prisms of a white transparent tremolite, with a density of 2·97, have been observed by Prof. Chapman, in a white crystalline limestone from Algona. Raphilite. The raphilite of Dr. Thompson, from Lanark, is nothing but a fibrous, radiating, grey hornblende, having a hardness of 5·5, and a specific gravity, when in powder, of 2·845. According to Dr. Thompson, it contains ten per cent. of potash; but an analysis of an authentic specimen gave silica 55·30, lime 13·36, magnesia 22·50, protoxyd of iron 6·30, alumina 0·40, manganese, traces, potash 0·25, soda 0·80, volatile 0·30 = 99·21. Another specimen, which had been purified by diluted hydrochloric acid, gave 57·20 of silica. The mineral is associated with carbonate of lime and phlogopite. The same vicinity furnishes a greenish-brown variety of actinolite, crystallized in prisms, and said by Dr. Thompson to be manganesian. A pale green or bluish-green variety, which may be referred to actinolite, or to pargasite, is common in druses in the Laurentian limestones. Pargasite. Finely terminated crystals of dark green pargasite, sometimes an inch in diameter, are found implanted upon, or imbedded in, a greenish-white pyroxene, at the High Falls, and at the Ragged Chute, on the Madawaska. A specimen in thick dark green, nearly opaque prisms, from the former locality, had a specific gravity of 3·050–3·058, and gave by analysis, silica 55·05, alumina 4·50, lime 13·44, magnesia 20·95, protoxyd of iron 5·85, volatile 0·35 = 100·14. Radiated masses of green actinolite also occur imbedded in the finely granular magnetic iron ore of Madoc.

Actinolite. Actinolite, disseminated in talc, occurs in beds with the serpentines of the Lower Silurian series; and a finely fibrous variety, without admixture, sometimes forms great beds of a very tough greenish rock. Such a mass occurs in St. Francis, Beauce, and gives by analysis, silica 52·30, lime 15·00, magnesia 21·50, protoxyd of iron 6·75, oxyd of nickel, traces, alumina 1·30, volatile 3·10 = 99·95. Mixtures of greenish hornblende with triclinic feldspars, form abundant beds of diorite in the same region.

Black hornblende. Black or greenish hornblende is very commonly disseminated through the feldspathic rocks of the Laurentian series; giving rise to syenite and syenitic gneiss, and also forming beds of hornblende rock, often schistose as at Blythfield, and at Lake St. John. Similar beds of black hornblende holding garnets, are found with the Silurian serpentines of Mount Albert. Crystallized black hornblende enters abundantly into the diorites of Yamaska Mountain and Mount Johnson, and is found sparingly, with black mica, in the granitoid trachytes of Brome and Shefford Mountains.

PYROXENE OR AUGITE.

This species is found abundantly in the Laurentian limestones, where a light greyish or greenish variety (diopside or sahlite), sometimes forms beds, or large segregated veins. Such is the case in Kildare; where a rock made up of nearly white cleavable pyroxene, with a little brown mica, is interstratified with limestone. At the High Falls, and at the Ragged Chute, on the Madawaska, a similar variety is associated with crystals of green hornblende, which have just been described, and with black tourmaline. The crystals of pale greyish-green pyroxene, often replaced on their acute lateral edges, are sometimes several inches in diameter. Those associated with the hornblende, whose analysis is given above, have a specific gravity of 3·273–3·275, and are composed of silica 54·20, lime 25·65, magnesia 17·02, protoxyd of iron 3·24, volatile 0·45 = 100·56. At the Calumet Falls similar; but slender crystals, sometimes six inches in length, occur, with large crystals of olive-green binaxial mica, imbedded in flesh-red crystalline limestone.

Pyroxene. Diopside.

An interesting variety of pyroxene, found by Dr. Wilson, in Bathurst, forms crystalline masses, mixed with a little mica, calcite, apatite, copper pyrites, and a pink crystalline mineral, to which the name of wilsonite has been given. This pyroxene is massive, cleavable, and sometimes exhibits small crystals. Its hardness is 6·5, and its density 3·19; its lustre is vitreous, and pearly on the cleavage surfaces. It is colorless or greyish-white, translucent, with an uneven, sub-conchoidal fracture. It contains a portion of alumina replacing silica,—a composition rarely met with in white non-ferruginous pyroxenes. One of two concordant analyses gave, silica 51·50, alumina 6·15, peroxyd of iron 0·35, lime 23·80, magnesia 17·69, volatile 1·10 = 100·59. A second yielded, silica 50·90, alumina and peroxyd of iron 6·77, lime 23·74, magnesia 18·14, volatile 0·90 = 100·45. The oxygen of the silica, in the first analysis, equals 27·28, and that of the alumina 2·87, the sum being 30·05; while the oxygen of the other constituents, the water included, amounts to 14·95. The ratio of these two numbers is very nearly 2 : 1, or that of pyroxene.

Aluminous pyroxene.

Large white semi-transparent prisms, often an inch in diameter, and highly modified, were many years since obtained in the vicinity of Ottawa, and are figured in Shepard's Mineralogy. They were imbedded in crystalline limestone, and probably from a boulder. The density of these crystals is 3·26–3·27, and their analysis gave silica 54·50, lime 25·87, magnesia 18·14, protoxyd of iron 1·98, volatile 0·40 = 100·89. A granular pyroxene rock which occurs with the ophiolite of Orford, has furnished beautiful tabular twin-crystals, which line geodes, associated with cinnamon-colored garnets, or are grouped in bladed masses of an opaque greenish-white. The crystals from the geode were opaque, and seemed somewhat earthy in their fracture, from incipient decomposition. Their density was 3·13–3·15, and they gave by analysis, silica 54·50, lime 25·20, magnesia 15·29, protoxyd of iron 4·86, volatile 0·55 = 100·40.

Grenville. The dark green pyroxene of Grenville sometimes offers cleavage surfaces of several inches in breadth; and it often occurs in large prisms, with pitted surfaces and rounded angles. Mixtures of similar pyroxene with orthoclase and quartz, generally including sphene, are often found, apparently forming beds among the limestones, as at Lachute, the Calumet Falls, and Elmsley. Beds of green granular pyroxene (coccolite), either alone, or with black mica, are also met with; and grains of green pyroxene are very often disseminated through the crystalline limestones, and sometimes through beds of quartzite. The peculiar forms from the Laurentian limestone of Calumet Island, resembling *Stromatopora rugosa*, have been figured on page 49. When the somewhat magnesian limestone is removed by an acid, the fossil is found to consist of an aggregation of brilliant crystalline grains of white pyroxene, whose analysis gave silica 54·90, lime 27·67, magnesia 16·76, volatile 0·80 = 100·13.

Hypersthene. The anorthosite rocks of the Laurentian series often contain a green granular or cleavable pyroxene, which passes into well characterized hypersthene. A specimen of this, associated with the andesine and ilmenite of Château Richer, had a hardness of 6·0, and a density of 3·41. Its color was blackish-brown, but yellowish-brown in thin laminæ; its streak and powder ash-grey. One of two analyses gave silica 51·35, alumina 3·70, protoxyd of iron, 20·56, lime 1·68, magnesia 22·59, volatile 0·10 = 99·98. The second yielded silica 51·85, alumina 3·90, protoxyd of iron 20·20, lime 1·60, magnesia 21·91, manganese, traces, volatile 0·20 = 99·66.

The name of augite is generally restricted to the black or dark colored varieties of pyroxene, which occur in dolerite and similar rocks. The

Augite. dolerites of the district of Montreal often enclose crystals of black augite, as in Montreal, Rougemont, and Montarville Mountains. The crystals imbedded in the olivinitic dolerite of the latter, are short, thick, terminated prisms, readily detached from their matrix. They have a hardness of 6·0, and a specific gravity of 3·341. Their analysis gave silica 49·40, alumina 6·70, lime 21·88, magnesia 13·06, peroxyd of iron 7·83, soda and traces of potash 0·74, volatile 0·50 = 100·11.

DIALLAGE.

Diallage is generally regarded as a variety of pyroxene, and is classed with bronzite and hypersthene, with which many varieties of it agree in composition. The hypersthene of the Laurentian anorthosites is sometimes replaced by a greenish sub-translucent diallage, which is probably of this nature. Much that is known as diallage among serpentine rocks, is however a hydrated mineral, which should perhaps constitute a new species. Diallage is often associated with the serpentines of the Silurian series in Canada, and sometimes forms rock-masses. A coarsely cleavable bronze-colored variety from the township of Ham, where it forms a rock, gave silica 50·00, magnesia 27·17, protoxyd of iron 13·59, lime 3·80, water 6·30 = 100·86. Another rock from Orford consists of small masses of celandine-green diallage, translucent, and with a pearly lustre, imbedded in an amorphous soft greenish base. The specific gravity of carefully selected fragments of this diallage was 3·02–3·03, and its hardness was 5·0. These still enclosed grains of magnetic iron, which were separated from the powder by a magnet, and equalled 4·37 per cent. Two analyses of different specimens of the mineral thus purified, were made, and gave as follows: Diallage Orford

	I.	II.		Oxygen.
Silica,	47·20	47·10	=	24·90
Alumina,	3·40	3·50	=	1·63
Lime,	11·36	11·34	=	3·24
Magnesia,	24·53	24·58	=	10·01
Protoxyd of iron,	8·91	8·55	=	1·89
Water,	5·80	5·85	=	5·20
Oxyds of nickel and chrome,	traces	traces		
	101·20	100·92		

Warm dilute nitric acid removed nothing from the pulverized diallage, nor from the rock. This gave, as a whole, silica 41·80, magnesia 26·13, protoxyd of iron 11·05, lime 7·00, alumina 6·80, oxyds of nickel and chrome, traces, water 7·60 = 100·38. From a comparison of this with the previous analyses, it would appear that the paste of the rock is a substance allied to chlorite or to pyrosclerite in composition.

This mineral evidently differs from pyroxenic diallage, both in the great excess of bases, and the large amount of water which it contains.

TALC.

This species is comparatively rare among the Laurentian rocks, where it seems to be generally replaced by pyrallolite. A greyish steatite or soapstone is however met with in this series, in the township of Elzivir. It gave to dilute nitric acid about twenty-five per cent. of carbonates of lime and magnesia, and left a soft flaky talc. This was freed by washing, from four or five per cent. of magnetic iron, and, after drying at 212° F., yielded to analysis, silica 59·10, magnesia 29·05, protoxyd of iron, with traces of manganese, 3·51, volatile 5·56 = 97·32. Unlike the talcs of the Silurian series, this mineral contained no traces of nickel. Talc

Among the altered Silurian strata, talc is abundant, sometimes in crystalline foliated masses, but it more frequently forms beds of a compact or schistose variety of steatite or soapstone, interstratified with serpentine, Steatite magnesite, or clay slate, and often enclosing actinolite, or bitter-spar. A greenish-white translucent steatite from Potton, gave by analysis, silica 59·50, magnesia 29·15, protoxyd of iron 4·50, alumina 0·40, oxyd of nickel, traces, volatile 4·40 = 97·95. A silvery-white flaky talc-schist, also from Potton, afforded silica 51·50, magnesia 22·36, protoxyd of iron 7·38, lime 11·25, alumina 3·50, oxyd of nickel, traces, volatile 3·60 = 99·59. The talc is here apparently mixed with hornblende, or with some other anhydrous silicate containing lime.

PYRALLOLITE OR RENSSELAERITE.

Rensselaerite. Under the name of rensselaerite, Dr. Emmons of New York described, in 1837, a steatitic mineral, which forms beds or large masses among the Laurentian rocks in the northern part of that State. It is generally massive or granular, but sometimes appears in regular crystals, which have the external form and the cleavage of pyroxene. Dr. Beck, who submitted to analysis an impure specimen of it from Canton, New York, declared it to be a mixture of steatite with pyroxene. He found it to contain silica 59·75, magnesia 32·90, lime 1·00, peroxyd of iron 3·04, water 2·85. This composition agrees closely with that assigned by Beudant to the so-called steatitic pyroxene of Sahla in Sweden, and with the pyrallolite of Nordenskiold, from Pargas in Finland, where it occurs in crystalline limestone with apatite, sphene, and green pyroxene; being, according to Nordenskiold, often incrusted with the latter mineral. Dana, in his Mineralogy, has pointed out the resemblance between the two minerals pyrallolite and rensselaerite, which are probably identical, so that the older name of pyrallolite should take precedence. (See Schwieger's Journal, xxxi, 386; and for rensselaerite, Reports by Emmons and Beck on the Geology and Mineralogy of New York, *passim*.)

Pyrallolite. A bed of pyrallolite occurs in crystalline limestone at Grenville. It is granular, and made up of strongly coherent cleavable grains, but druses of small crystals are occasionally met with in the mass. Its hardness is from 2·5 to 3·0. The density of the mineral from Grenville, is 2·757; that of a coarsely columnar radiating variety from Charleston Lake, 2·644. A specimen from an unknown locality, in the vicinity of Brockville, exhibits cleavage surfaces one fourth of an inch broad. The color of the mineral is generally greenish-white or sea-green, sometimes pearl-white. Very dark colored, nearly black varieties are also described by Dr. Emmons. It is translucent, with a vitreous lustre on the cleavage surfaces, elsewhere waxy. The mineral is sectile and unctuous like steatite. Impure massive varieties of it sometimes occur, as in Rawdon; where a rock, which is associated with crystalline limestones, and has the aspect of pyrallolite, holds scales of silvery mica, and of graphite. A bed of pyrallolite also occurs in Ramsay. Unlike talc, the pyrallolite from Grenville is attacked and partially decomposed by boiling in concentrated sulphuric acid. A portion thus treated, gave up 3·89 per cent. of magnesia. It loses no water at 300° F., and only 3·80 per cent. by a long continued red heat; but when heated to whiteness, the loss is greater. Neither lime, manganese, nor nickel, were detected in the specimens analyzed, which were three in number. I is the granular variety from Grenville, carefully freed from adhering calcite; II, a columnar specimen from Charleston Lake; and III, crystals from Canton, New York, obtained from Dr. Emmons.

	I.	II.	III.
Silica,	61·60	61·90	61·10
Magnesia,	31·06	30·42	31·63
Protoxyd of iron,	1·53	1·45	1·62
Water,	5·60	6·54	5·60
	99·79	100·31	100·05

The specimen analyzed by Beck was doubtless impure, as was probably that of Nordenskiold. The mineral seems to be identical with the steatitic substance from China, which has been mistaken for agalmatolite, and like this is wrought into small vases and other objects of use and ornament. It is evidently, as maintained by Dr. Emmons, a distinct species; and as a rock, it replaces, for the most part, in the Laurentian system, the talcs, which are frequent in other series of metamorphic rocks. It differs but little from talc in composition, except in a somewhat greater amount of water; and the two specimens may perhaps be regarded as dimorphous conditions of the same silicate of magnesia.

SERPENTINE.

This species, either alone or with various admixtures, is found in large beds, both in the Laurentian and Silurian series, and constitutes the rocks to be described in a subsequent chapter by the name of ophiolites.

Among the massive and nearly pure Laurentian serpentines, may be mentioned those of Grenville and of Burgess, which are generally pale-yellowish, or greyish-green; unless, as in the latter locality, they are penetrated in parts by red peroxyd of iron. They also occur in this series intermingled with carbonates of lime and magnesia, and disseminated in grains, or forming veins, both in limestones and dolomites. The serpentines of the Laurentian series have a lower specific gravity, and contain less oxyd of iron and more water than ordinary serpentines. The analyses of some of them are subjoined. I is the retinalite of Dr. Thompson, from Grenville, where it is imbedded in a white limestone. Its color varies from honey-yellow to oil-green, and its density is 2·47–2·52. II is a similar serpentine, of a pale wax-yellow, from the Calumet Island; density 2·36 – 2·38. III, grains of honey-yellow serpentine, separated by dilute

Laurentian serpentines.

Retinalite.

nitric acid from a white lamellar dolomite from Grenville. IV is the reddish-brown serpentine-rock or ophiolite of Burgess, from which a portion of carbonates of lime and magnesia was first removed by acetic acid:

	I.	II.	III.	IV.
Silica,	39·34	41·20	44·10	39·80
Magnesia,	43·02	43·52	40·05	38·40
Peroxyd of iron,	1·80	·80	1·15	7·92
Water,	15·09	15·40	14·70	13·80
	99·25	100·92	100·00	100·00

A pale greenish-grey opaque and earthy serpentine, or pipe-stone, from Calumet Island, contains a mixture of argillaceous matter, and gave by analysis, silica 37·50, magnesia 37·58, alumina and a little oxyd of iron 9·00, water 15·00 = 99·08.

Huronian serpentine.

No serpentine has yet been observed in the rocks of the Huronian series in Canada; but Mr. Whitney has described an ophiolite belonging to them, which forms the headland of Presqu'île, near Marquette, in northern Michigan, and may be noticed in this connection. It is blackish-green, and contains an admixture of octahedral crystals of magnetic iron, besides from two to six per cent. of an insoluble silicate, probably hornblende. The remaining portion is a serpentine, containing a large proportion of protoxyd of iron. (American Journal of Science [2], xxviii, 18.)

Silurian serpentines.

The serpentines of the altered Silurian rocks in Eastern Canada, often form vast masses, almost without admixture. At other times, they enclose diallage, actinolite, garnet, and chromic iron, or are intermingled with carbonate of lime, with dolomite, and sometimes with ferruginous magnesite; forming varieties of ophiolite rock, into which talc sometimes enters. The almost constant presence of small portions of oxyds of chrome and nickel, is to be remarked in the analyses, not only of these serpentines, but of the other magnesian rocks of the region; while these two metals appear to be altogether wanting in similar rocks of the Laurentian series. The analyses of a few specimens of these serpentines are subjoined. I, a finely granular olive-green massive serpentine, from Orford, enclosing grains of magnetic and chromic iron-ores; density 2·597. II, a fragment of blackish-green serpentine, from a conglomerate ophiolite in Orford. III, a massive greenish-white serpentine, near to a bed of chromic iron in Ham; density, 2·546. IV, a fibrous serpentine (picrolite), from Bolton; density 2·607.

	I.	II.	III.	IV.
Silica,	40·30	42·90	43·40	43·70
Magnesia,	39·07	36·28	40·00	40·68
Protoxyd of iron,	7·02	7·47	3·60	3·51
Oxyd of nickel,	·26	·15	....	undet.
" chrome,	traces	·25	....	"
Water,	13·35	13·14	13·00	12·45
	100·00	100·19	100·00	100·34

Foliated and fibrous varieties of serpentine are common in veins in the ophiolites of the Silurian series; and they constitute the varieties which have been described under the names of baltimorite, marmolite, picrolite, and chrysotile. The latter occurs in silky flexible fibres, whose direction is transverse to the walls of the vein; and it constitutes much of the so-called asbestus or amianthus of serpentine rocks. The true asbestus is, however, a fibrous tremolite or hornblende. Chrysotile.

A yellowish-white compact earthy mineral is found filling fissures in the massive pyrallolite of Grenville. It is very soft and sectile, polishes under the nail, acquiring a waxy lustre, and adheres strongly to the tongue. Some portions of the mass contain disseminated scales of silvery mica. The mineral in powder is decomposed, like serpentine, by boiling sulphuric acid, and gave, silica 46·66, magnesia (by difference) 38·05, protoxyd of iron 1·33, volatile 13·96 = 100·00. The physical characters of this substance separate it from serpentine, and ally it to meerschaum and aphrodite, which latter mineral it resembles in composition. Aphrodite.

ALUMINOUS SILICATES.

Having described the principal silicates of protoxyds hitherto observed in Canada, next in order may be noticed those minerals which contain alumina, and are for the most part double silicates of this base, and a protoxyd, such as potash, soda, lime, magnesia or protoxyd of iron, either with or without water. Of the simple aluminous silicates, only andalusite and pholerite have been met with in the province. Kyanite is found in the adjacent state of Vermont and farther southward, and might be expected in south-eastern Canada, but has not yet been detected. The same thing may be said of pyrophyllite, which occurs in North Carolina, in rocks supposed to be of the same age with those of Vermont and the Eastern Townships, both crystallized with quartz, and massive, giving rise to a kind of aluminous steatite. Aluminous silicates.

The minerals of the feldspar group, including scapolite, orthoclase, and the triclinic feldspars, will now be described, and will be followed by the zeolites, agalmatolite, glauconite, chlorite, and some related alumino-magnesian silicates. To these will succeed beryl, tourmaline, the micas, and the denser double silicates, garnet, epidote, chloritoid, and staurotide, together with andalusite. After these will be noticed zircon, spinel, corundum, and quartz.

SCAPOLITE.

This species is abundant in the Laurentian rocks of northern New York, where it is generally associated with pyroxene and sphene. Large crystals of scapolite are met with in a similar association in Hunterstown. It

Scapolite. has also been observed in Grenville; and a lilac-colored scapolite in irregularly aggregated crystals, forms masses in limestone at Calumet Island. An interesting variety was found associated with black mica in a boulder, near Perth. It has a hardness of 5·5, and a density of 2·640 – 2·667, is greenish-grey in color, very tough and subtranslucent, with a waxy lustre, pearly upon the cleavage surfaces, which are very distinct in two directions at right angles. Its analysis gave silica 46·30, alumina 26·20, lime 12·88, magnesia 3·63, protoxyd of iron 0·60, potash 2·88, soda 4·30, volatile 2·80 = 99·59. This mineral is remarkable for the considerable amounts of potash and magnesia which it contains.

ORTHOCLASE.

Orthoclase. This species of feldspar, which enters largely into the composition of granite, syenite, gneiss, trachyte, and many porphyries, is very abundant among the rocks of the Laurentian system. A reddish colored variety is the predominant mineral in the coarse-grained gneiss, which is characteristic of this series of rocks. A beautiful white porphyroid gneiss from the Rivière Rouge, in Argenteuil, consists of a fine-grained base of orthoclase, with a little quartz, containing besides red garnets, and small quantities of silvery-mica, large cleavable masses of white semi-transparent orthoclase, having a density of 2·56. From its analysis, I, given below, it will be seen to contain potash, with but little soda: the same is true of the granular base of the rock, II. A fragment of reddish feldspathic gneiss from Grenville, in which orthoclase was the predominant mineral, contained however a larger proportion of soda, as is shown by its analysis, III.

	I.	II.	III.
Silica,	65·75	70·10	69·00
Alumina,	19·40	16·40	17·90
Peroxyd of iron,	....	....	....
Lime,	0·45	1·42	2·80
Potash,	13·60	10·96	3·86
Soda,	0·69	0·59	3·70
Volatile,	0·25	0·40	1·00
	100·14	100·07	98·26

Perthite. The perthite of Dr. Thompson is a reddish orthoclase, which, with white quartz, forms a coarse granite in Burgess. In this rock, cleavage surfaces, several inches broad, are sometimes met with, which are barred with lighter and darker bands. These are flesh-red and reddish-brown in color; and they exhibit, in certain lights, golden reflections like aventurine, which are very beautiful in some polished specimens. The density of this feldspar is 2·57–2·58. One of two concordant analyses gave silica 66·44, alumina 18·35, peroxyd of iron 1·00, lime 0·67, magnesia 0·24, potash 6·37, soda

5·56, volatile 0·40 = 99·03. A second determination gave silica 66·50, alumina and peroxyd of iron 19·25, lime 0·56, and potash 6·18.

Dr. Bigsby has noticed, under the name of aventurine, a largely crystallized flesh-red feldspar, which, like the perthite, shines with golden points, and, according to him, forms part of a great granitic vein traversing gneiss, on the north-east shore of Lake Huron, twenty miles east of the French River. Aventurine feldspar.

Masses of a rock, brought from the Labrador coast, consist of a pale reddish-brown cleavable feldspar, mixed only with a small quantity of dark green hornblende. This feldspar, which is seemingly orthoclase, sometimes offers cleavages half an inch broad, which exhibit golden-bronze reflections of great beauty, resembling those of some varieties of labradorite. A fine green orthoclase in a granitic vein has also been brought from the same region.

Associated with the Laurentian limestones there are frequently found beds of a coarse-grained rock, made up of white feldspar and dark green pyroxene, with brown sphene, and occasionally with quartz. This peculiar rock has been observed at Lachute, where it contains brown tourmaline, plumbago, and magnetic pyrites; at the Calumet Falls; and in Grenville, Elmsley, and Burgess. The feldspar has generally the cleavages and other characters of orthoclase. A specimen, probably from Chatham, with brown sphene and quartz, had a specific gravity of 2·55–2·57, and gave by analysis, silica 65·20, alumina 18·30, lime 0·34. A partial determination of the alkalies, gave potash 8·57, soda 1·75 ; showing it to be a nearly pure potash orthoclase.

The feldspar which occurs with pyroxene in the Laurentian rocks of Hammond, St. Lawrence County, New York, and closely resembles those just described, was by Breithaupt distinguished by the name of loxoclase; Loxoclase. but according to Smith and Brush it has the cleavage and density of orthoclase, with which it agrees in composition. It is however remarkable for the large amount of soda which it contains. A pure crystal of this feldspar gave to these chemists, soda 7·81, potash 4·35, lime 1·09; and another specimen, soda 7·98, potash 2.36, and lime 2·36. (American Journal of Science [2], xvi, 43.)

A white feldspar, which is found with sphene and pyroxene, at Willsborough, New York, in a rock similar to that of Chatham, is triclinic, beautifully striated, and has the aspect of oligoclase. The mineral associations of these various feldspars are similar to those of the scapolite mentioned above.

The orthoclase from trachytic rocks often contains a large amount of soda. The following are analyses of feldspars from the trachytes of Canada. IV, orthoclase, from the porphyritic trachyte of Chambly; V, orthoclase of the granitoid trachyte of Brome Mountain, density 2·575; VI, orthoclase from Shefford Mountain, density 2·561; VII, feldspar of compact white trachyte from Mount Royal; VIII, feldspathic residue Orthoclase of trachytes.

from a phonolite from Lachine, which contained a large proportion of natrolite, and of carbonates of lime, magnesia, and iron.

	IV.	V.	VI.	VII.	VIII.
Silica, ...	66·15	65·70	65·15	63·25	59·70
Alumina, ...	19·75	20·80	20·55	22·12	23·25
Lime,................	·95	·84	·73	·56	·99
Potash, ...	7·53	6·43	6·39	5·92	9·16
Soda,................	5·19	6·52	6·67	6·29	2·97
Volatile, ...	·55	·50	·50	·93	2·23
	100·12	100·79	99·99	99·07	98·30

Orthoclase of mineral veins.

Lake Superior.

Mr. J. D. Whitney has called attention to the frequent occurrence of orthoclase in the mineral veins of Lake Superior, where it is associated with native copper, epidote, calcite, natrolite, analcime, quartz, and saponite. It is sometimes found incrusting the latter two species, and at others is covered by calcite or natrolite ; the minerals, according to Mr. Whitney, being associated in such a manner as to show the contemporaneous crystallization of the copper, natrolite, calcite, and orthoclase. The latter species, from its associations and peculiar aspect, was at first mistaken for stilbite. It forms crystalline lamellar masses, small geodes, or groups of implanted crystals, which are pale or bright red in color. The crystals are seldom more than one tenth of an inch in length, but are sometimes distinct enough for measurement. This orthoclase gave to Mr. Whitney's analysis, silica 65·45, alumina 18·26, potash 15·21, soda 0·65, oxyd of iron 0·57, manganese, a trace, = 100·14. (American Journal of Science [2], xxviii, 16.)

A particular interest is attached to the existence of orthoclase in veins, associated with minerals which are evidently of aqueous origin, for the reason that hitherto there were but few examples of the occurrence of feldspar under conditions which could leave no doubt of its aqueous origin.

Eastern Townships.

Other instances of a similar kind are however met with in veins in the slates of the Eastern Townships, where a flesh-red orthoclase occurs so intermingled with white quartz and chlorite, as to show the contemporaneous formation of the three species. The orthoclase generally predominates, often reposing upon or surrounded by chlorite ; and at other times it is imbedded in quartz, which covers the latter. Drusy cavities are also lined with small crystals of the feldspar, and have been subsequently filled with a cleavable bitter-spar, containing more or less of the carbonates of iron and manganese, and sometimes associated with specular iron, rutile, and sulphurets of copper. These veins are found cutting both the nacreous argillaceous slates, and the chloritic slates of the Eastern Townships, and are well seen in Leeds, Inverness, and Sutton. A study of them will show a transition from veins containing quartz and bitter-spar, with a little chlorite or talc, through others in which feldspar gradually predominates, until we arrive at veins made up of orthoclase and quartz, sometimes including mica, and having the characters of a coarse-grained granite; the occasional presence of sulphurets of copper and specular iron characterizing all of them alike. It is probable that these, and indeed a great proportion of quartzo-feldspathic veins are of aqueous origin, and have been deposited from solutions in or fissures in the strata, precisely like metalliferous lodes. This remark applies especially to those granitic veins which include minerals containing the rarer elements. Among these are boron, phosphorus, fluorine, lithium, rubidium, glucinum, zirconium, cerium, tin, and columbium, which characterize the mineral species apatite, tourmaline, lepidolite, spodumene, beryl, zircon, allanite, cassiterite, columbite, and many others. Granitic veins

ALBITE.

A coarse-grained granite, which is probably intrusive, occurs in the township of Bathurst, the feldspar of which was described by Dr. Thompson under the name of peristerite, in allusion to its bluish opalescence, but is found to be albite. In some portions of the rock the quartz is disseminated through the feldspar, so as to give rise to what is called a graphic granite, but large cleavable masses are free from this admixture, and exhibit the usual striation of the crystals of the triclinic feldspars. The color is white, passing into pearl-grey and reddish, and the mineral shows an opalescence, in which blue predominates, mingled however with pale green and yellow. Its hardness is 6·0, and its density 2·625. Analysis gave silica 66·80, alumina 21·80, potash 0·58, soda 7·00, lime 2·52, magnesia 0·20, peroxyd of iron 0·30, volatile 0·60 = 99·80. Another specimen yielded silica 67·25, lime 2·03. Albite. Peristerite.

A similar granite, consisting of large cleavable masses of white albite, with quartz and mica, is found at the lake of Three Mountains, on the Rivière Rouge; and some of the garnet-bearing gneiss of that vicinity is also albitic. Mingled with the opalescent albite of Burgess are found portions of pale reddish orthoclase, an association not uncommon in granites. A white feldspar, which is sometimes found with flesh-red orthoclase in boulders of granitoid Laurentian gneiss, is probably albite or oligoclase.

OLIGOCLASE.

A feldspar having the composition of oligoclase forms, with black hornblende, the intrusive diorite of Mount Johnson. It often occurs in crystals half an inch in diameter, which weather to an opaque white. The color of this feldspar is white, rarely greenish or greyish. Its lustre is vitreous, inclining to pearly. The specific gravity of a fragment was 2·631, of the mineral in powder 2·659. Its analysis gave silica 62·05, alumina 22·60, peroxyd of iron 0·75, lime 3·96, potash 1·80, soda 7·95, volatile 0·80 = 99·91. Another specimen yielded silica 62·10, and lime 3·69. Oligoclase.

ANDESINE AND LABRADORITE.

Andesine. The triclinic feldspars, containing lime and soda, which make up the great anorthosite formation of the Laurentian series, offer considerable variations in their composition. Some of them have that assigned to andesine, others that of labradorite, or are intermediate between the two, while others are near to anorthite. The following analyses will give some notion of the variable composition of these feldspars. I and II are of a reddish cleavable feldspar, which occurs in large striated cleavable masses, with hypersthene and ilmenite, at Château Richer, and has a density of 2·66–2·67. III is the greenish granular base in which the preceding is imbedded. It has a specific gravity of 2·67, and was treated, previous to analysis, with acetic acid, which removed a few thousandths of carbonate of lime. IV, a pale lavender-blue vitreous, semi-transparent feldspar in large cleavable striated masses, the surfaces of which are often curved. It occurs in a boulder at Château Richer, and has a density of 2.68–2·69. V, a specimen similar to the last, from a larger boulder, in the adjacent parish of St. Joachim. These two are imbedded in a reddish granular base, with grains of ilmenite, and a little brown mica. VI, a similar feldspar from Lachute, where it occurs in large finely striated cleavable masses, in a greenish granular base. It is semi-transparent, and of a lavender-blue, passing into sapphire-blue. This feldspar has a density of 2·687.

	I.	II.	III.	IV.	V.	VI.
Silica,..............	59·55	59·80	58·50	57·20	57·55	58·15
Alumina,...........	25·62	25·89	25·80	26·40 }	27·10	{ 26·09
Peroxyd of iron,.....	0·75	0·60	1·00	0·40 }		{ 0·50
Lime,...............	7·73	7·78	8·06	8·34	8·73	7·78
Magnesia,...........	traces	0·11	0·20	....	....	0·16
Potash,.............	0·96	1·00	1·16	0·84	0·79	1·21
Soda,..............	5·09	5·14	5·45	5·83	5·38	5·55
Volatile,............	0·45	....	0·40	0·20	0·20	0·45
	100·15	99·82	100·57	99·66	99·75	99·89

Labradorite. To these may be added the following: VII, a bluish-white granular homogeneous translucent rock from Rawdon, with a density of 2·69. VIII, a similar rock from Château Richer, pale bluish or greenish grey, with red spots. The lustre on the cleavage surfaces of the grains is vitreous, but elsewhere waxy. The rock contains small scattered flakes of black mica, and has a density of 2·68. IX, a bluish opalescent cleavable feldspar from Morin, with a density of 2·684–2·695. X, a lavender-blue cleavable feldspar, with a grey opalescence, from a boulder in Drummond, Canada West, and having a density of 2·697. XI, a pale sea-green translucent cleavable feldspar, with a density of 2·695–2·703, from a granular mass of a similar character, forming a boulder at Hunterstown. XII, a greenish-white granular variety of anorthosite rock, from a boulder near Ottawa, having a density of 2·73. This is a portion of the specimen upon which Dr. Thompson founded the species named by him bytownite. Bytownite.

	VII.	VIII.	IX.	X.	XI.	XII.
Silica, ...	54·45	55·80	54·20	54·70	49·10	47·40
Alumina, ...	28·05	26·90	29·10	29·80	26·80	30·45
Peroxyd of iron, ...	0·45	1·53	1·10	0·36	0·80	0·80
Lime, ...	9·68	9·01	11·25	11·42	14·67	14·24
Magnesia, ...	....	0·27	0·15	traces	traces	0·87
Potash, ...	1·06	0·86	undet.	0·23	undet.	0·38
Soda, ...	6·25	4·77	"	2·44	"	2·82
Volatile, ...	0·55	0·45	0·40	0·40	1·30	2·00
	100·49	99·59		99·35	98·96	

The analyses I and II have the composition ascribed to andesine, while VII, VIII, IX, and X have that of labradorite. The beautifully pure and crystalline feldspars IV, V, and VI have a composition intermediate between these two, while XI, and the bytownite, XII, approach to anorthite.

The bytownite gives by analysis nearly the same results as the feldspar from the intrusive diorite of Yamaska Mountain. This rock is coarsely crystalline, and made up of black hornblende, with a little yellow sphene, and a white triclinic feldspar, the cleavage surfaces of which are sometimes half an inch broad, and beautifully striated. The density of the powdered feldspar was 2·756 – 2·763. Its analysis gave silica 46·90, alumina 31·10, peroxyd of iron 1·35, lime 16·07, magnesia 0·65, potash 0·58, soda 1·77, volatile 1·00 = 99·42. Another specimen gave silica 47·00, alumina and iron oxyd 32·65, lime 15·90. Both of these feldspars may be looked upon as impure anorthite. Anorthite.

The following also are analyses of feldspars from intrusive rocks. XIII, grains separated by crushing and washing from a granitoid micaceous trachyte of Yamaska Mountain, and having a density of 2·563. XIV, selected grains from another portion of the same rock. XV, cleavable grains of white vitreous feldspar, separated by washing from the micaceous diorite of Belœil, and still holding a little mica. XVI, grains of a yellowish vitreous feldspar from the peridotic dolerite of Montarville, and having a density of 2·73 – 2·74. XVII, feldspar of a similar peridotic dolerite from Mount Royal, with a small admixture of augite. Feldspars of intrusive rocks.

	XIII.	XIV.	XV.	XVI.	XVII.
Silica, ...	61·10	58·60	58·30	53·10	53·60
Alumina, ...	20·10	21·60	24·72	26·80	25·40
Peroxyd of iron, ...	2·90	2·88		1·35	4·60
Lime, ...	3·65	5·40	5·42	11·48	3·62
Magnesia, ...	0·79	1·84	0·91	0·72	0·86
Potash, ...	3·54	3·08	2·74	9·71	undet.
Soda, ...	5·93	5·51	6·73	4·24	"
Volatile, ...	0·40	0·80	0·50	0·60	0·80
	98·41	99·71	99·32	99·00	

Constitution of feldspars

The analysis XVI gives nearly the composition of labradorite, while XIII, XIV, and XV are unlike any recognized variety. The variations in the composition of feldspathic minerals are well known to be very great, and seem to countenance the view that the homœomorphous species albite, anorthite, and orthoclase, may crystallize together in variable and indefinite proportions. The so-called species oligoclase, andesine, and labradorite are connected by feldspars intermediate in composition, of which we have examples in IV, V, and VI. All of these triclinic feldspars may be regarded as admixtures of albite and anorthite; while the soda-bearing feldspars of the trachytes, and the feldspars like perthite, and like XIII and XIV, would appear to be mixtures of orthoclase with albite, or some other triclinic feldspar.

It is worthy of note that in all the triclinic feldspars whose analyses are given above, the specific gravity is greater as the silica and alkalies diminish, and the alumina and lime increase, in amount. All of the triclinic feldspars have thus a common atomic volume, in which they agree with the lithia-feldspar, petalite. (Am. Jour. of Science [2], xviii, 270.)

Opalescent feldspars

The most important localities of these feldspars have already been mentioned in describing their different varieties, and in mentioning the distribution of the anorthosite rocks in Chapter III. The brilliant play of colors which makes the labradorite prized as an ornamental stone, is by no means a constant character. It has not been observed in the beautiful varieties of these feldspars from Château Richer; but it is frequent in large cleavable masses, imbedded in the anorthosites of Morin and Mille-Iles, and also in boulders scattered along the valley of the Ottawa, and to the southward of it. The most western exposure of these feldspars known, is that noticed by Dr. Bigsby, who has described a breadth of five miles, occupied by anorthosite on the coast of Lake Huron, about sixty miles west from Penetanguishene, and ninety miles east from the French River. Here it forms the main-land and numerous small islands, among which are found coarse-grained varieties of bluish and grey feldspar, with purple, green, and flame-colored opalescence. These colored reflections are not confined to those triclinic feldspars which have the composition of labradorite, but are seen in some which approach to andesine in composition, and even in albite, —the white variety called peristerite, which is described above, being beautifully opalescent.

NEPHELINE AND SODALITE.

Nepheline. Sodalite.

Crystals of white nepheline, with a fine blue variety of sodalite in small grains, have been found sparingly in the granitoid trachyte of Brome. Grains of orange-red nepheline or elæolite are abundant, with black hornblende, in a white feldspathic rock, which is found in boulders on Pic Island, in Lake Superior.

PETALITE AND SPODUMENE.

Petalite is here mentioned among the minerals of Canada, upon the authority of Dr. Bigsby, according to whom this mineral was found with tremolite, in a large boulder on the lake shore, at Toronto. Its only known locality *in situ*, on this continent, is at Bolton, in Massachusetts, where it occurs with scapolite in crystalline limestone. Spodumene, which is found in several localities in New England, in granitic veins with tourmaline and beryl, has been observed, in a single instance, in a small rolled mass of granite, near Perth. Petalite. Spodumene.

ZEOLITES.

The true zeolites, which are hydrous silicates of alumina with a silicate of a protoxyd, may be mentioned in this connection. Several minerals of this class have been observed in the amygdaloidal traps of Lake Superior, and more sparingly about Montreal. Among these, a fibrous zeolite, described by Prof. Chapman as thomsonite, is found, according to Dr. Bigsby, of a red color at Gargantua, and both red and green at Point Mainainse, where it is associated with calcite. Prehnite, laumontite, and analcime are also common among the minerals of the amygdaloid of the north shore of Lake Superior, generally associated with native copper, and often forming its gangue. Analcime abounds with the native copper of Michipicoten Island. Zeolites. Thomsonite. Analcime.

A radiated zeolitic mineral, probably natrolite, occurs in small quantities in druses in the traps near Montreal, associated with heulandite, chabazite, and analcime. The latter two minerals have been observed with quartz and calcite in druses in a porphyritic trachyte on the Chambly canal. A zeolitic mineral forms an integral part of many of the trachytic rocks about Montreal, which, through this admixture, pass into phonolites,—to be described in their proper place. The zeolite in these, which is intermingled with orthoclase and with carbonates, readily gelatinizes with acids, and has apparently the composition of natrolite. It sometimes forms thirty or forty per cent. of the rock. Natrolite.

Prehnite is one of the most common vein-stones of the native copper on Lake Superior; and in the mines of the southern shore, it has been found in radiating masses, imbedded in the blocks of copper. A mineral to which the name of chlorastrolite has been given, is found imbedded in the amygdaloid of Isle Royale, and in worn pebbles along the shore. As it is somewhat prized as an ornamental stone, it may be mentioned in this connection, although it has not yet been found on the northern shore of the lake. It forms small masses of a radiated or stellated structure, and is opaque, with a rich bluish-green color, and a pearly, somewhat chatoyant Prehnite. Chlorastrolite.

lustre. It had been separated from prehnite, which it closely resembles in composition, on account of its somewhat higher specific gravity, and also because it contains more oxyd of iron and more water than prehnite. According to Prof. Chapman, however, its specific gravity varies from 2·98 to 3·20, from the presence of more or less magnetic oxyd of iron, which often forms the nucleus of the fibrous masses of chlorastrolite. The amount of water he also found to vary, in different specimens, from 4·11 and 4·18 to 5·51 per cent.

Apophyllite. Apophyllite, although not a proper zeolite, may be here mentioned as occurring in foliated masses or plates, often of a red color, associated with calcite in Prince's vein on Spar Island. The related species, pectolite, has been observed on Isle Royale. Here also finely crystallized datholite has been found, and a white massive porcelain-like variety of the same mineral is met with at some of the mines on the southern shore.

AGALMATOLITE OR GIESECKITE.

Agalmatolite. Under this head it is proposed to notice a peculiar mineral which, under different forms, occurs both in the Laurentian and Silurian series, and sometimes forms rock-masses among them. The name of agalmatolite, or figure-stone, was originally given to a soft unctuous mineral, which is carved by the Chinese into ornaments. The researches of Scheerer and of Brush have however shown that these figure-stones are not all alike, but may be referred to three species, very distinct in chemical composition, though closely resembling each other in specific gravity, hardness, and general aspect. Of these, the first is a hydrous silicate of alumina and potash, having the composition of gieseckite. The second is a hydrous silicate of alumina, and is apparently a compact pyrophyllite. The third is a silicate of magnesia, having the composition of talc or pyrallolite, to which last species it belongs (see page 470). Of these three figure-stones, the second and third are nearly infusible before the blow-pipe, and are scarcely attacked by acids; while the first fuses to a white enamel, and is readily decomposed by hydrochloric acid, the silica separating in a pulverulent form.

The minerals known by the names of gieseckite, liebnerite, and pinite, all of which appear to crystallize in the hexagonal system, agree in composition, being hydrous silicates of alumina and potash, like the first mentioned kind of figure-stone, which seems to be only a massive variety of gieseckite. So long, therefore, as the crystalline form of agalmatolite is unknown, it may be provisionally united with gieseckite.

Gieseckite. The crystallized gieseckite which occurs in the Laurentian limestones of Diana, Lewis County, New York, associated with a dark brown pyroxene, and with magnetic pyrites, has been described by Prof. Brush. It forms large and thick hexagonal prisms, sometimes two inches or more in diameter, and often exhibiting pyramidal planes. Considerable variations are observed in the angles of these crystals, whose cleavage is sometimes very distinct with the sides of the prisms, and at others scarcely perceptible. Its colors are pea-green and leek-green, and its lustre vitreous or greasy. Thin fragments are translucent. The specific gravity of the mineral is from 2·73 to 2·75, and its hardness about that of calcite, or from 3·0 to 3·5. Its composition is very constant: one of three closely agreeing analysis gave to Brush, silica 45·70, alumina 31·65, protoxyd of iron 1·10, lime 2·21, magnesia 3·46, soda 0·90, potash 8·06, water 7·01 = 100·09. (Am. Jour. of Science [2], xxvi. 64.)

The name of wilsonite has been given to a mineral discovered in the township of Bathurst, by Dr. Wilson of Perth. It is associated with a white aluminous pyroxene, described on page 467, together with calcite, mica, and prisms of blue apatite. The wilsonite is in rose-red prismatic masses, which have two perfect parallel cleavages, apparently nearly at right angles, giving to the mineral a somewhat fibrous aspect, besides two distinct diagonal cleavages. The mineral has a hardness of 3·5, or a little greater than that of calcite, on the planes of easy cleavage, but attains 5·5 at the extremities of the prisms. Its specific gravity equals 2·76–2·77. The lustre of the mineral is vitreous, shining, and somewhat pearly on the cleavage surfaces: thin fragments of it are translucent. Its reactions with the blow-pipe, and with strong acids, are like those of agalmatolite. Dilute hydrochloric acid removes from the powdered mineral a portion of carbonate of lime, without however attacking the silicate, or changing its color. Two analyses of the wilsonite thus purified, gave the following results: Wilsonite

	I.	II.
Silica,	47·50	47·70
Alumina,	31·17	31·22
Magnesia,	4·25	4·14
Lime,	1·51	0·39
Potash,	9·22	9·38
Soda,	0·82	0·95
Water,	5·50	5·35
	99·97	99·13

It contains, in addition, traces of maganese, to which its color is probably due. As gieseckite has, by some mineralogists, been looked upon as the result of an alteration of nepheline or some other hexagonal species, so wilsonite has been called an altered scapolite. The notion of such alterations or pseudomorphism is, however, rejected by many of the best authorities at the present day, and there is no good reason for supposing that these minerals ever had a different composition from their present one. The crystalline form and cleavages of wilsonite are obscure; but its other Pseudomorphism.

characters, and its composition approach so closely to those of gieseckite, that it may with propriety be considered as a variety of this mineral species for the present.

Dysyntribite. Associated with the iron ores of the Laurentian system, at Rossie and at Diana, in New York, occurs a rock which had been regarded as serpentine until 1849, when Prof. C. U. Shepard described it as a hydrous silicate of alumina, to which, from its toughness, he gave the name of dysyntribite. He, however, overlooked the presence of potash in the mineral; and in 1853, Profs. Smith and Brush, by their analyses, showed that it contained a large proportion of this alkali, and was closely allied to agalmatolite and to pinite in composition. It has a hardness of 3·0 – 3·5, and a specific gravity of 2·76 – 2·81, is of a dull greyish-green color, sometimes mottled with red, and is somewhat translucent on the angles. This rock has not yet been found in the Laurentian system in Canada, but is represented in the Silurian series.

Parophite. In 1852, before the true composition of dysyntribite was known, a similar rock, from St. Nicholas, which had at first been taken for serpentine, was described by the name of parophite. It occurs in the vicinity of an intrusive mass of trap, which traverses shales belonging to the Quebec group, apparently converting portions of them into a pale green translucent unctuous substance, which sometimes forms layers an inch in thickness, and is seen coating interstratified beds of sandstone, and also filling up small fissures in an indurated red argillite. In one instance, a layer of the shale several inches in thickness, was found to be earthy within, but translucent at its contact with the overlying rock. In a continuation of the layer, where it became thinner, the transformation of the shale into the green translucent mineral was complete. Comparative analyses showed that this does not differ in composition from the earthy shale, the change from the one to the other being only molecular. This parophite, or rather agalmatolite, is massive and granular, or schistose in texture. Sometimes it is botryoidal, with a concentric structure and a conchoidal fracture. Its hardness varies from 2·5 to 3·0, and its specific gravity from 2·68 to 2·78. The lustre of the mineral is waxy and shining, and its color varies from greenish-white to olive-green. It is sub-translucent, and unctuous to the touch, like steatite. The accompanying slate, which passes in a little distance into the agalmatolite, is dark ash-grey, marked with red. Its laminæ are somewhat curved, the surfaces feebly shining and slightly unctuous. It is completely earthy and opaque, even on the edges, very soft, so as to be scratched by the nail, and not at all gritty.

A layer of agalmatolite, which had in like manner been taken for serpentine, forms a thin bed in clay slate, near the Famine River, in the parish of St. Francis, Beauce. It is honey-yellow, translucent, granular in texture, with a waxy lustre, and is readily cut with a knife, giving an unctuous powder. The same mineral occurs with chloritic slates on the east shore of Lake Memphramagog, on the fifteenth lot of the first range of Stanstead, forming a belt one hundred and fifty feet wide. In some portions the agalmatolite is granular and nearly free from admixture; in others, it holds a good deal of quartz, and becomes very schistose. A thin layer of the pure agalmatolite, at this locality, has a banded structure and a ligneous aspect, with a shiny satiny lustre. It is translucent, of a wax or amber-yellow color, and, being very unctuous to the touch, resembles steatite. The analyses of some of the above substances are subjoined. Agalmatolite

I and II are the greenish translucent agalmatolite of St. Nicholas: III is the dark ash-grey earthy schist, passing in a short distance into the preceding: IV, the granular agalmatolite of St. Francis; V, the ligneous agalmatolite of Stanstead.

	I.	II.	III.	IV.	V.
Silica,	48·42	48·50	48·10	50·50	50·30
Alumina,	27·60	27·50	28·70	33·40	32·60
Protoxyd of iron,	4·50	5·67	4·80	traces	traces
Lime,	2·80	1·30	2·10	"	....
Magnesia	1·80	2·24	1·41	1·00	1·20
Potash,	5·02	5·30	4·49	8·10	undet.
Soda,	2·78	1·91	1·53	·63	"
Water,	6·88	7·40	8·40	5·36	6·50
	99·80	99·82	99·53	98·99	

Similar rocks to the above occur in the continuation of the same series southward into Vermont. In the recent Report on the Geology of that State, page 505, is an analysis, by Mr. G. F. Barker, of what had been called a magnesian slate, from Pownal, Vermont. It was bluish-grey, unctuous, and had a specific gravity of 2·90: its composition is given in the analysis VI below. VII, VIII, and IX are analyses by Smith and Brush, of different specimens of the dysyntribite of Shepard, from northern New York. (Am. Jour. of Science [2], xvi, 50.]

	VI.	VII.	VIII.	IX.
Silica,	42·90	44·80	46·70	44·74
Alumina,	42·20	34·90	31·01	20·98
Protoxyd of iron,	....	3·01	3·69	4·27
" manganese,	....	0·30	traces	traces
Lime,	0·78	0·66	"	12·90
Magnesia,	1·98	0·42	0·50	8·48
Potash,	5·24	6·87	11·68	3·73
Soda,	1·33	3·60	traces	traces
Volatile (water),	5·60	5·38	5·30	4·86
	100·03	99·94	99·88	99·96

In VI, an undetermined portion of peroxyd of iron is included with the alumina. VII and VIII, as will be seen, approach near to pure agalmatolite in composition; while in IX the smaller amounts of alumina and alkalies, and the large proportions of lime, and magnesia as silicates, indicates an admixture of something like pyroxene. The onkosine of Kobell, which occurs at Salzburg, in masses in a micaceous dolomite, is a substance similar to the above.

The conclusion from all these analyses is, that there exists a hydrous silicate of alumina and potash, remarkable for the small proportion of silica that it contains, which occurs crystallized, and in a nearly pure state, in gieseckite, wilsonite, liebnerite, and pinite. In a massive form, and often more or less impure, it forms a stratified rock, which has been described under the various names of dysyntribite, parophite, magnesian slate, and agalmatolite,—which latter name it will be convenient to retain. The analyses of the specimens from St. Nicholas appear to show that this mineral exists there as an earthy sedimentary deposit, which has been converted into green translucent agalmatolite by the action of an intrusive rock. The local metamorphism from this cause has here produced, within a limited space, similar changes to that wide-spread action which has altered the whole series of strata farther south, and given rise to the agalmatolites of St. Francis and of Stanstead.

GLAUCONITE OR GREEN-SAND.

Glauconite. The glauconite or green-sand of the Cretaceous formation in Europe and the United States, is a hydrous silicate of protoxyd of iron and potash, with a variable amount of alumina. It appears to be related to the agalmatolite just described, by the small proportion of silica and the large amount of potash which it contains. Glauconite occurs in rounded grains, which are sometimes disseminated through limestone, and at others form layers, nearly pure, or mingled only with portions of clay or of quartz sand. These grains, according to the observations of Ehrenberg and Bailey, often occur filling the shells of polythalamia, small spiral mollusks and tubuli, and even the cavities of corals and the spines of echini. With these casts are however other rounded and irregular grains of green-sand, which do not appear to have been formed in any such moulds. This substance is not only abundant in Cretaceous and Tertiary deposits, but is now forming in the ocean, and fills the shells of recent species of polythalamia, obtained from deep-sea soundings along the coast of North America. (Amer. Jour. of Science [2], xxii, 281.)

The grains of glauconite have about the hardness of gypsum, and are blackish-green: when crushed upon white paper they give an olive-green stain. A portion of the glauconite from the Cretaceons formation of New Jersey, was freed from clay by washing, and then submitted to analysis by digestion in hydrochloric acid. From the residue, about twenty-five per cent. of quartz sand was separated. The soluble portion consisted of silica 50·70, alumina 8·03, peroxyd of iron 22·50, lime 1·11, magnesia 2·16, potash 5·80, soda 0·75, volatile 8·95 = 100.00. Other analyses by Rogers and by Fisher, of glauconite from the same region, agree closely with this, but give from 3·85 to 6·50 of alumina. Mallet found the latter amount in the same mineral from Alabama; while the glauconite of Westphalia, according to Von Dechen, contains ten per cent. of alumina. This base, in variable proportions, seems, then, to enter into the composition of glauconite, replacing a part of the protoxyd of iron.

Greensand of Quebec group

The rocks of the Quebec group are, in some localities, characterized by grains of a soft green mineral, which closely resembles the glauconite of more recent formations, and sometimes constitutes a considerable proportion of beds of sandstone or shale. A sandstone of this kind from Point Lévis, which was free from calcareous matter, and abounded in these grains, was reduced to powder, and digested with hydrochloric acid until the green mineral was decomposed. The separated silica was removed by carbonate of soda from the residual quartzose sand, and the soluble matters, from two different specimens of the rock, were as follows for 100 parts:

Point Lévis

Silica,	11·40	12·26
Alumina,	5·66	6·84
Protoxyd of iron,	7·56	6·38
Lime,	0·20	0·18
Magnesia,	0·44	0·86
Potash,	1·60	1·48
	26·86	28·00

Orleans Island

On the Island of Orleans, between beds of a dolomitic conglomerate, are thin layers of a friable sandstone, made up of grains of quartz, with others a soft green mineral resembling that just described, and giving a bright bluish-green powder. By crushing the rock and sifting, the coarser grains of quartz were removed, and dilute nitric acid then dissolved a portion of carbonate of lime which formed the cement of the rock. The analysis of the green mineral was effected by hydrochloric acid, and the liberated silica was separated from the insoluble quartz sand. I and II give the results of two analyses of the substance, while III represents its composition as calculated after deducting the quartz.

	I.	II.	III.
Silica,	31·32	31·30	50·7
Alumina,	12·20	12·15	19·8
Protoxyd of iron,	5·29	5·27	8·6
Magnesia,	2·26	.....	3·7
Potash	5·05	5·60	8·2
Soda,	0·33	.....	0·5
Water (by ignition),	5·25	.....	8·5
Quartz,	35·96	.....	....
	97·66	.....	100·0

This substance evidently differs from the glauconite of more recent formations in the smaller amount of iron, and the great proportion of alumina, which it contains. Green grains, apparently similar to those of the Quebec group, are found in the fossiliferous magnesian limestones of the same age in Texas; and layers of a green mineral, described by Dr. Owen as a silicate of iron, are abundant in the Lower Magnesian limestones of Minnesota, where they are used by the Indians as a pigment. A speci-
Mississippi. men of this from Red Bird, on the Mississippi, was interstratified and intermingled with a magnesian limestone, which was removed by dilute nitric acid. A mixture of the green mineral with angular grains of quartz, was thus obtained, and gave by an analysis of 3·420 grams, as follows: insoluble sand 1·590, silica ·804, protoxyd of iron ·356, alumina ·198, lime ·043, magnesia ·022, potash ·120, soda ·017, volatile ·167, loss ·103 = 3·420. The soluble portion, calculated for 100 parts, is as follows: silica 46·58, protoxyd of iron 20·61, alumina 11·45, lime 2·49, magnesia 1·27, potash 6·96, soda 0·98, volatile 9·66 = 100·00. Another portion gave protoxyd of iron 19·73, alumina 11·03. The analyses of the glauconite from New Jersey and from Minnesota show that a variable proportion of alumina may enter into the composition of this silicate, and serve to connect the more ferruginous mineral of the former locality with the green-sand of Orleans Island. In this connection, it may be mentioned that beds of a similar green-sand or glauconite occur near the base of the Lower Silurian series in Russia.

Prof. E. J. Chapman has described bright green streaks and markings in beds of a silicious limestone of the Black River formation, in the township of Rama. The green matter is said, in some cases at least, to be collected around minute crystals of decomposed iron pyrites. It was supposed, from its color, to be a compound of copper, but, according to Prof. Chapman, it contains no traces of this metal. Silica, oxyd of iron, and water were however detected in its composition, so that it is probably related to glauconite. (Canadian Journal, iv, 493.)

CHLORITE, PYROSCLERITE, AND CLINTONITE.

Chlorite. Chlorite has not yet been observed in the Laurentian series; but it is occasionally found disseminated in the diorites of the Huronian series, which pass into a soft green schistose rock, that appears to be a chloritic slate. Among the altered Silurian strata, chlorite is of frequent occurrence. A pure massive variety, made up of a confused aggregation of small scales, occurs with quartz, and sometimes with bitter-spar and feldspar, in what appear to be veins among these schistose rocks. Chlorite also occurs disseminated in dark green scales in limestones and in dolomites of this series, or mixed with grains of quartz and feldspar, and sometimes with specular iron, giving rise to chloritic sandstones and slates. Green scales of what seems to be chlorite, are also seen in the reddish talcoid argillaceous slates, whose analysis gives a little magnesia, which may probably be due to an intermixture of this mineral.

Dr. Bigsby has described the occurrence of chlorite among the crystalline rocks to the north of Lake Superior, on Rainy Lake, and also on the Lake of the Woods, where a bed of slaty chlorite occurs in greenstone, and holds octahedral iron ore and cubic pyrites.

The chlorite of the older authorities includes several closely related species, now regarded as distinct. Among these are chlorite proper (including pennine and leuchtenbergite), clinochlore, and ripidolite, which differ in optical and crystallographic characters, and offer, moreover, some variations in chemical composition. They are all, however, basic hydrous silicates of alumina, with magnesia; a variable portion of which is replaced by protoxyd of iron. The same metal, in the state of peroxyd, according to Rammelsberg, sometimes replaces a part of the alumina. All of these chloritic minerals have an eminently foliated structure, and resemble talc on the one hand and the micas on the other. Closely related to the chlorites, both in structure and in composition, is pyrosclerite, to which vermiculite, rhodochrome, and kammererite belong. These latter varieties contain small portions of oxyd of chrome, to which they owe a purplish color. They are generally found in serpentine, with chromic iron, and the localities of this ore in Melbourne and Bolton present small portions of what appears to be kammererite. Foliated magnesian silicates. Pyrosclerite.

Clintonite is the name which has been given to a foliated hydrous silicate of alumina and magnesia, containing some lime, which constitutes a very distinct species, and includes the holmesite of Dr. Thompson, and the xanthophyllite and disterrite of other authors. Clintonite occurs with blue spinel in a crystalline limestone in Daillebout. Clintonite.

LOGANITE AND SOME ALLIED MINERALS.

Related to the foliated or mica-like group of magnesian species, which includes talc, the chlorites, pyrosclerite, clintonite, and the magnesian micas, is a series of minerals, closely resembling these in composition, density, and hardness, but entirely different in structure. They are prismatic, and may be described as spar-like, with the form and the cleavage of pyroxene, or of hornblende. Having generally been regarded as results of the alteration of one or other of these two minerals, the rank of distinct species has been refused to them, while the specific distinctness of the corresponding foliated minerals is not disputed. Sparry magnesian silicates.

First among these sparry magnesian minerals, is the one which corresponds to talc, and has already been described by the name of pyrallolite, or rensselaerite (page 470). To this series also belong the following alumino-magnesian minerals, which have been described by Dr. Beck as occurring among the crystalline limestones of Orange County, New York. They are grey or greenish-grey in color, somewhat translucent, soft, readily cut with a knife, and unctuous to the touch. Both of these minerals are crystallized in long rhomboidal prisms, having the cleavage and the angles of hornblende. Their specific gravity is not given; but their composition, as found by Dr. Beck, is subjoined in the analyses I and II. (Trans. Am. Assoc. Geologists 1840–42, 244.) III is the analysis, by Delesse, of a closely related mineral, which occurs in the crystalline limestone of the Vosges, in France, and resembles serpentine in its external characters. It is uncrystalline, soft, of a waxy lustre, a greenish color, has a specific gravity of 2·622, and contains traces of chrome and of manganese. (Ann. des Mines [4], xx, 155.)

	I.	II.	III.
Silica,	35·00	34·66	38·39
Alumina,	32·30	25·33	26·54
Peroxyd of iron,	....	....	·59
Lime,	10·80	5·09	·67
Magnesia,	20·70	25·22	22·16 (by diff.)
Water,	1·17	9·09	11·65
	99·77	99·39	100·00

Loganite.

Calumet Falls.

Hydrated aluminous magnesian minerals, sparry in crystallization, and related to the above, are met with in several localities among the Laurentian limestones in Canada. The first one to be mentioned occurs at the Calumet Falls. It is associated with pale green serpentine, brown phlogopite, and apatite, in a white crystalline limestone, and has been described by the name of loganite. It occurs in short thick oblique rhombic prisms, replaced on the edges, or on the acute solid angles. The crystals are generally rounded, but present a prism of 124°, or near to that of hornblende. There is a distinct cleavage with the sides and the base of the prism, and an imperfect one with the longer diagonal. The hardness of the mineral is about that of calcareous spar, and its specific gravity is from 2·60 to 2·64. The surface of the crystals is dull, but the lustre of the cleavages is vitreous and shining. The color is clove-brown or chocolate-brown, often pale, and the mineral is sub-translucent, brittle, and with an uneven fracture. The crystals, which are seldom more than one fourth of an inch in diameter, are penetrated by carbonate of lime, from which they are with difficulty freed. The mineral is infusible before the blowpipe, and partially decomposed by acids.

In the following analyses, a portion of carbonic acid, combined with the lime, is included in IV and V. In VI, the composition is calculated for 100 parts, excluding the carbonate of lime.

	IV.	V.	VI.
Silica, ...	32·84	32·14	33·28
Alumina,................	13·37	13·00	13·30
Magnesia, ...	35·12	36·43	35·50
Peroxyd of iron, ...	2·00	2·28	1·92
Volatile, ...	17·02	16·83	16·00
Lime,..................	·96	·93	....
	101·31	101·61	100·00

Associated with the extensive deposit of crystalline phosphate of lime in North Elmsley, is a mineral closely resembling the loganite in its characters. It exists as a small bed in the limestone, and forms with it a granular mixture, inclosing masses of the pure mineral, which closely resembles pyroxene in appearance. The prismatic cleavages are perfect, the basal cleavage indistinct. The hardness is not greater than calcareous spar, and the specific gravity from 2·538 to 2·539. The color of the mineral is greenish-grey; its powder is white and unctuous to the touch. The lustre is resinous, shining; the mineral is brittle and somewhat translucent on the edges. Crystals of hard unaltered dark-brown sphene, and small masses of flesh-colored calcite, are imbedded in it. The analyses of two pure specimens of this sparry silicate gave VII and VIII. North Elmsley

A mineral almost identical with this occurs in North Burgess, in a pyroxenic rock, with large crystals of a magnesian mica, which last has been wrought to a considerable extent. The mineral in question is found in imbedded cleavable masses, sometimes several inches in diameter. It has the cleavage of pyroxene, a hardness between gypsum and calcite, and a specific gravity of 2·32–2·35. It is pale greyish-green in color, very unctuous to the touch, translucent on the edges, and has a waxy lustre. The results of two analyses of this mineral are given under IX and X. North Burgess.

	VII.	VIII.	IX.	X.
Silica	36·90	36·50	39·70	38·90
Alumina...............	11·13	10·80	14·20	14·30
Magnesia	28·11	28·26	25·84	25·62
Protoxyd of iron........	9·18	9·54	4·50	4·32
Water.................	14·00	14·62	16·20	17·66
	99·32	99·72	100·44	100·80

The two minerals last described approach nearly in composition and in general character to loganite. This latter was by Dana referred to pyrosclerite, with which it closely agrees in composition; but it differs completely in the absence of the micaceous or foliated structure, and also in containing more water. The low specific gravity of the mineral IX and X is worthy of notice. The variations in the composition of this sparry silicate from different localities are not more considerable than those of the different varieties of chlorite and of serpentine; and although they may hereafter constitute grounds for specific distinctions, it will be well, for the present, to include the silicates from North Burgess and North Elmsley, with that from the Calumet, under the name of loganite. This mineral is to be distinguished from pyrosclerite or kämmererite, not only by its greater amount of water, but by a crystalline form resembling that of pyroxene or hornblende, and a sparry structure very distinct from the micaceous one of pyrosclerite, which is due to the perfect basal cleavage possessed by this latter species in common with the micas, chlorites, and talc. The sparry minerals pyrallolite and loganite are thus represented in the latter group by talc and pyrosclerite, while the sparry silicates described by Beck and Delesse (I, II, and III), have no known foliaceous representatives. Gieseckite represents in composition a hydrous potash mica.

The pyroxenic rock from North Burgess, which encloses the loganite, closely resembles it in cleavage and in color, but has a greater hardness, and a specific gravity of 3.003. It is mingled with a portion of carbonate of lime; after removing which by a dilute acid, the mineral gave, by analysis, as follows: silica 54·30, alumina 3·70, protoxide of iron 2·07, lime 10·39, magnesia 23·61, volatile 5.43 = 99·63.

BERYL.

Beryl. This species is frequently met with in granitic veins, associated with garnet, tourmaline, and chrysoberyl among the crystalline strata of Maine, New Hampshire, Massachusetts, and Connecticut, which are supposed to be of palæozoic age. It has not, however, been noticed among the rocks of Vermont, or of south-eastern Canada. In the Laurentian system, granitic veins with tourmaline, zircon, and mica, the associates of beryl, are met with; and in one of these in Saratoga County, New York, chrysoberyl occurs in some abundance. According to Dr. Bigsby, beryl is found in well-defined pale green crystals, with black mica, in a porphyritic granite, associated with gneiss and mica schist on the east side of Rainy Lake, two hundred and thirty miles to the north of Lake Superior.

TOURMALINE AND AXINITE.

Tourmaline. Black tourmaline is abundant in many places among the Laurentian rocks. A remarkable locality is described by Dr. Bigsby as occurring among the Thousand Islands, on the south side of the English channel, and near the upper end of Tar Island, on Yeo's Island, which is about three hundred yards long, and divided by a ravine into two unequal parts; on the south-western of which, and on the face of a shelving mound of whitish granite, is a bed twelve paces in diameter, consisting of large crystals of black tourmaline, with greenish-yellow mica, quartz, and feldspar. In other parts of the same island, black tourmaline abounds, in granitic veins which traverse a fine-grained gneiss. Other localities mentioned by Dr. Bigsby are Murray Bay, and Cape Tourmente. Finely terminated crystals of black tourmaline, an inch in diameter, occur in white quartz on the eighteenth lot of the fourth range of Bathurst, and in quartz veins in Eardley. Granitic veins, holding the same mineral, are met with in the township of Ross, on the Roche-Fendue Channel, in Carrying-Place Bay, on Charleston Lake, on Stoney Lake in Dummer, and on the west side of the North River at St. Jérôme. Here the tourmaline is associated with small crystals of zircon. Black tourmaline also occurs associated with pyroxene and hornblende on the Madawaska (see pages 35 and 467). Other localities are Elmsley, Lachute, St. Felix, and the Calumet Falls.

A peculiar variety of black tourmaline is found in white quartz near Madoc, and in Elzivir. It forms veins of an inch or more in width, made up of very fine fibres transverse to the sides of the vein, velvet black in color, and with a silky lustre resembling masses of what is called mineral charcoal, for which it had been mistaken. The powder of the mineral from Madoc is bluish-black, becoming pale by ignition. A partial analysis of it gave silica 36·50, alumina 27·45, peroxyd of iron 14·90, magnesia 6·05, and lime 1·12. This shows the mineral to be an iron-magnesia tourmaline, which, in parts, may be observed in the form of black acicular crystals penetrating the quartz.

Brown tourmaline is frequently met with in the limestone of the Laurentian series. At the Calumet Falls, crystals of this mineral, an inch in diameter, have been found imbedded in flesh-red limestone, with idocrase. They are somewhat translucent, of a rich yellowish-brown color, highly modified, and with brilliant planes. The specific gravity of the these crystals is 3·03. Similar crystals, almost equal in beauty, have been found with pyroxene in limestone, in the township of Ross, and also in Clarendon; and a single transparent crystal, remarkable for its modifications, was obtained near Hunterstown. This, together with a crystal from Ross, is figured in Dana's Manual of Mineralogy, 4th edition, page 270, figures 457 and 460. Slender delicate prisms of hair-brown tourmaline occur in white quartz, in Fitzroy, and at the Island Portage, Lac des Chats. At McGregor's quarry at Lachute, grains and imperfect crystals of brown tourmaline are disseminated in the limestone, of which they seem to mark the lines of stratification. Brown tourmaline.

The rare species axinite is said by Dr. Bigsby to have been found in fine crystals, lining a cavity in a boulder of primitive rock at Hawkesbury. Axinite.

MICAS,—MUSCOVITE AND PHLOGOPITE.

The group of the micas includes two principal divisions: those which are essentially silicates of alumina and alkalies, chiefly potash, often with lithia and fluorine, including muscovite and lepidolite; and the magnesian micas Micas.

phlogopite and biotite; the former group generally belonging to granitic rocks, and the latter to limestones. The magnesian micas often present some variations in their composition, and the hydrated ones offer a natural transition to the foliaceous magnesian species, chlorite and pyrosclerite.

Muscovite. Among the localities of muscovite may be noticed the tourmaline locality on Yeo's Island, described above, and many of the granitic veins already mentioned. Large crystals are also found in an immense vein of graphic granite on Allumette Lake (page 36). A porphyritic granite on Cape Tourmente, according to Dr. Bigsby, holds great crystals of mica a foot in diameter. Mica enters, to a small extent only, into the composition of the gneiss of the Laurentian system: and a dark brown mica is sparingly met with in the anorthosites of the same series. In the altered rocks of the Eastern Townships, micaceous schists are abundant, generally mingled with quartz; but in some cases, a rock is found which is almost entirely made up of a mineral approaching in composition to a hydrous mica. In Shipton, a mineral of this sort has been mistaken for a compact chlorite or potstone, and wrought to some extent. It consists of an aggregation of small greenish-grey scales, and contains silica 51·50, alumina 29·20, protoxyd of iron 9·27, magnesia 1·08, potash 1·54, soda 1·59, water 5·10 = 99·28. Crystals of silvery mica occur in a quartz vein in Barford, with white apatite, copper pyrites, and magnetic pyrites.

Chromiferous mica. A bright green colored mica, which contains in combination a portion of oxyd of chromium, is found in several localities in the Eastern Townships. Minute scales of it occur in the magnesite of Sutton; and it is met with, in larger plates and imperfect crystals, in a dolomite from Bolton. This mica is probably allied to the chromiferous mica from the Tyrol, which has been named fuchsite.

Phlogopite. Phlogopite is very common among the Laurentian limestones, sometimes both in more or less abundantly disseminated in small scales or crystals, pure limestones and dolomites. The colors of these small crystals are generally some shade of yellow or brown; but in rare cases, they are of a deep olive-green or silver-white. At the Calumet Falls, delicate olive-green prisms of phlogopite, sometimes an inch in diameter and several inches in length, are found imbedded with crystals of pyroxene in a pink, lamellar limestone. In Burgess, large tables of a steel-grey mica, with a somewhat metallic lustre, are found in a similar limestone, with crystallized apatite; a prism of which was in one case found imbedded in a crystal of mica.

The largest specimens of phlogopite are generally found in beds near to bands of quartzite or pyroxenic gneiss, which often limit the crystalline limestones, or are interstratified with them. The mica occurs in large tabular crystals with pyroxene and calcite, and often with quartz, orthoclase, and rarer minerals. Examples of this are met with in Grenville and in North and South Burgess; in all of which, the mica is obtained in large sheets, which, being transparent and free from flaws, are wrought and employed for the same purposes as the muscovite or potash mica of granites. In North Burgess, the phlogopite is imbedded in a pyroxenic rock, with loganite (page 490), and affords plates which sometimes measure twenty by thirty inches.

This mica was submitted to analysis, and gave as follows: silica 40·97, alumina 18·56, magnesia 25·80, potash 8·26, soda 1·08, volatile 1·00, loss, probably fluorine, 4·33 = 100·00. Another specimen gave silica 40·55, alumina 18·10, volatile 0·66. In one of these analyses the mica was decomposed by heated sulphuric acid, and in the other by fusion with carbonate of soda. The alumina contained no trace of oxyd of iron.

PHOLERITE.

This mineral is identical in composition with the kaolin which arises from the decomposition of feldspars, and it may be regarded as that substance in a crystalline condition. From its foliated or micaceous structure, it may be considered as a hydrated mica, bearing to muscovite a relation analogous to that which the chlorites and pyrosclerite sustain to phlogopite. Pholerite occurs in the form of white unctuous films in the joints of many quartzose sandstones of the Huronian series; and what appears to be the same mineral is occasionally met with in small botryoidal masses, lining cavities in the jasper conglomerate of the same series. In a sandstone of the Quebec group, just below the Chaudière Falls, pholerite is met with filling fissures, and sometimes forms masses half an inch thick, composed of minute soft scales, very unctuous and slightly coherent. The masses have a greenish or yellowish-white color. Before the blowpipe, the mineral exfoliates in white cauliflower-like shapes, but is infusible. It gives off an abundance of water when heated in a glass tube, and assumes a fine blue color when ignited after having been moistened with nitrate of cobalt. The mineral was separated as much as possible from intermingled grains of quartz, by crushing it and suspending it in water. It was then levigated and dried at 212° F., when its analysis gave silica 46·05, alumina 38·37, lime 0·61, magnesia 0·63, water 14·00 = 99·66. Another analysis yielded silica 45·55, and water 13·90.

Pholerite

GARNET AND IDOCRASE

Garnet forms with epidote and idocrase a group of double silicates of alumina and protoxyd bases, distinguished from the feldspars by their much greater specific gravity and hardness, and by the fact that sesquioxyds of iron and manganese sometimes replace wholely or in part the alumina, while magnesia, or the protoxyds of these same metals, may take the place of the lime and alkalies which form the protoxyd bases of the feldspar series.

Chloritoid may be looked upon as a hydrated species belonging to the same group of silicates.

Garnet. Garnet is frequently met with in the Laurentian rocks. It is often disseminated in grains or imperfect crystals through the gneiss, and characterizes great masses of quartzite. Beds of nearly pure red garnet-rock are sometimes met with, as in gneiss in St. Jérôme, in quartzite in Rawdon, Marmora, and at Bay St. Paul. Imperfect crystals, several inches in diameter, occur in the gneiss of Murray Bay. A rose-red garnet, disseminated in small masses through a white orthoclase gneiss at Lake Simon, on the river Rouge, gave by analysis, silica 37·80, alumina 21·00, lime 1·81, magnesia 8·85, protoxyd of iron 29·03, volatile 0·18 = 98·67.

Idocrase. Small crystals of cinnamon-colored garnet have been observed with crystals of wax-yellow idocrase, pyroxene, and zircon, in calcareous spar at Grenville, and also imbedded in limestone with brown tourmaline and idocrase, in a boulder; the three species being nearly alike in color. Large crystals of brown idocrase occur with brown tourmaline, at the Calumet Falls.

White garnet-rock. A remarkable variety of white lime-alumina garnet occurs with the serpentines of the Eastern Townships. In Orford it is found in small rounded masses, which, with a little intermingled serpentine, make up a rock. This garnet is compact, very tough, and has a conchoidal fracture. It is sub-translucent, with a waxy lustre, greenish or yellowish-white in color, and has the hardness of quartz, and a specific gravity of 3·52–3·53. Its analysis gave silica 38·60, alumina 22·71, lime 34·83, magnesia 0·49, oxyds of iron and manganese 1·60, soda and a trace of potash 0·47, volatile 1·10 = 99·80. After intense ignition, which did not effect its fusion, the mineral gelatinized with hydrochloric acid.

An apparently homogeneous rock, composed in great part of a similar garnet, occurs in contact with serpentine, in St. Francis. It is extremely tough, and so hard as to scratch deeply the surface of agate. Its specific gravity is 3·33–3·36. This rock has a sub-conchoidal fracture, a feebly shining lustre, is yellowish-white and somewhat translucent. Another variety in the same vicinity is greenish-white, somewhat granular, and exhibits imperfect crystals in drusy cavities. It has a specific gravity of 3·39–3·43. Grains of native gold have been observed in this white garnet-rock. Another rock, near by, was found to consist of a similar white garnet, with a density of 3·49, mingled with a softer white feldspathic mineral, of density 2·73–2·83, and with a greenish and greyish hornblende, having a specific gravity of 3·046; the whole forming a coarse-grained aggregate.

The compact garnet-rock, of density 3·33, did not effervesce with heated nitric acid: and it gave on analysis, silica 44·85, alumina 10·76, peroxyd of iron 3·20, lime 34·38, magnesia 5·24, volatile 1·10 = 99·53. The alumina and oxyd of iron, with 22·69 of silica and 21·07 of lime, make up 57·72 of garnet, and the remaining elements form 40·71 per cent. of a bi-silicate of lime and magnesia, approaching to pyroxene in composition. A white massive garnet-rock, similar to that from Orford, and associated with serpentine, comes from Beyreuth, in Bavaria.

Green chrome-garnet.

A beautiful green garnet occurs in the sixth lot of the twelfth range of Orford. It forms granular masses, or is disseminated with millerite (sulphuret of nickel), in a white crystalline calcite. The largest crystals are found in druses in the massive portions, but do not exceed a line in diameter, and are dodecahedrons, sometimes with their edges replaced. The mineral is transparent, with an emerald-green color, which is not altered by a red heat. This garnet resembles closely the ouvarovite from the Urals, but differs in containing a much larger proportion of alumina and less oxyd of chrome. Its analysis gave silica 36·65, alumina 17·50, oxyd of chrome 6·20, protoxyd of iron 4·97, lime 33·20, magnesia 0·81, volatile 0·30 = 99·63. Another analysis gave oxyd of chrome 6·93, protoxyd of iron 4·80, lime 33·29. This beautiful garnet, if obtained in sufficiently large crystals, would constitute a gem equal in beauty to the emerald.

Large dodecahedrons of cinnamon-colored garnet, and others which are yellowish or nearly white, occur with crystals of pyroxene (page 467), in the immediate vicinity of this chrome-garnet.

EPIDOTE.

Epidote

A compact yellowish-green mineral, which resembles epidote in specific gravity and hardness, is occasionally met with in a reddish feldspathic gneiss of the Laurentian series. Good examples of this occur near Carleton Place. Crystalline epidote is also frequently found in amygdaloidal traps on Lake Superior, and is associated with native copper. At Mamainse, crystals of epidote are met with, implanted upon mesolite, and rarely associated with small brown garnets.

Epidote characterizes large portions of the altered Silurian rocks. It is there generally associated with quartz, often forming veins or kernels, with imperfect crystals, in a granular quartz-rock, which passes into mica-schist: chlorite is a frequent accompaniment. In many parts occur beds which are entirely made up of quartz and epidote ; sometimes in distinct grains, at others forming a homogeneous rock, generally pale green, very tough and sonorous. This rock is met with in beds among the chloritic schists from St. Armand to Gaspé. A specimen from the Grand Matanne River, having a hardness of 7·0, and a density of 3·04, gave by analysis, silica 62·60, alumina 12·30, peroxyd of iron 9·40, lime 14·10, magnesia 0·72, soda 0·43, volatile 0·16 = 99·71; which corresponds to a mixture of 61·33 parts of epidote and 38·22 parts of quartz. This rock, which is the epidosite of some lithologists, is also found in characteristic specimens in Melbourne. Well crystallized greenish epidote is found in the concretionary argillaceous rock of St. Joseph, which is described on page 255.

CHLORITOID.

Chloritoid. This mineral species is of common occurrence in the micaceous schists of the Quebec group, in Eastern Canada, in which it is disseminated in small grains and crystalline plates. It is abundant in a fine-grained greyish wrinkled micaceous slate from Brome; and in larger specimens, from Leeds, where it occurs in a schistose rock, which is pearl-grey in color, passing into greenish-grey, and is made up of quartz, with a mineral having a talcose aspect, but aluminous in composition, and apparently a mica. The chloritoid is imbedded in this rock, in small lamellar masses, rarely more than one fourth of an inch broad, and one eighth of an inch thick. Spherical masses, half an inch or more in diameter, are sometimes found, composed of plates of the mineral radiating from a centre, and often making up one half of the volume of the rock. The chloritoid has a perfect cleavage in one direction, and two less distinct transverse cleavages. The lamellæ are often curved, and are not easily separable. The hardness of this mineral is equal to that of feldspar, and its specific gravity is 3·513. Its color is dark-greenish grey, passing into black. The planes of perfect cleavage have a brilliant vitreous lustre, but the fracture presents a feeble waxy lustre. The powder of the mineral is greenish-grey, becoming reddish by ignition. Its analysis gave, silica 26·30, alumina 37·10, protoxyd of iron 25·92, protoxyd of manganese 0·93, magnesia 3·66, water 6·10 = 100·01.

Phyllite. This species is identical with what has been described by the names of barytophyllite, chlorite spar, sismondine, and masonite. The mineral from Massachusetts, to which Dr. Thompson gave the name of phyllite, is perhaps the same species, inasmuch as a specimen obtained from Mr. Heuland in London, and designated as "phyllite from North America" is chloritoid, closely resembling that from Leeds. The ottrelite of Hauy, from Ottrez in Luxembourg, cannot be distinguished from the same species.

STAUROTIDE.

Staurotide. Staurotide is found in mica schists in Vermont, but has not yet been met with in Eastern Canada. According to Dr. Bigsby, however, it occurs in the gneiss to the north of Lake Superior, (see page 65,) where it is abundant in very small crystals on Rainy Lake, and in much larger crystals on the river Lacroix, at the second portage from the lake of the same name.

ANDALUSITE OR CHIASTOLITE.

This species occurs in somewhat micaceous argillites of Upper Silurian or Devonian age, on Lake St. Francis. In some cases the mineral forms slender flesh-red prisms, not more than one tenth of an inch in diameter. In other portions of the rock, larger crystals inclose a black material, giving rise to that variety of andalusite which exhibits a cross in its transverse section, and is known as chiastolite (pages 430 and 433). Andalusite. Chiastolite.

ZIRCON.

This mineral is found in some abundance associated with pyroxene, tabular-spar, calcite, orthoclase, sphene, and plumbago, at Grenville, where terminated prismatic crystals half an inch in diameter are sometimes met. These are reddish-brown and opaque; but smaller crystals from the same locality are cherry-red and transparent. The specific gravity of this zircon is 4·60–4·62; and it gave on analysis, silica 33·7, zirconia, with a trace of oxyd of iron, 67·3 = 101·0. Zircon.

Small brownish crystals of zircon have been found in St. Jérôme, with black tourmaline, in granitic veins which traverse gneiss. At Pic Island, in Lake Superior, a mass of unstratified rock, composed of red somewhat opalescent feldspar and black hornblende, contains small crystals of zircon.

SPINEL.

On the tenth lot of the first range of Burgess, the flesh-red Laurentian limestone abounds in crystals of black spinel, which may be traced over an extent of a mile or more. The crystals are sometimes an inch, or even two inches in diameter, and are occasionally coated with mica, though often brilliant, and exhibiting a replacement of the edges of the octahedron. Fine groups of crystals, detached from the limestone, have here been found loose in the soil. Black spinel in imperfect crystals occurs with apatite and fluor-spar, in crystalline limestone in the township of Ross. Small crystals of it have also been found with chondrodite in a boulder of crystalline limestone near Ottawa; and in a bed of micaceous limestone in the seigniory of Daillebout, small translucent octahedrons of blue spinel are met with. Spinel.

CORUNDUM.

Corundum has been observed on the second lot of the ninth range of Burgess, and in the immediate vicinity of a deposit of copper pyrites. Here, in contact with the crystalline limestone, occurs a rock made up of feldspar, quartz, calcite, silvery white mica, and sphene. Disseminated throughout this aggregate were small grains of a mineral whose color Corundum varied from light rose-red to sapphire blue, while its hardness, which was greater than that of topaz, showed the mineral to be corundum. Small crystals of light-blue corundum have been found elsewhere in the limestone of the vicinity.

QUARTZ.

Quartz. Notwithstanding the abundance of this mineral in the form of quartzite among the different geological formations of the province, interesting mineralogical varieties of quartz are rare. The trappean rocks along the north shore of Lake Superior, however, yield amethysts in great abundance, which are sometimes of a fine color. The small crystals of quartz known as Quebec diamonds, occur in fissures in the limestones of the Quebec group, and are occasionally an inch or more in diameter, and terminated at both ends. The crystals from this locality offer some unusual modifications in their form: Mr. Dana has figured one of them in his Manual of Mineralogy, 4th edition, p. 146. These crystals are generally colorless, but sometimes of a smoky brown, and in some rare instances, according to Dr. Bigsby, contain a drop of pale bituminous liquid. Fine transparent crystals are also found in the soil in Lacolle, and in drusy cavities in the dolomites of the Calciferous formation in many places.

Large prismatic crystals of transparent quartz have been found in drusy cavities of the quartz veins of the Bruce Mines. They are generally incrusted with small crystals of copper pyrites. In the quartz veins at Harvey's Hill Mine also, large transparent prismatic crystals several inches in length occur, and sometimes hold regular crystals of copper pyrites, which are completely encased in the quartz.

Agate. Agates are found in great abundance in the amygdaloids of Lake Superior, and sometimes of considerable size and beauty. They abound in rolled masses on the beaches of Michipicoten and St. Ignace Islands, at Thunder Bay, and elsewhere along the coast. Agate or chalcedony is here sometimes met with filling veins in a kind of pitchstone porphyry. Small agates of delicate colors are also found, together with pebbles of jasper, among the conglomerates of the Bonaventure formation, and are known to collectors by the name of Gaspé pebbles (page 404).

Jasper. Beds of a red ferruginous jasper, often finely clouded, occur near Sherbrooke and also at Rivière Ouelle. The jasper of the latter locality is traversed by veins of chalcedony. Jasper pebbles of various colors abound in the conglomerates of the Huronian series. Beds of chert or hornstone occur alike among the limestone of the Huronian series (p. 57), the Upper Copper-bearing rocks of Lake Superior (p. 67), and their equivalents of the Quebec group. Hornstone is also occasionally met with in nodules or in layers among the limestones of the Trenton and Niagara groups, and in great abundance in the Corniferous formation, to which it has given its name. In various formations and localities chalcedonic quartz is found in limestone, replacing organic remains, in which the cavities are sometimes filled or lined with quartz crystals. This is well seen in the Trenton formation on the Ottawa (page 176), and in the Corniferous formation in various parts of Western Canada. The remarkable veins of chert in the syenite of Grenville are described on page 41.

METALS AND METALLIC MINERALS.

Under this head may be noticed the various metals which are found in Canada in a native state, together with their ores, including oxyds and sulphurets. They will be arranged as follows, beginning with the less perfect metals: titanium, tungsten, molybdenum, chromium, uranium, cerium, arsenic, nickel, cobalt, manganese, iron, zinc, copper, lead, mercury, silver, gold, platinum, and iridium. Metals.

TITANIUM,—ILMENITE AND RUTILE.

In the form of titaniferous iron ore or ilmenite this element is very abundant in the Laurentian series, where it appears to belong to the anorthosites or triclinic feldspar rocks. In St. Jérôme, Rawdon, and Château Richer it occurs disseminated in grains, or in thin plates, which seem to mark the lines of stratification. In the latter locality it forms masses of several ounces weight, in a rock made up of andesine with a little hypersthene. In the parish of St. Urban, at Bay St. Paul, great masses of ilmenite are intercalated in the stratification. One of these, with a thickness of ninety feet, was traced for a distance of three hundred feet, and is said to be continued, with perhaps slight interruptions, for the distance of a mile. Several smaller masses of the ore are also seen in the neighborhood. The ilmenite is sometimes penetrated by grains of a greenish triclinic feldspar, which forms the surrounding rock, and it contains in many parts, orange-red transparent grains of pure titanic acid. This ilmenite is coarsely granular or crystalline, and has a density of 4·56 – 4·66. Its analysis gives titanic acid 48·60, protoxyd of iron 37·06, peroxyd of iron 10·42, magnesia 3·60 = 99·68. The ilmenite of Château Richer has a density of 4·65, and gives titanic acid 39·86, peroxyd of iron (in part as peroxyd) 56·64, magnesia 1·44, insoluble quartz, 4·90 = 102·84. Titanium. Ilmenite. Bay St. Paul.

The iron ores of the altered Silurian strata are very often titaniferous. Such is the case with many of those of Brome and Sutton, which contain one or two hundredths of titanic acid, probably as ilmenite, and are moreover sometimes associated with sphene and rutile. In the seigniory of St. Francis, Beauce, there is a bed of granular iron ore, forty-five feet wide, in serpentine. When crushed and washed, to free it from a small portion of earthy matters, it may be separated by the magnet into two portions. St. Francis.

About two thirds of the whole is common magnetic oxyd of iron; while the remaining non-magnetic portion is ilmenite, which gave titanic acid 48·60, peroxyd of iron 40·70, magnesia 2·44, insoluble 4·20, water and loss 4·06 = 100·00. A bed of magnetic iron occurring in serpentine at West Troy in the state of Vermont, contains in like manner four per cent. of titanic acid, probably in the form of ilmenite.

Rutile. In the auriferous sands of Canada the black residue left after washing, contains a large quantity of ilmenite, mixed with chromic iron, rutile, and magnetic and specular oxyds of iron. In Sutton, small red flattened crystals of titanic acid are found with chlorite, specular iron, and orthoclase feldspar. It is difficult to determine whether they belong to the species rutile, or to brookite, both of which are pure titanic acid. The same doubt applies to the red grains of titanic acid in the ilmenite from St. Urban, which sometimes make up as much as one tenth of the mass of ore. It is, however, probably rutile, which is the more common species, and is met with crystallized in chlorite slate, in New England, in conditions similar to that of Sutton. Rutile, in delicate acicular crystals, has been observed in drusy cavities, with quartz, at the Wallace mine, on Lake Huron. Connected with the presence of titanium in the metamorphic strata of the Eastern Townships, may be mentioned its occurence in the red ferruginous slates of Granby, which yield small portions of it on analysis. It is probable, however, that this element is very often present in argillaceous rocks. Titanic acid was also found in an impure greenish earthy limestone from Granby, which, besides thirty per cent. of carbonate of lime, contains small portions of manganese, chrome, and nickel, together with about six per cent. of titanic acid. In like manner, the insoluble residue (amounting to forty-six per cent.) from a ferruginous dolomite from Rougemont, gave by analysis seven per cent. of titanic acid, which, as in the previous case, is in an unknown state of combination.

Titanic acid

SPHENE.

Sphene. Small veins of opaque yellowish sphene, sometimes stained green by copper, have been found in the iron slates of Sutton. Minute amber-yellow crystals of sphene are also met with in the granitoid trachytes of Brome, Shefford, and Yamaska, and in the diorite of Mount Johnson. The crystals, which are brilliant and transparent, are seldom larger than a grain of rice, and generally much smaller. Some of them, however, admit of crystallographic measurement, and give the angles of sphene. The partial analysis of a small portion of this mineral, from Yamaska Mountain, gave silica 31·5, titanic acid 40·0, the remainder being lime. In addition to sphene, these intrusive rocks often contain titanium in the form of ilmenite.

Sphene is often met with in the Laurentian limestones, generally associated with those aggregates of quartz, pyroxene, and orthoclase feldspar, which have been repeatedly noticed. The crystals, which are often of considerable size, are generally clove-brown or chocolate-brown, but sometimes yellowish or amber colored. Among other localities of crystallized sphene, may be mentioned Lachute, Calumet Falls, and Burgess, where a honey-yellow variety occurs with green pyroxene and corundum. In North Elmsley, brown sphene is found imbedded in loganite, at the quarry of phosphate of lime, and also, near by, with pyroxene. Crystallized sphene occurs imbedded in calcareous spar, with Lederite. pyroxene, tabular-spar, and zircon, on the tenth lot of the fifth range of Grenville. Grenville. The plumbago mine formerly wrought by Mr. Harwood, on the same lot, affords a remarkable massive variety of sphene, well known to mineralogists, which, from its peculiar cleavages, was, by Sheperd, distinguished as a sub-species, with the name of lederite. Dana has however shown that, although the same abnormal cleavage exists in crystals of lederite from other localities, these have nevertheless the crystalline forms of ordinary sphene, with which the Grenville mineral agrees completely in composition. It is found with pyroxene, tabular-spar, and calcite, in masses several inches in diameter; and perfect cleavage-forms measuring one or two inches may be obtained. It has the usual hardness of sphene, and a specific gravity of 3·49–3·50. It is of a light chocolate-brown in color, and is somewhat translucent. Its analysis gave silica 31·83, titanic acid, with a trace of oxyd of iron, 40·00, lime 28·31, volatile 0·40 = 100·54. The titanic acid extracted from this mineral exhibits all the characters of that from other sources.

TUNGSTEN.

The only example of an ore of tungsten yet known in Canada was found Wolfram by Prof. Chapman, in a boulder of Laurentian gneiss, on Lake Couchiching, which contained crystals of wolfram, or tungstate of iron and manganese, with magnetic iron ore. The specific gravity of this wolfram was 6·938, and its analysis yielded tungstic acid 73.45, a substance having the characters of niobic acid 1.95, protoxyd of iron 9·05, protoxyd of manganese, by difference, 15·35, silica 0·20 = 100·00. A particular interest is attached to this mineral species, inasmuch as it is frequently associated with the oxyd of tin, an ore which has not yet been found in the Laurentian rocks.

MOLYBDENUM.

Molybdenite, or sulphuret of molybdenum, has been observed in small quantities in a quartz vein at Terrace Cove on Lake Superior. It has also been several times met with associated with pyroxene on Mud Lake, Molybdenite. in the vicinity of Balsam Lake, in one case accompanied with copper pyrites in quartz. It also occurs sparingly in flakes in a reddish gneiss at St. Jérôme. The only locality in which this mineral has been observed in considerable quantity is at the mouth of the Quetachoo River, in Manicouagan Bay, on the north shore of the Gulf of St. Lawrence. Here, in a bed of quartz six inches thick, in gneiss, molybdenite occurs in nodules of from one to three inches in diameter, and in flakes, which are sometimes twelve inches broad, and one fourth of an inch thick.

URANIUM.

Uranium. An ore of this rare metal is said to occur at Maimanse, where it forms a vein about two inches in width, at the junction of the trap and syenite. It was first described in 1847 by Dr. J. L. Leconte as a new ore of uranium, under the name of coracite. It is amorphous, pitch-black in color, with a grey streak, a resinous lustre, and a conchoidal fracture. Its hardness is 3·0, and its density 4·38. According to Mr. J. D. Whitney, who subsequently analysed it, it is distinguished from pitchblende by its ready solubility in cold hydrochloric acid, and contains oxyd of uranium 59·30, lime 14·44, oxyd of lead 5·36, oxyd of iron 2·24, alumina 0·90, silica 4·35, carbonic acid 7·47, water 4·64, with traces of magnesia and manganese = 98·70. Mr. Whitney, with much probability, suggests that the oxyd of lead, and a portion of the lime, are to be regarded as combined with the sesquioxyd of uranium.

Uran-ochre, in the form of a sulphur-yellow crystalline crust, has been observed lining fissures in the magnetic iron ore of Madoc.

CHROMIUM.

Chromic iron. The presence of oxyd of chromium has not yet been recognized in the Laurentian or Huronian series, but it is very widely diffused among the magnesian rocks of the Quebec group, the serpentines of which everywhere contain disseminated grains, nodules, and sometimes beds of chromic ore. Grains and crystals of it are also met with in the dolomites and steatites of this group. Workable beds of this ore are found in the townships of Bolton, Ham, Melbourne, and at Mount Albert, in Gaspé. The ore from Bolton gave by analysis, oxyd of chromium 45·90, protoxyd of iron 35·68, alumina 3·20, magnesia 15·03 = 99·81. Another specimen, from a large boulder of chromic iron ore found near Lake Memphramagog, yielded oxyd of chrome 49·75, protoxyd of iron 21·28, alumina 11·30, magnesia 18·13 = 100·46.

Both of these specimens are remarkable for the large amount of magnesia which they contain, since this element is sometimes entirely wanting in chromic iron. The difference in the amount of alumina in the two ores is another instance of the extremely variable composition of this mineral.

When the chromiferous serpentines are decomposed by sulphuric acid, a portion of oxyd of chromium is dissolved, while the separated silica generally contains grains of chromic iron, mixed with others of magnetite. In some cases, however, the whole of the chromium in the mineral appears to be in the state of a silicate. Traces of chromium are found not only in the serpentines, but in the diallage, actinolite, and chlorite of the Quebec group; and the same element in larger quantity gives an emerald-green color to a mica which is found in the magnesite of Sutton, and in crystals in dolomite from Bolton and other localities (page 494). It also enters into the composition of a purple kammererite or pyrosclerite, which is sometimes mingled with the chromic iron ore of Bolton. The green chrome-garnet from Orford has already been described (page 497). Oxyd of chromium, in small amount, is found in an unknown state of combination in an impure earthy unaltered limestone from Granby. **Chromiferous silicates.**

CERIUM.

Some small crystals of a mineral having the aspect of allanite were found in a feldspathic rock near Bay St. Paul, and gave by analysis a portion of oxyd of cerium with lanthanum. Minute crystals of a similar mineral have been observed in a rock composed of labradorite and hypersthene, from Lake St. John. **Cerium.**

ARSENIC.

Ores containing arsenic are found in small quantities in several localities. An arsenical ore from Michipicoten Island containing, besides nickel and copper, from forty-seven to fifty-three per cent. of arsenic, is found by several analyses to consist of a mixture, in variable proportions, of the arseniurets of copper and nickel. Another ore from the Wallace Mine on Lake Huron, contains, besides iron, nickel, and sulphur, six per cent. of arsenic. Both of these will be described among the ores of nickel. Arsenic, in the form of arseniate of cobalt, also occurs in rose-red incrustations on calcareous spar at Prince's Mine on Lake Superior. **Arsenic.**

Arsenical sulphuret of iron, or mispickel, which contains about forty-five per cent. of arsenic, is found well crystallized with argentiferous galena in a quartz vein on the Chaudière in St. Francis; and still more abundantly in small crystals, also with argentiferous galena, in a large vein of quartz on Moulton Hill near Lennoxville. It is also said to occur at Harvey's Hill in Leeds. **Mispickel.**

NICKEL AND COBALT.

These two metals are mentioned together because they are generally associated in nature. They have been met with in many localities in Canada. A bed of quartz six or eight inches wide in the Laurentian **Nickeliferous pyrites.**

gneiss on the eleventh concession of the seigniory of Daillebout, on the river Assumption, contains a considerable amount of iron pyrites, which yields to analysis 0.55 per cent. of oxyd of nickel, mixed with cobalt. A similar iron pyrites, which occurs with pyritous copper in Escott, contains small portions of cobalt and nickel; but a more remarkable locality of cobaltiferous iron pyrites is found in Elizabethtown near Brockville. The pyrites, which is massive, brilliant, and in great abundance, yields to analysis from 0·5 to 0·6 per cent. of oxyd of cobalt. Further details of this deposit, and of the modes of extracting the cobalt, will be given in a subsequent chapter.

Cobalt.

Nickel.

An ore of nickel from the Wallace Mine on Lake Huron consists in great part of sulphurets of iron and nickel, with a little arsenic, and is a fine-grained steel-grey mixture, whose analysis, after deducting earthy matters derived from the gangue, gave as follows for 100 parts: iron 41·79, nickel 13·93, arsenic 6·02, sulphur 38·16, copper 0·10 = 100·00. A portion of the iron is probably contained as oxyd in the gangue. The nickel contains a few thousandths of cobalt. When exposed to moist air, this ore becomes covered with an efflorescence of minute acicular greenish-white crystals, which consist of nickel-vitriol, or hydrated sulphate of nickel.

Nickel vitriol.

Two ores of nickel were discovered a few years since in a vein cutting a bed of amygdaloid on Michipicoten Island. The first of these is a brittle massive ore, associated with quartz, and having a brilliant metallic lustre, and a color varying from tin-white to bronze yellow. Its hardness is 5·0, and its specific gravity from 7·35 to 7·40. This mineral is variable in composition. The results of four analyses were as follows:

Arseniuret of nickel.

	I.	II.	III.	IV.
Arsenic,	37·36	44·67	.....	....
Copper,	44·70	30·81	27·60	10·28
Nickel,	17·03	24·55	27·29	36·39
Silver,	.....	0·25	0·21	.....
	99·09	100.28	.....	.....

It would appear from calculation that these varying results are due to mixtures of copper-nickel or nickeline, which consists of 44·1 of nickel and 55·9 of arsenic, with the arseniuret of copper, domeykite, which contains 71·7 of copper and 28·3 of arsenic. The nickel from this ore contains traces of cobalt.

The second ore, said to be from the same mine as the preceding, occurs as the gangue of native copper and native silver, which are scattered through it in grains. The mineral is amorphous, greenish-yellow or apple-green in color, with a waxy lustre and a conchoidal fracture. It is very soft, polishing under the nail, and falling to pieces when immersed in water. It is decomposed by acids, and is found to be essentially a hydrated silicate of nickel. The analysis of one specimen dried at 212° F. gave silica 33·60, oxyd of nickel 30·40, protoxyd of iron 2·25, lime 4·09, magnesia 3·55, alumina 8·40, water 17·10 = 99·39. Another specimen dried at a higher temperature, yielded silica 35·80, oxyd of nickel 32·20, water 12·20. It contains, besides, traces of cobalt and copper, and appears to be identical with the nickel-gymnite of Dr. Genth. A third specimen, which contained small grains of the native metals disseminated, gave silver 2·55, copper 18·51, and oxyd of nickel 20·85. Silicate of nickel

The frequent occurrence of nickel in small quantities among the magnesian rocks of the Quebec group has been already noticed. It is seldom or never absent from the serpentines, steatites, diallages, and actinolites of this series, but rarely forms more than two or three thousandths of the mineral, in which it generally appears to be combined as a silicate. With the chrome-garnet of Orford, the sulphuret of nickel (millerite) occurs in small grains and prismatic crystals, disseminated through the mixture of garnet and calcite in quantities which may become available. In the magnesite of Sutton, it exists in very small quantities as a nickeliferous pyrites; and in that of Bolton it incrusts the fissures of the rock with a green stain of what appears to be a hydrocarbonate. The proportion of oxyd of nickel determined upon a large portion of the magnesite of Bolton was found to be one thousandth. It was free from cobalt. The chromic iron ore from Ham, however, gave on analysis 0·22 per cent. of oxyd of nickel, in which cobalt could be detected. The dolomites which are associated with the serpentines of this altered series of rocks, often give traces of nickel on analysis: and it was found associated with oxyd of chrome, in the earthy limestone from Granby already noticed. Sulphuret of nickel

MANGANESE.

The ores of manganese have as yet been met with only in small quantities in Canada, and in the form of earthy hydrated peroxyd or wad, which occurs in various localities in alluvial deposits, often associated with bog iron ore. Specimens of the bog manganese from Bolton were much mingled with sand and pebbles, and contained but 26·5 per cent. of pure peroxyd of manganese. An ore in reniform masses from Stanstead, was more free from earthy matters than the last, but contained a large amount of oxyd of iron, and gave 37·0 per cent. of peroxyd of manganese. The bog iron ores from near St. Maurice sometimes contain several hundredths of peroxyd of manganese, and the two ores occasionally pass into each other by varying mixtures. The association of these two metals in superficial deposits shows that oxyd of manganese is capable of being dissolved and again precipitated, under conditions similar to the oxyd of iron, and probably by the intervention of organic matters. Earthy oxyd of manganese

A film of peroxyd of manganese is often found incrusting and cementing sand and pebbles in alluvial deposits; and the native gold in the valley of the Chaudière is frequently discolored by a coating of the same oxyd. In many of the rocks of the Eastern Townships, manganese exists in the form of a protosalt, generally as carbonate. These rocks are distinguished by weathering to a brownish-black. A ferruginous dolomite from Sutton, contains more than seven per cent. of carbonate of manganese. The bitter-spar which is met with in the quartz veins among the altered slates of this region is sometimes manganesian, and some beds of the green Sillery sandstones blacken exteriorly from the peroxydation of a portion of manganese which they contain. It is doubtless from the partial decomposition of such rocks that has been derived the manganese to form the earthy ores already noticed.

Carbonate of manganese.

In connection with the manganesian character of the rocks of the Eastern Townships, it may be mentioned that beds of silicate of manganese, sometimes with the peroxyd, occur among the crystalline rocks of Vermont, and that workable deposits of manganese ore are found with the hydrous iron ores of that state.

IRON AND ITS ORES.

The native silicate of iron, lievrite, has already been noticed on page 465. Under the present head are included the carbonate of iron, the magnetic oxyd, the anhydrous peroxyd, and the combinations of this last with water and organic matters, constituting limonite and iron ochre: to these must be added the sulphurets of iron. The native nickeliferous iron from Madoc is also to be mentioned here; although there is little doubt that, like similar masses in other parts of the world, it is of extra-terrestrial origin, and an aerolite. The specimen here noticed was found, in 1854, upon the surface of a field, and weighed 370 pounds. Its shape is rudely rectangular, and flattened on one side. The surface is irregularly pitted, as is generally the case with meteoric masses, and coated with a film of oxyd of iron. This iron is malleable, and highly crystalline in texture, and when etched by an acid exhibits beautifully the peculiar markings which are known as the Widmannstättian figures. Its analysis shows it to be an alloy of iron, with 6·35 per cent. of nickel. Small portions of the phosphuret of nickel and iron are disseminated through the iron, and, in making a section of it, rounded masses of magnetic iron pyrites were met with.

Native iron of Madoc.

CARBONATE OF IRON.

The crystalline carbonate of iron, or spathic iron ore, is said to occur with copper pyrites in quartz, on Echo Lake. A brownish cleavable spar from Leeds, which has been called spathic iron, is a double carbonate of lime and magnesia, with only a few hundredths of carbonate of iron. A similar admixture of iron characterizes most of the bitter-spar found in the metalliferous veins of that region, as well as the dolomites and magnesites of the Eastern Townships. An example of the occurrence of a large proportion of carbonate of iron, is seen in the magnesite of Sutton (page 457), which thus exhibits a transition to spathic iron. This ore occurs in beds, in the schistose rocks of Plymouth in Vermont. Carbonate of iron.

The earthy argillaceous variety of carbonate of iron, which is known as clay iron-stone, is found in considerable abundance in layers and nodules, among the shales which are interstratified with the Gaspé sandstones. (See the section given on page 394.)

MAGNETIC OXYD OF IRON.

This ore, to which the names of oxydulated iron, and magnetite, are often given, forms great beds among the Laurentian rocks, in Hull, Grenville, South Sherbrooke, South Crosby, Madoc, Belmont, and many other localities. The occurrence of these has already been alluded to on page 26, but a detailed description of these important deposits will be reserved for a future chapter. The ore is sometimes disseminated in grains through the Laurentian gneiss, but the great masses are generally associated with the crystalline limestones. The magnetite of this region is sometimes fine grained and compact, and at other times coarsely crystalline and granular, but is rarely in crystals. Well defined cubes of magnetite, with replaced edges, have, however, been found at the contact of the iron ore with limestone, near Portage du Fort. The finely granular ore of Madoc sometimes exhibits polarity, constituting a natural lodestone. The magnetite of the Laurentian rocks is generally very free from foreign matters. Small portions of carbonate of lime, of mica, and more rarely of actinolite, are however occasionally disseminated through it, and, in some cases, scales of graphite. Magnetic iron ore.

Magnetic ore is of frequent occurrence among the crystalline rocks of the Eastern Townships, sometimes in octahedral crystals, which are disseminated in chloritic slates; or, as in Sutton, in a chloritic dolomite, which contains large quantities of the carbonates of iron and manganese. Beds of massive magnetic ore have been found in the same series, in Leeds, and in St. Francis, Beauce, where a large bed of ore in serpentine is found to be a granular mixture of magnetite and ilmenite (p. 501).

PEROXYD OF IRON, OR RED HEMATITE.

This mineral, which is sometimes called oligist iron ore, and, in its different varieties, constitutes the specular, micaceous, and earthy red iron ores, is frequently found in the Laurentian system, though less abundant than magnetite. It forms beds, as in McNab, or large irregular masses arranged in the planes of stratification, as on Lake Nipissing. It Peroxyd of iron.

Red hematite. is also found at Hudson's Wharf, on the Lac des Chats. The ore in these localities is compact or finely crystalline. Ore of a similar character occurs in small beds in the Potsdam sandstone, in Bastard and Ramsay; and in little layers and nodules in the sandstone of the Sillery formation near St. Nicholas. The peroxyd of iron is intermingled in considerable proportion with the shales of this series, and gives to them their deep red color. Beds of an impure fossiliferous peroxyd of iron occur among the shales of the Clinton formation, near Hamilton; but, as in the Sillery formation, the oxyd is mingled with the argillaceous sediments, and only here and there accumulated in a comparatively pure state.

Among the altered rocks of the Eastern Townships, red hematite is of frequent occurrence. Scales and crystalline plates of it are often disseminated in chloritic and epidotic rocks; and a micaceous or foliated or micaceous variety of the ore is sometimes found in veins of quartz, cutting these rocks, as in the Pinnacle Mountain in St. Armand. Elsewhere it occurs in tabular crystals, or thick plates, sometimes with feldspar, and at others with copper-glance in bitter-spar, as in Leeds.

Micaceous iron. Micaceous peroxyd of iron, mingled with variable quantities of quartz and chlorite, form great beds of a schistose rock in this region. This rock is what has elsewhere been named itabirite, or specular schist, and is in some parts a rich ore of iron, while in other parts it passes into the ordinary chloritic slates of the country.

HYDROUS PEROXYD OF IRON, OR LIMONITE.

Brown hematite. This ore of iron, which is also known by the name of brown hematite, includes the so-called bog-iron ore, and a large proportion of the iron ochres which are found in great abundance in many localities, but especially in the St. Lawrence valley in Lower Canada, where it overlies the superficial deposits of clay and sand, and generally holds a portion of these matters in admixture. Limonite. These bog ores or limonites moreover often contain portions of oxyd of manganese and phosphoric acid; besides a variable amount of organic matter, which is still more abundant in the iron ochres.

The composition of the purer varieties of limonite corresponds to 85·6 of peroxyd of iron and 14·4 of water, but the following analyses will show the variations to be met with among the bog ores. The volatile portion includes water and organic matter. I is an ore from Petite Cote, Vaudreuil; II, *a* and *b*, from Cote St. Charles, Vaudreuil; III, from Upper Rocky Point, Eardley; IV, from Bastard, twentieth lot, second concession; V, an ore used at the St. Maurice forges, and considered of the best quality, with a bright reddish-brown color externally, and a brilliant black fracture; VI, from the same region, called by the workmen a rotten ore; VII, from the same vicinity as the last two, but dark colored from the presence of manganese, and evolving chlorine when dissolved in hydro-

Bog iron ore.

chloric acid. A portion of the silica in this last ore is chemically combined with the oxyd of iron, and separates in a gelatinous form from the hydrochloric solution.

	I.	II *a*.	II *b*.	III.	IV.	V.	VI.	VII.
Peroxyd of iron	74·50	76·95	.....	57·15	77·80	77·60	74·30	64·80
Sesquioxyd of manganese	.....	.....	.....	.....	.....	·30	traces.	5·50
Alumina	·30	·80	.....	1·60	.....	.....	.....	.....
Silica	7·10	1·50	5·43	21·60	1·76	5·40	3·60	4·80
Phosphoric acid	....	.....	1·52	.....	·61	1·81	1·80	undet.
Volatile matters	18·95	19·80	19·70	18·85	16·50	17·25	22·20	23·65
	100·85	99·05		99·20	96.67	102·36	101·90	98·75

Origin of limonite.

It will be observed that in all of these ores the amount of volatile matter exceeds that of the water which the hydrated peroxyd should contain. The iron in some of them exists in part as protoxyd, giving rise to an excess in the analysis. This is evidently connected with the presence of organic matters, whose power to reduce peroxyd of iron to the condition of protoxyd is well known. Waters charged with these matters, the results of the decay of vegetable substances, permeate ferruginous sediments and reduce the peroxyd of iron to the state of protoxyd; which is thus rendered soluble in water, and is brought to the surface either as a carbonate of protoxyd, or, when organic matter is abundant, as a combination of protoxyd of iron with some one of those organic matters which have received the names of crenic, geic, and humic acids. These protosalts of iron absorbing oxygen from the air, the metal is rendered insoluble, and is precipitated from the solution of the carbonate as a hydrated sesquioxyd, or, from the organic solution, as a compound of this oxyd the vegetable acid. While the purer limonites are nothing more than the hydrous sesquioxyd of iron, the bog ores consist of variable mixtures of this with the organic compound, and some of the ochres about to be described are probably this combination in a nearly pure state.

Iron ochres.

Ste Anne.

Extensive deposits of these ochres are found along the north side of the river St. Lawrence, in the vicinity of the beds of bog ore, and also in Middlesex County. Pointe du Lac near Three Rivers, and Ste. Anne, Montmorenci, are remarkable localities of the ochre, and at the latter place it is easy to observe it in the process of formation. Here, over an area of four acres, is a deposit of ochre varying from four to seventeen feet in thickness, which is yellowish-brown at the surface, becoming reddish or purplish-brown in those parts which are most exposed to air and light. At a little distance below the surface, however, the ochre is greenish in color; and when recently dug up it is greenish-white, indicating a compound of protoxyd of iron, which however grows yellowish, from peroxydation, as the mass dries. Water oozes in a great many places from the surface of the ochre, and collects in depressions. It is at first colorless, transparent, and ferruginous to the taste, but by exposure to the air soon lets fall a reddish-brown precipitate of ochre, and becomes tasteless. As this precipitate is buried by subsequent accumulations of the ochre, it is again reduced to a protoxyd, either by the reaction of the organic matter which it contains, or by that derived from the decaying roots and trees, which are abundant in the deposit, and it thus assumes the greenish color already noticed. A specimen of this ochre was submitted to a chemical examination. It was pulverulent, earthy, and of a light brownish-yellow. After being dried at 212° F., it was gently crushed and sifted, to separate some few vegetable remains. The ochre thus purified, when closely pressed into a crucible, covered, and heated to redness, evolves inflammable gases, and leaves a black mixture of metallic iron, with charcoal, which, when exposed to the air, even after cooling, takes fire spontaneously, and is changed into red oxyd of iron. When ignited in an open vessel, and carefully stirred to promote oxydation, it lost in three experiments from 36·10 to 36·20 per cent. of its weight. Hydrochloric acid dissolved the ochre, leaving 3·6 per cent. of silicious sand; and on evaporating the solution, a farther portion of silica, equalling 1·15 per cent. separated in a gelatinous state. The solution now contained only traces of phosphates, and no other mineral impurities. After adding tartaric acid and ammonia, the iron was thrown down as sulphuret, and gave 59·10 per cent. of peroxyd. 100 parts of the ochre thus yield peroxyd of iron 59·10, silica 4·75, water and organic matters 36·10 = 99·95. In order to ascertain the nature and the proportion of the organic matters combined with the iron-oxyd, a portion of the ochre was boiled, for half an hour, in a platinum vessel, with one half its weight of hydrate of potash and two or three parts of water. By this means the organic matter was dissolved, giving a deep brown liquid, from which acetic acid threw down no precipitate. Acetate of copper now separated a dark brown matter, which was regarded as apocrenate of copper, and equalled 2·21 per cent. of apocrenic acid. Carbonate of ammonia then gave a slight white precipitate of crenate of copper; but it was evident that the greater part of the organic matter was present in some other form. It was found that neutral acetate of lead precipitated it almost entirely from the acetic solution as a dark brown compound with oxyd of lead; a small additional portion only being subsequently separated on the addition of ammonia. The mixed lead precipitates, dried at 212° F., contained 36·6 per cent. of oxyd of lead, and indicated an amount of organic matter equal to 16·16 per cent. the weight of the ochre.

Examination of the ochre.

Organic acids.

The dried ochre, by exhaustion with a solution of caustic potash, lost 20·47 per cent. of its weight: another experiment gave 20·8. Deducting from the mean of these, 1·15 of soluble silica, there remains 19·48; and as this dissolved silica would also be mingled with the lead precipitate, it must be deducted from 16·16, leaving 15·01 per cent. for the organic acids combined with the oxyd of lead. As these were wholly precipitated with the oxyd of lead, it would appear that they exist in the ochre in a higher state of hydratation than in the lead precipitate, so that the portion dissolved out by potash consists of 15·01 of organic acids, as they exist in the compound with oxyd of lead, and 4·47 of water = 19·48; giving for the whole amount of water 21·14 per cent. The composition of the ochre is therefore, peroxyd of iron 59·10, organic acids 15·01, water, by difference, 21·14, soluble silica 1·15, sand 3·60 = 100·00.

This compound of peroxyd of iron with water and organic acids is evidently different from the hitherto described ores of iron, and should, probably, constitute a distinct species. The bog iron ores containing organic matter, may be regarded as variable mixtures of this organic salt of peroxyd of iron with limonite.

The oxalate of iron, or oxalite, has been observed upon the black schists at Kettle Point in Bosanquet. It appears as a sulphur-yellow incrustation, which when heated on charcoal, before the blow-pipe, blackens and becomes magnetic. Oxalite.

IRON PYRITES.

Under this head may be noticed the ordinary cubic sulphuret of iron, and the magnetic pyrites or pyrrhotine. The species marcasite, or white iron pyrites, has not yet been recognized in Canada. Sulphurets of iron.

Cubic pyrites is often found in the Laurentian gneiss and limestones, but seldom in finely crystallized varieties. It is not unfrequently met with in quartz veins in these rocks, often with massive foliated pyrrhotine, and sometimes contains small portions of nickel and cobalt, as the pyrites of Daillebout, of Escott, and that of Elizabethtown. The latter mass is of great and unknown extent, forming apparently an irregular bed in the crystalline rocks, and consists in part of a porous cellular variety with a greenish tinge, and in part of a pure massive pyrites, almost tin-white when recently fractured, but assuming a golden tarnish in the air. It is the latter form of the pyrites from this locality, which, according to Mr. Macfarlane's experiments, contains the greatest proportion of cobalt. Localities of pyrites of some importance are indicated in the second lot of the seventh range of Clarendon, also in the seigniory of Terrebonne, where there is a vein four feet in width. Another vein, said to be forty feet wide, occurs in the Augmentation of Lanoraie. Cubic iron pyrites.

Iron pyrites is of common occurrence in the rocks of the Huronian series, and in the metalliferous veins of Lake Superior. It is also occasionally found lining fissures in the Lower Silurian limestones, and replacing fossils, in the Utica formation. In the Quebec group, it forms concretionary masses, often several inches in diameter, among the schists near Cape Rouge and on the island of Orleans. In the Eastern Townships, iron pyrites is sometimes associated with the ores of copper, as in Garthby; where a great bed, which occurs in serpentine, is in some parts mingled with copper pyrites, and in others is nearly pure sulphuret of iron.

Magnetic pyrites.

Magnetic pyrites or pyrrhotine is found with cubic pyrites near St. Jerome; and, it is said, by Prof. Chapman, to be abundant near Balsam Lake. It occurs in many other localities; among which may be mentioned St. Francis, Beauce, where it is found in a quartz vein with cubic pyrites, mispickel, blende, and galena, and Barford, where it is associated with copper pyrites, native copper, apatite, and mica, also in a vein of quartz.

ZINC.

Sulphuret of zinc.

The only ore of this metal yet observed in Canada is the sulphuret or zinc blende. This occurs in some of the veins on Lake Superior, as at Mamainse and at Prince's Mine, where it is abundant with copper-glance and native silver. It has also been found in small quantities in veins of calcite in the Laurentian rocks, in the county of Berthier, and at St. Irénée. Among the rocks of the Quebec group, blende has been found disseminated in dolomite in St. Armand, in Leeds, and in a quartz vein in St. Francis, Beauce, with mispickel and argentiferous galena. It occurs in like manner in small portions, with galena in calcite, at the Ramsay lead mine. Blende is also occasionally met with in small masses of a honey-yellow color, imbedded in the limestones of the Trenton group at Kingston, Montreal, and Montmorency Falls, and in the dolomites of the Niagara formation, in the west. At Niagara Falls, it sometimes appears to replace fossils; and at other times, occurs in beautiful wax-yellow cleavable masses, imbedded in nodules of gypsum.

COPPER.

Copper ores.

The ores of copper observed in Canada are copper pyrites, the variegated sulphuret or erubescite, and the vitreous sulphuret or copper-glance, besides native copper, and small portions of the blue and green carbonates, and more rarely, of the red oxyd. In the rocks of the Laurentian series, copper is frequently met with in the form of yellow sulphuret. Thus, in Escott, this ore is found in a bed with magnetic iron and with iron pyrites; and, according to Dr. Bigsby, variegated sulphuret of copper occurs among the beds of magnetic iron ore on Crow Lake in Marmora. Small veins and masses of very pure copper pyrites sometimes incrusted with the blue carbonate, occur in the crystalline limestone in several localities in the township of Burgess, and large rolled masses of copper pyrites have been found on Gananoque Lake. In Bastard also, small portions of this ore have been found in a vein with calcareous spar, and in similar conditions in Fitzroy, and with blende in a vein in the Augmentation of Lanoraie. The

Copper pyrites.

great deposits of native copper in the trappean rocks of the north shore of Lake Superior often present beautifully crystallized varieties, associated with calcite, prehnite, and laumontite, and sometimes with red oxyd of copper, and with native silver. The veins intersecting these rocks also afford copper pyrites, and the variegated and vitreous sulphurets of copper. The copper-bearing veins which traverse the Huronian rocks on the north side of Lake Huron, at the Bruce Mines and several adjacent localities, contain, in a gangue of quartz, the yellow, variegated, and vitreous sulphurets, generally massive, but in some cases crystallized, and occasionally associated with heavy-spar, calcite, and pearl-spar. Besides the ores in the veins, the yellow sulphuret is sometimes found in the beds, as at Root River, where it occurs disseminated in a greenish argillite. The diorite from White Fish Lake in like manner contains minute portions of copper pyrites, with nickeliferous magnetic pyrites and magnetic iron ore. The arseniuret of copper, domeykite, which occurs with nickeline on Michipicoten Island, has already been noticed on page 506. Native copper.

The distribution of copper through the rocks of the Quebec group, is very general, and seems to indicate that this metal was almost everywhere present in the waters from which these strata were deposited. The copper generally occurs in the form of one of the sulphuretted ores, but more rarely in the native state, or as red oxyd, or green or blue carbonate. The sulphurets are generally found in the beds in grains, plates, and lenticular masses, sometimes of considerable size. Occasionally, as in a portion of the Acton mine, the variegated and vitreous sulphurets form the cement of a conglomerate rock, enclosing masses and grains of chert and of limestone. The ores of copper are not confined to any one division of the rocks of the Quebec group. Sometimes, as at Acton and Upton, they are in the dolomites, or, as in Ascot, in a chloritic limestone, while in many other localities they are found in micaceous or chloritic slates, or in steatite. Ores of copper are also disseminated in small portions through the slaty iron ores of Brome and Sutton ; and small stains and flakes of the green carbonate are found among the slates and sandstones of the Quebec group, at Sillery and St. Nicholas. Red oxyd of copper occurs in cinnabar-red stains upon blackish shales, at Acton. Sulphurets of copper.

Native copper has been found in thin plates imbedded in a greenish layer running with the stratification, in the midst of a mass of red slates, near St. Henri, in the bed of the Etchemin River. Masses of native copper found in the ruins of the red slates from Point Lévis, and in the drift in the Chaudière valley, have probably had a similar source. Small portions of native copper have also been met with in a bed of amygdaloidal diorite, at St. Flavien. In the more altered portions of this copper-bearing region, the ores of the metal are also found in veins. At Acton, the dolomites are traversed by quartz veins, which contain only traces of copper; but in Leeds and Inverness, great numbers of these veins or courses are met with, which traverse the slates. They are seldom continuous for great lengths, but often include large quantities of variegated and vitreous sulphurets of copper, in a gangue of quartz and bitter-spar. Near to Harvey's Hill, in Leeds, is a vein which traverses steatite, and contains, in a gangue of bitter-spar, vitreous copper, with specular iron, and native gold. In a quartz vein in Barford, copper pyrites and dendritic native copper occur with apatite and mica.

LEAD.

Sulphuret of lead

The only ore of lead met with in Canada is the sulphuret or galena. This is found in many localities on Lake Superior, as at Prince's Mine, Thunder Cape, and Pointe des Mines, where it occurs in small quantities in veins, often associated with blende, and with iron and copper pyrites. This galena sometimes contains a notable proportion of silver. Veins holding galena are found in very many localities cutting the Laurentian limestones, as in the townships of Bedford, Lansdowne, and Ramsay. The gangue of the galena in these veins is calcareous spar, and more rarely sulphate of barytes. Small portions both of blende and of copper pyrites are associated with the lead at Ramsay. This vein traverses the dolomites of the Calciferous formation, and, from its resemblance to those of Bedford, and Lansdowne, which occur in the older Laurentian system, it is probable that all of these latter are more recent than the Calciferous formation. At Bay St. Paul, small portions of galena are found in veins of white calcite, mixed with green fluor-spar, which here traverse the rocks of the Trenton group (page 161).*

Ramsay.

Quebec group.

Small quantities of galena have been found in the black calcareous shales of the city of Quebec, in veins with white calcite and purple fluor-spar. In various other parts of the Quebec group, galena has been met with, sometimes disseminated in the dolomites, and at others forming small layers or detached masses, generally granular in texture, and associated with the ores of copper, as at Acton, Upton, and Ascot. So far as yet examined, these ores contain but little silver. More highly argentiferous galena has, however, been found in small quantities in quartz veins, as at the rapids of St. Francis on the Chaudière, and at Moulton Hill near Lennoxville; in both cases with mispickel. A similar vein has been observed in St. Armand, a little to the east of Cook's Corners. It runs with the stratification, through the dolomitic limestone, and contains, beside argentiferous galena, small portions of copper pyrites and blende. The latter mineral is also disseminated in the adjacent limestone. Galena occurs in workable quantities in veins which traverse the Gaspé lime-

Lennoxville.

* On page 463, the fluor-spar of this locality is said, by advertence, to occur in veins cutting the Potsdam sandstone.

stones at Cape Gaspé and Indian Cove (page 400). The dolomites of the Niagara formation, throughout Western Canada, frequently contain galena in disseminated grains and crystals, in small fissures of the rock, often with pearl-spar, and sometimes associated with blende. For a description of one of these localities in the township of Clinton, see page 324.

SILVER.

Native silver occurs in small quantities at several of the copper locations on Lake Superior, as St. Ignace and Michipicoten Islands, where it is sometimes associated with copper-glance, and at other times with native copper, the two metals being often soldered together, or the silver completely imbedded in the copper. At Prince's Mine, native silver has been found in a vein of calcareous spar, with sulphuret of silver, copper-glance, blende, and arseniate of cobalt. The quantity of sulphuret was small; but the native silver was disseminated in considerable abundance, in small laminæ, through the calcareous spar. It was however confined to a mass of a few hundred weight, which yielded three and a half per cent. of silver. The silver contained a portion of gold, equal to one part in seven thousand. Native silver.

The copper ores of the Eastern Townships frequently contain small portions of silver. One thousand parts of copper reduced from a specimen of the mixed variegated and vitreous sulphurets of Acton, yielded about two parts of silver. Traces of silver were also found in the copper pyrites of Upton; and from 10,000 parts of copper reduced from the pyrites found in a quartz bed on the seventeenth lot of the seventh range of Ascot, there were obtained nine parts of silver and one and two-thirds parts of gold.

It is well known that the native sulphuret of lead is almost never free from silver, which is sometimes present in so large a quantity as to constitute a silver ore. A vein which occurs at the rapids of the Chaudière in St. Francis, Beauce, contains, in a gangue of quartz, argentiferous galena, blende, mispickel, besides cubic and magnetic pyrites, with minute grains of native gold. A portion of galena from the assorted and washed ore, which still retained an admixture of blende and pyrites, gave by assay sixty-nine per cent of lead, and thirty-two ounces of silver to the ton of 2240 pounds of ore. The assay of a second portion of the same dressed sample gave, however, not less than 256 ounces of silver to the ton. This result was probably due to the presence of a fragment of native silver, or some rich silver ore among the dressed galena; inasmuch as a third assay, of another portion of the ore, more carefully dressed than the first, yielded thirty-seven ounces of silver to the ton. The silver from the cupellation of the reduced lead contained a little gold, and both silver and gold were obtained from the blende and pyrites of the same vein. 1000 grains of the pyrites, still mingled with a small portion of Argentiferous galena St. Francis.

the other ores, were roasted, and then fused with litharge, borax, salt of tartar, and metallic iron. The resulting button of lead gave by cupellation 0·15 grains of an alloy of gold and silver. 700 grains of the blende treated in the same manner, gave 0·19 grains of a similar alloy, of a pale yellow color. The two precious metals seem thus to be generally disseminated throughout the ores of this vein.

Moulton Hill. The galena from Moulton Hill, mentioned above, was much mixed with mispickel, even in selected specimens. A portion of the crushed and washed ore gave by assay twenty-eight per cent of lead; and this contained one part in 500 of silver, equal to sixty-five ounces to the ton of lead. A galena which occurs at Meredith's location on Lake Superior, associated with variegated copper ore, in calcareous spar with laumontite, yielded thirty ounces of silver to the ton of reduced lead.

The other lead ores of the country, so far as examined, for the most part contain but very small portions of silver. The galena of Bedford yielded rather less than two ounces, that of Lansdowne an ounce and a half, and that of Ramsay two and a half ounces of silver to the ton of ore: subsequent trials gave less than two ounces. Specimens of galena from Bay St. Paul, Brome, Chateauguay, Fitzroy, from the North Petite Nation River, and from near Toronto, have also been assayed, and yield only traces of silver. A specimen of the galena from Acton gave eighty-two per cent. of lead, containing two ounces of silver to the ton of metal. The lead from the galena of Upton gave, in like manner, from two to three ounces of silver to the ton.

The native gold of the Eastern Townships is always alloyed with a certain portion of silver.

MERCURY.

Mercury. The native gold obtained from the gravel of the Rivière du Loup is often found to be covered with a white coating of mercurial amalgam, and globules of running mercury are said to have been met with in washing the auriferous sand of this region. It is not impossible that the presence of the mercury here may be accidental; but traces of this metal have been observed in like manner with the native gold of Plymouth, in Vermont, and a native amalgam of gold is found both in Columbia and California. It may here be mentioned, that, according to Mr. Hautefeuille, the native copper from one of the mines on the south shore of Lake Superior, contains, besides a portion of silver, about one part in 4000 of mercury.

GOLD.

The existence of gold in the sands of the Chaudière valley was first made known by Lieutenant, now General, Baddeley, R. E., in 1835 [Am. Jour. Sci. (1), xxviii, p. 112]; and within the last twelve years repeated examinations have shown that the precious metal is not confined to that region, but exists in the superficial deposits of a wide region on the south side of the St. Lawrence, extending from the St. Francis to the Etchemin rivers, and from the first line of hills on the north-west to the province line on the south-east. The source of the gold appears to be the crystalline schists of the Notre Dame range; and the materials derived from their disintegration, not only constitute the superficial material among the hills of this range, but are spread over a considerable area to the south of them. These same gold-bearing rocks may be traced south-westwardly, along the great Appalachian chain to the southern United States, and are supposed to belong, for the most part, to the Quebec group. Native gold has, however, been found in small grains with galena, blende, and pyrites, in a well-defined quartz vein, cutting slates which are supposed to be of Upper Silurian age, at the rapids of St. Francis, on the Chaudière. In Leeds, at Nutbrown's shaft, masses of native gold of several pennyweights are found with copper-glance and specular iron ore, in a vein of bitter-spar; and small grains of the metal have also been found imbedded in the white garnet-rock described on page 496. These latter localities belong to the rocks of the Quebec group; but the precious metal has rarely been found in place, and the working of it in Canada has been confined to the superficial deposits of clay, sand, and gravel already mentioned. The occasional occurrence in these of pieces of gold partially imbedded in quartz, shows that it was derived, in part at least, from beds or veins of this mineral, which are common among the talcoid slates of the region. The observations among the gold-bearing rocks of the Southern States seem to show, that the precious metal was originally deposited in the beds of various sedimentary rocks, such as slates, quartzites, and limestones, and that by a subsequent process it has been, in some instances, accumulated in the veins which intersect these rocks. The formation of these veins would seem, from the one above described at St. Francis, to be subsequent to the Silurian period. The same considerations apply to the copper and lead ores of the Eastern Townships.

Native gold.

Its source.

Gold in veins.

The gold is found very generally disseminated throughout the diluvial deposits over the region already designated in Canada, and is not confined to the river beds; the action which distributed the gravel over the surface being anterior to the formation of the present water-courses. When, by the process of washing, the heavier portions of the auriferous gravel have been brought together, they are found to contain abundance of black ferruginous ores, consisting of magnetic iron, hematite, both specular and compact, chromic iron and ilmenite, with occasional grains of garnet, rutile, and more rarely zircon and corundum. The gold is in grains, sometimes angular, but more often rounded, and varying in size

Diluvial gold.

from masses of half a pound to a fine dust, which last is separated by amalgamation from the black iron sand.

Alloy of gold. The gold thus obtained is alloyed with a portion of silver: a small mass from St. Francis, Beauce, contained 13·27 per cent. The specific gravity of five worn fragments of gold from the Rivière du Loup was as follows: 15·76,—16·49,—16·65,—17·60,—17·77. The third specimen, after being hammered into a thin plate, and annealed, had a specific gravity of 17·024, and gave 13·60 per cent. of silver. The fifth, after a similar treatment, acquired a specific gravity of 17·848, and gave 12·23 per cent. of silver. A third specimen, in fine scales, had a density of 16·57, and contained 10·76 per cent. of silver. It would seem from the variations in specific gravity, that these specimens of native gold were not homogeneous, but were cavernous and held earthy impurities. An apparently pure fragment, weighing 7·5 grammes, had a specific gravity of 15·76; but by prolonged fusion with nitre and carbonate of soda, it lost 1·76 per cent. of its weight, and acquired a specific gravity of 17·43. In the assays above given, the gold was precipitated by oxalic acid from its solutions, which contained, besides, only traces of copper and iron. The pure gold thus separated, after fusion with nitre, had a specific gravity of 18·68–19·04, as determined on two specimens.

Ferruginous sand. A portion of the gold-dust from the washings at the Rivière du Loup was subjected to amalgamation, and left one third of its weight of black ferruginous sand, of which eighteen per cent. were magnetic. The non-magnetic portion was rendered soluble by the successive action of hydrochloric acid and fused bisulphate of potash, leaving 4·8 per cent of silicious residue. From the solutions, which contained iron and chromium, ebullition threw down 23·15 per cent of titanic acid. The liquid was examined without success for tin, uranium, cerium, and the rarer metals, which are sometimes found in the auriferous gravel of other regions. The gold obtained by the distillation of the amalgam lost 4·27 per cent of its weight by fusion with borax, and the assay of the resulting ingot gave 12·87 per cent of silver. This gold contained neither copper nor palladium, but a minute trace of platinum.

The presence of small portions of gold associated with silver in the copper pyrites from Ascott, and with the native silver from Prince's Mine, has been noticed on page 517.

PLATINUM AND IRIDOSMINE.

Platinum. Grains of native platinum have been found in small quantities among the native gold of the Rivière du Loup, and also, it is said, in other locali-

Iridosmine. ties in the same region. Associated with the platinum are small hard steel-gray plates of a metal insoluble in aqua-regia, and having the characters of iridosmine, the native alloy of osmium and iridium.

CARBONACEOUS MINERALS.

Under the head of carbonaceous minerals may be mentioned the various forms of liquid and solid bitumen, carburetted hydrogen gas, bituminous shales, coal, and graphite. Of these, the latter species is common to the Laurentian and the altered palæozoic rocks, but the others are only met in the unaltered palæozoic strata.

BITUMENS.

Bitumen.

Portions of hydrocarbonaceous matters, probably derived from organic remains, are found from the base of the palæozoic rocks in Canada, and in many cases assume the form of bitumen. The presence of a bituminous matter is evident in many of the limestones and dolomites of the Quebec group, from the odor which these rocks evolve when heated, struck, or dissolved in acids. Its presence is still more strongly marked in the limestones of the Trenton group, and indeed in most of the palæozoic limestones of Canada. In many places it appears in the form of petroleum or mineral oil. Thus, in the limestones of the Trenton group in Pakenham, the cavities of large orthoceratites sometimes hold several ounces of it; and it is said to occur in similar conditions in Lancaster. In the limestone of the Birdseye formation, at the Rivière à la Rose, Montmorenci, petroleum exudes in drops from fossil corals. A petroleum spring rises from the Utica formation on the Grand Manitoulin Island; and Dr. Beck has described a similar spring issuing from the Hudson River formation in the township of Guilderland, near Albany in New York. But it is chiefly in the higher formations that petroleum is met with in Canada. In the vicinity of Gaspé Basin, it has been observed in several places rising from strata of Devonian age. In describing these rocks on page 402, the springs of petroleum on the St. John's River and on Silver Brook have already been described, as well as the occurrence of the oil in the cavities of an amygdaloidal greenstone dyke at Tar Point. Other localities of petroleum have since been noticed in that vicinity, at the entrance to Gaspé Basin, and also near the north-east corner of the Douglastown lagoon. About a mile and a half to the south-east of Gaspé Basin, and on the line of the northern anticlinal, is found a layer of mineral pitch or dried bitumen, about an inch in thickness, lying beneath the surface of vegetable mould, while the soil for some distance to the eastward is saturated with petroleum.

Petroleum.

Gaspé.

The dolomites of the Niagara formation in the western basin are generally more or less bituminous: in some parts of western New York they are said to contain so much solid bitumen, that it exudes from the rock when this is heated. The limestone of the Corniferous formation is, in certain portions, still more bituminous. The occurrence of petroleum in certain

Corniferous formation. coralline beds in Bertie has been already noticed on page 378. Two oil-bearing beds are here visible, the one three and the other eight inches in thickness, while others were said to be concealed by the water in the quarry. When the rock is recently broken, the oil is seen to be confined to the cells of corals, which belong to the genera *Heliophyllum* and *Favosites*, and make up a great part of the beds in question. The corals are surrounded by a solid crystalline encrinal limestone, which is free from oil; but, as the limestone dries by exposure to the air, the oil spreads, and colors the portions around the corals, giving rise to the appearance of a continuous band of the dark oil-stained rock, which is limited both above and below by the solid and light-colored limestone. This appears to be not only destitute of petroleum, but impermeable to it. In some of the beds were found large *Heliophylli*, where pores were open, but contained no oil. A thin and continuous bed of *Favosites* was white, porous, and destitute of petroleum, while beds above and below were filled with it. One of these, three inches in thickness, was seen to be twice interrupted in a distance of a few feet, giving rise to the appearance of lenticular masses of dark oil-stained coralline limestone, imbedded in the lighter colored and compact rock. The surface of the latter may be readily wetted with water, which runs off from the oily beds without moistening them. Where these rocks are exposed in quarrying, the oil flows out, and may be collected on the pools of water; but its quantity does not seem to be considerable. The beds of limestone are here somewhat inclined; they are very massive, and the oil-bearing layers show no disposition to separate from the contiguous portions.

Bertie.

Petroleum in corals.

A similar coralline bed, impregnated with petroleum, and lying immediately beneath a layer of chert, occurs a mile to the west of the village of Jarvis; and the quarries in the limestone of the Corniferous formation at Gravelly Bay in Wainfleet, present petroleum under similar conditions to those described in Bertie. In the township of Rainham, shells of *Pentamerus aratus*, in the same limestone, are found, having an interior cavity lined with crystals of calcite and filled with petroleum.

Asphaltum. In other localities the bitumen in this formation is solid, and takes the form of asphaltum or mineral pitch. On the sixth and seventh lots on the south line of Kincardine is a quarry where about twenty feet of the Corniferous limestone is exposed. The lower beds are yellowish-grey, massive, finely granular, fitted for building, and holding a few corals. In the upper part of the section are thinner slaty beds, some of them of a dark chocolate color, alternating with pale yellowish earthy layers. Specimens from one thin bed in the upper part of the section contained no less than 12·8 per cent. of bitumen soluble in benzole. In others, which were much less colored, the combustible matter, which gave a smoky flame when the stone was placed on the fire, was in great part insoluble in the same liquid.

Kincardine.

A brown crystalline porous magnesian limestone from the Grand Manitoulin Island, had in like manner portions of asphaltum in its interstices, and contained from 7·4 to 8·8 per cent. of soluble bitumen.

Petroleum occurs in conditions similar to those just mentioned in the Devonian limestone of Ohio, and in the higher members of the Devonian rocks in New York, where, according to Hall, there are found, both at the base and the summit of the Hamilton formation, septaria containing mineral oil. The overlying Devonian sandstones of the Portage and Chemung group are very often impregnated with petroleum, and have long been known to yield oil springs. It is in these sandstones, and in still higher strata, that are found the oil wells of Pennsylvania and Ohio; but it seems probable that these, like the wells of Western Canada, have their source in the oil-bearing Corniferous formation just described. The oil springs of Enniskillen, and of the banks of the Thames, were known to the Indians, and to the settlers of Western Canada, from a very early period; and since an economic use has been found for the petroleum, the wells dug in these districts have afforded large quantities of it. Oil wells.

The districts yielding oil in Western Canada were made known by natural oil springs, small quantities of petroleum being found floating upon the surface of the water, or, as in Enniskillen, forming, by its drying up, beds of a tarry bitumen. On sinking through the clay, which in Enniskillen covers the surface of the rock with a thickness of from forty to sixty feet, a bed of gravel is generally met with, from which considerable supplies of petroleum are obtained. These constitute what are called surface wells; but they are generally less productive in oil than those which are bored in the older stratified rock beneath, and which are known as rock wells. The relations of the oil springs and the reservoirs of oil to the anticlinals of the rocky strata, are discussed on page 379. The areas within which natural oil springs have been observed in Western Canada, besides the one found on Grand Manitoulin Island, are four in number. Two of these are in Enniskillen, one in the southern part of the township, on Oil Creek, and another in the northern part. A third locality is in the townships of Mosa and Oxford; on the Thames, and a fourth on the Big Otter Creek in Dereham, near Tilsonburg. Wells have been sunk in all these places; in the two former, with great success. In Enniskillen, as already mentioned on page 386, the shales of the Hamilton formation are found beneath the clay; while in Dereham, the Corniferous limestone is covered only by about forty feet of drift clay. Further descriptions of these wells, and of the mode of working them, will be given in a subsequent chapter. Enniskillen. Tilsonburg.

The modifications which petroleum undergoes by exposure to the air, are very instructive. Partly by volatilization, and partly by oxydation, it becomes less fluid, and eventually is changed to a solid form. Thus, near to Oil Creek, in Enniskillen, the thickened oil forms two layers, known

Thickened petroleum.

as gum beds, of a viscid tarry consistency, and covering together two or three acres, with a thickness varying from a few inches to two feet. At Petrolia, in the northern part of Enniskillen, in sinking a well near a natural oil spring, a bed of mineral pitch or asphaltum, similar to that just described, but more solid, was met with at a depth of ten feet in the clay, and reposing upon a layer of gravel of four feet. This bed of bitumen is from two to four inches in thickness, and is readily separable into thin layers, which are so soft as to be flexible, and show upon their surfaces the remains of leaves and insects, which had become imbedded in the bitumen during its slow accumulation and solidification. It is mingled with a considerable portion of earthy matter. This little deposit is instructive, as showing the probable manner in which certain beds of bituminous rocks may have been produced with the concurrence of previously formed sources of petroleum.

Mineral pitch.

In some instances the hardened bitumen is found in the cavities of the bituminous rocks themselves. Thus, at Kincardine, a black, hard, brilliant form of mineral pitch occurs in small quantities in the fissures of the bituminous limestones above described ; and at the quarries in Bertie already noticed, a peculiar change is observed in the bitumen of the corals which have been long exposed at the outcrop of the rock. It is converted into a black matter, which lines the cells ; and it no longer repels water, like the oily corals from within. Benzole, which readily dissolves the bitumen from these, does not affect the black color of the weathered corals, in which the bitumen has evidently been converted into an insoluble modification, as is shown by the following observations. A fragment of a *Favosites* impregnated with this black matter, was crushed and treated with dilute muriatic acid, which removed the carbonate of lime, and left five per cent. of a brownish-black residue. This, when exposed to heat, burned with flame, without melting, and left a voluminous, coherent, coaly residue, which gave a little ash. When treated with a large amount of boiling benzole, the residue gave up only 16·5 per cent. of soluble bitumen; and the subsequent analysis of the insoluble portion afforded volatile matter 28·1, carbon 67·7, ash 4·2 = 100·00. From these results, it appears that the soluble and liquid bitumen of the corals had become in great degree replaced

Altered bitumen.

group, and has in different localities been mistaken for coal. It was first described by Vanuxem, in the Geology of New York, under the name of anthracite, as occurring in the Calciferous formation with crystals of bitter spar and quartz. It sometimes coats these crystals, or the walls of the cavities, and at other times appears in the form of buttons or drops, evidently, according to Mr. Vanuxem, having been introduced into these cavities in a liquid state, and subsequently hardened in a layer above the crystals, showing, by its having conformed to them, that this coal-like matter was once in a plastic state. It is very pulverulent, brittle, of a shining black, and according to Vanuxem yielded but a small amount of ash, and 11·5 per cent of volatile matter, which he regarded as consisting of water. (Geology of New York, iii, 33.) Coal-like matter.

In the Quebec group in Canada, which is regarded as the equivalent of the Calciferous formation, this substance has been observed at Quebec, Orleans Island, Pointe Lévis, Sillery, St. Nicholas, Lotbinière, Drummondville, Acton, the vicinity of the Chatte River in Gaspé, and many other places. It fills veins and fissures in the limestones, shales, and sandstones, and even in the trap rocks which traverse these. Sometimes it is found in buttons or drops, as described by Vanuxem, forming botryoidal masses. At other times it lines fissures, and is seen, as at Drummondville and at Sillery, spread over a surface which had been previously encrusted with small crystals of calcite. The shrinking of the layer has here given rise to cracks, such as are sometimes seen in a coat of varnish. In other cases it fills fissures several inches in diameter; so that it has been mistaken for coal, and attempts have been made to work it at Quebec and elsewhere. The mineral is never, however, in true beds like coal, but is always confined to veins and fissures which cut the strata; showing its deposition to have been posterior to the formation of the rocks. Near to the camp, on the western portion of the island of Orleans, there is a considerable vein of it in the shales, from which several hundredweights might be easily obtained. At St. Flavien in Lotbinière there occurs, in the copper-bearing slates, a vein of it an inch or two in width. The walls of the vein are lined with quartz, and the coaly matter is itself cut by thin veins of quartz, of later formation. In another specimen from this locality, the vein is nearly filled with crystalline quartz, and the bituminous matter is in small almond-shaped masses in the centre of the vein. At Acton it fills irregular cracks and fissures, and sometimes forms masses of several inches in diameter. This matter is of a shining black color, very brittle, breaking into irregular fragments with a conchoidal fracture. It is easily pulverized, giving a very black powder, and flies to pieces when heated. It varies considerably in its chemical characters. The mineral from Acton is much harder than from the other localities mentioned. When heated to redness in a close vessel, it gives off a portion of water, but no inflammable gas or vapor, and loses 6·9 per cent.

Quebec group. Orleans Island. St. Flavien. Acton.

of its weight; leaving a carbon which is difficult of combustion, and gives when incinerated 2·2 parts of ash. Like the specimens described by Vanuxem, it approaches to anthracite in its characters. That from the other localities examined, gives off, when heated, a greater or less proportion of combustible vapor, which condenses in part into a tarry liquid. Carefully selected specimens yield after incineration only a few thousandths of ash, apparently due to accidental impurities. In a specimen from the Mountain Hill, Quebec, the volatile matter equalled 19·5 per cent.; that from the Island of Orleans, 21·0; that of St. Flavien, 15·8; and from another locality, six miles from this, 24·5 per cent. The latter, when exposed to heat, swells up, and leaves a porous coke, the fragments adhering like a caking coal. The same thing is observed, to a less extent, with the specimens from Orleans Island. These carbonaceous matters are insoluble in benzole, with the exception of that last mentioned, which appears to contain a small amount of soluble bitumen. The resemblance of this substance to the altered insoluble bitumen from the Devonian corals at Bertie, taken in connection with the evidences that it was once in a liquid state, are such that it can scarcely be doubted that the coaly matters of the Quebec group have resulted from the slow alteration of liquid bitumen in the fissures of the strata. This is the more probably as the magnesian limestones of the Quebec group at Point Levis are still distinctly bituminous.

The chert beds among the Upper Copper-bearing rocks of Lake Superior, which are supposed to be the equivalents of the Quebec group, contain small portions of a black anthracitic matter, filling fissures, and apparently identical with the material just described (p. 68). A carbonaceous matter, not unlike this, has been described by Durocher as occurring in Sweden, among crystalline rocks which are not improbably of the same age as those of the Quebec group.

Origin of bitumens. As to the origin of bitumens, it has been by some supposed that they have had their origin in the action of heat on coal and similar organic matters, which by a slow distillation have yielded these oily matters, that have been condensed in the overlying strata. To this is to be objected the fact that bitumens occur in rocks in which there is no evidence of the action of heat; and moreover, that, from the distribution of the bitumen, at the ordinary temperature, and under the normal conditions of climate." (Proc. Geol. Society of London, May 1860.)

In the palæozoic rocks of North America, the organic matter which has yielded the bitumen, must be derived either from a marine vegetation, or from the remains of marine animals. These, especially the lower forms, differ but little in elementary composition from plants, and may as readily yield bitumen by their change. The transformation by which organic matters may be converted into bitumen, does not differ very greatly from that which produces the more bituminous coals,—to some of which indeed, certain of the asphaltums approach very closely in composition. The true petroleums retain a larger proportion of hydrogen, and result from a change, under conditions as yet but imperfectly understood, by which a greater proportion of hydrogen is retained in combination. The diverse results of the fermentation of sugar under varying conditions, suggest analogies to the different transformations of vegetable and animal tissues which have resulted in the formation of lignite, coal, anthracite, asphaltum, and petroleum, together with carbonic acid and gaseous hydrocarbons as accessory products. Palæozoic bitumens.

While a vegetable origin is assigned to the bitumen of more recent geological formations, it is probable, that, although a marine vegetation may have in some degree contributed to the formation of the bitumen of the palæozoic strata; an accumulation of molluscous animals in certain strata may have given rise, by a sub-aqueous decomposition, to the petroleum which is now found in these rocks. The small amount of organic matter which the corals contain, would, in itself, be altogether inadequate to the production of the quantity of oil which is found associated with them; so that other organic bodies, which have left no solid skeletons, must have furnished by far the greater part of the petroleum of these palæozoic limestones.

The light carburetted hydrogen or marsh-gas, which is so often a product of the transformation of organic matters at ordinary temperatures, is abundant in the palæozoic rocks of Canada, and issues from many mineral springs. Those of Caledonia, Varennes, and Caxton, in the Lower Silurian series, give off great volumes of this gas, which keep the waters in constant agitation. Many other less important instances of the same kind might be mentioned; while in the higher strata of Western Canada, this gas is still more abundant, as at the well-known burning-spring near Niagara Falls, and in the region of the oil wells. In boring these, reservoirs of it are frequently penetrated, from which the gas is liberated with explosive violence. In nearly all the oil wells there is a greater or less disengagement of inflammable gas; so that it would appear that the strata almost everywhere in that region hold, in a condensed state, portions of light carburetted hydrogen, which is discharged wherever a natural fissure or an artificial boring furnishes a vent. Marsh-gas.

BITUMINOUS SHALES, OR PYROSCHISTS.

Bituminous shales.

The epithet bituminous is commonly applied not only to rocks like those of Bertie, Kincardine, and the Grand Manitoulin, which contain ready-formed bitumen, but to coals, shales, and similar matters, which when strongly heated suffer decomposition and give off volatile oily hydrocarbons. These bodies, which closely resemble bitumen in composition and properties, do not exist ready formed in the coals and shales, but, like the similar oily matters obtained by destructive distillation from lignite, peat, and even from wood, are products of decomposition. The black inflammable shales which belong to the Coal formation, and to many lower and higher geological horizons, are of this character, and owe their combustibility, and their property of yielding oily hydrocarbons by distillation, to an admixture of a substance allied in composition to coal or lignite. The German name of *brandscheifer*, which may be translated by *pyroschist*,* may serve to distinguish these inflammable shales from others, which, like the slaty limestone of Kincardine, contain ready-formed bitumen. Pyroschists occur in at least two horizons in Canada. They form the black shales of the base of the Portage and Chemung group of the Devonian series, and those of the Utica formation of the Lower Silurian. These latter contain very variable amounts of combustible matter; and they give when distilled, besides inflammable gases, portions of oily matter, which, in the shales of Collingwood, the richest yet examined, are equal to four or five per cent. The Devonian shales of Kettle Point, in Bosanquet, in the same manner yielded, by experiments on a small scale, 4·2 per cent. of crude oil, together with a portion of ammoniacal water.

Pyroschists.

It is probable that some of the strata of the Quebec group, as well as the black shales at its base (page 234), are pyroschists; for the altered rocks of this series are in many places very carbonaceous, and contain an admixture of plumbago.

COAL.

Coal

The black bituminous shales or pyroschists of the Portage and Chemung group contain the remains of terrestrial plants, including a species of *Calamites*, the flattened stems of which are sometimes found to be con-trial vegetation prevailed throughout the whole series, yet in no other part of the thickness of 7000 feet was there observed a distinct coal seam. The same Upper Devonian strata, in the state of New York, contain, in like manner, thin seams of coal, which are of no economic importance. The rocks of the Bonaventure formation in Gaspé (page 405), the only representatives in Canada of the true coal-bearing series, have afforded nothing but a few carbonized plants.

PLUMBAGO OR GRAPHITE.

Plumbago occurs in the altered rocks of the base of the palæozoic series, in the Eastern Townships, generally finely disseminated in calcareous or argillaceous shales, rendering them soft, unctuous, black, and shining; but it has nowhere been found among them in sufficient quantity to be of economic value. Examples of these plumbaginous slates are to be seen, among other localities, in Granby, Melbourne, and St. Henry; in the latter place enclosing graptolites. The altered Devonian limestones of Owl's Head are also plumbaginous. The plumbago which is found in Massachusetts, in the continuation of this metamorphic region, is well known to belong to more recent rocks, and to be, in fact, the coal of the Carboniferous system in an altered condition. The principal deposits of plumbago in Canada, however, belong to the Laurentian series, and by analogy suggest the existence of great accumulations of organic matters in the sediments of that remote period. *Plumbago* *Metamorphic origin*

The plumbago of the Laurentian rocks generally occurs in beds or seams of from a few inches to two or three feet in thickness. These are often interrupted, giving rise to lenticular masses, which are sometimes nearly pure, and at other times mingled with carbonate of lime, pyroxene, and other foreign minerals. These deposits of plumbago generally occur in the limestones, or in their immediate vicinity, and granular varieties of this rock often contain large crystalline plates of plumbago. At other times, this mineral is so finely disseminated as to give a bluish-grey color to the limestone, and the distribution of bands thus colored serves to mark the stratification of the rock. Workable deposits of plumbago occur in the townships of Burgess, Lochaber, and Grenville. In one locality in the latter township, it is associated with sphene, zircon, pyroxene, and tabular-spar. *Laurentian series*

The plumbago of the Laurentian series is, however, not confined to the limestones. Large crystalline scales of it are occasionally disseminated in pyroxene rock, in pyrallolite, and sometimes in quartzite and in feldspathic rocks, or even in magnetic oxyd of iron, as at the Hull ore bed. A description of those localities of plumbago which are of economic importance will be given in another chapter.

SULPHUR.

Sulphur. Native sulphur is of rare occurrence in Canada. In some countries it is found in abundance associated with gypsum, and it is met with in small quantities in the gypsum of the Onondaga formation in New York, although it has not yet been seen in this position in Canada. The numerous springs impregnated with sulphuretted hydrogen in Western Canada, however, often give rise to deposits of sulphur, which encrusts the objects over which the water flows. This is well seen at the Charlotteville sulphur spring. In some other localities, small accumulations of sulphur are found, which probably owe their origin to the action of similar springs. In the township of Clinton there is a deposit of this kind, which is said to be found at the surface of the ground, and affords masses of pure yellow compact or fine-grained sulphur, cavities in which are lined with small transparent crystals of sulphur. Dr. Bigsby has described native sulphur in a pulverulent form, and in minute crystals, coating the calcareous shales at the foot of Niagara Falls, on both sides of the river. Here also, as sulphurous springs are not uncommon in these rocks, it is probable that, as at Charlotteville, the sulphur is derived from the decomposition of sulphuretted hydrogen gas.

CHAPTER XVIII.

WATERS OF MINERAL SPRINGS AND OF RIVERS.

MINERAL WATERS OF CANADA; THEIR DIVISION INTO SIX CLASSES.—ALPHABETICAL LIST OF MINERAL SPRINGS.—TABLES OF ANALYSES OF WATERS.—OBSERVATIONS ON THEIR CHEMICAL COMPOSITION; SALTS OF POTASH AND SODA; SALTS OF LIME AND MAGNESIA; BARYTA AND STRONTIA; IRON, MANGANESE, AND ALUMINA; CHLORIDS, BROMIDS, AND IODIDS; SULPHATES, SULPHURETS, AND SULPHURIC ACID; ALKALINE AND EARTHY CARBONATES; SILICA AND SILICATES; BORATES AND PHOSPHATES; ORGANIC MATTERS.—GEOLOGICAL DISTRIBUTION OF MINERAL SPRINGS.—WATERS OF THE ST. LAWRENCE AND OTTAWA RIVERS.

The unaltered palæozoic rocks of Canada abound in mineral springs, a great number of which have been submitted to chemical analysis. It is proposed in the present chapter to notice, in alphabetical order, such springs as have been examined,* giving, in some cases, the results of their chemical examination, but reserving most of the analyses for a series of tables at the end of the list, which will serve to show the comparative composition of the principal mineral springs. After this, the chemical and geological history of these waters will be considered more at length. The result of some examinations of the waters of the St. Lawrence and Ottawa rivers will be appended to the chapter. Mineral springs.

The mineral waters of Canada may for convenience be arranged in six classes, according to their chemical composition. In the first three classes chlorids predominate; in the fourth, carbonates; and in the fifth and sixth, sulphuric acid and sulphates. The waters of the first, second, and sixth classes are neutral; those of the third and fourth are alkaline; and those of the fifth are acid. Classification.

The first class includes saline waters containing chlorid of sodium, with large portions of chlorids of calcium and magnesium, sometimes with sulphates. The carbonates of lime and magnesia are either present only in very small quantities, or are altogether wanting. These waters are generally very bitter to the taste, and always contain portions of bromids and iodids. Examples,—St. Catherines, Ancaster, Whitby, Hallowell. First class.

* In many cases, the springs not having been visited by the officers of the Geological Survey, the locality is given on the authority of the person collecting the water.

Second class

The second class includes a large number of saline waters, which differ from the first in containing, besides the chlorids of sodium, calcium, and magnesium, considerable portions of bicarbonates of lime and magnesia, the latter carbonate generally predominating. Small quantities of oxyd of iron, and of baryta and strontia, are frequently present. These waters generally contain much smaller proportions of earthy chlorids than the first class, and are therefore less bitter, and more pleasant to the taste. Examples,—Plantagenet, St. Léon, Ste. Geneviève.

Third class

The third class includes those saline waters which contain, besides chlorid of sodium, a portion of carbonate of soda, with bicarbonates of lime and magnesia. Small amounts of baryta, strontia, and of boracic and phosphoric acids, are often present in these waters, and bromids and iodids are very rarely wanting. Examples,—Caledonia, Varennes, Fitzroy.

Fourth class

The waters of the fourth class differ from the last in containing but a small proportion of chlorid of sodium, while the carbonate of soda predominates. These waters generally contain a much smaller amount of solid matters than those of the previous classes, and have not a very marked taste until evaporated to a small volume, when they are found to be strongly alkaline. Examples,—Chambly, St. Ours.

Fifth class

The fifth class includes acid waters, which are remarkable for containing a large proportion of free sulphuric acid, with sulphates of lime, magnesia, protoxyd of iron, and alumina. These springs, which are few in number, and characterized by their acid styptic taste, generally contain some sulphuretted hydrogen. Examples,—Tuscarora and Niagara.

Sixth class

In the sixth class may be included some neutral saline waters in which the sulphates of lime, magnesia, and the alkalies predominate, chlorids being present only in small amounts. To this class belongs a mineral water from Hamilton, and another from Charlotteville.

ALFRED.

Alfred.

The water of a saline spring, said to occur on the ninth lot of the tenth range of Alfred, belongs to the second class, and contains 14·5 parts of solid matter in 1000. It rises from the Lower Silurian limestones.*

On the tenth lot of the sixth range of Alfred, two mineral springs are said to occur, both of which yield saline and somewhat alkaline waters of the third class, containing a small proportion of sulphates. The specimens examined were mingled with surface water.

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* By the Lower Silurian limestones, in this chapter, are to be understood those of the Trenton group, and of the Chazy and Calciferous formations, excluding the rocks of the Quebec group, which in certain districts represent the Calciferous formation, and also give rise to mineral springs.

ANCASTER.

The water of a salt well about two miles east of the village of Ancaster belongs to the first class. An attempt was formerly made to manufacture common salt from it; but from the large amount of earthy chlorids, the purification of the salt was found to be difficult. For its analysis, see Table I, 1. Ancaster.

A sulphurous water belonging to the second class occurs about a mile and three quarters north-west of the village of Ancaster. When examined in 1847, the water had a specific gravity of 1005·2, and, besides the ingredients mentioned in the analysis below, contained a small portion of bromine. The amount of sulphuretted hydrogen was found equal to only 0·4 of a cubic inch in 100 cubic inches of water. The water appeared to be slightly thermal, inasmuch as its temperature was 50° F., while an adjacent fresh-water spring was only 48° F. The water of this spring was analyzed in 1854, by the late Dr. George Wilson, of Edinburgh, and gave for 1000 parts, as follows:

Chlorid of sodium,	3·5476
" potassium,	·0052
" calcium,	1·3528
" magnesium,	·4190
Sulphate of lime,	·6500
Carbonate of lime,	·2035
" magnesia,	·0160
" iron,	·0274
Silica,	·0097
Organic matters, phosphoric acid, alumina, and iodine,	traces.
	6·2312

The carbonates exist in the water as bicarbonates. The sulphuretted hydrogen was, by Dr. Wilson, found equal to 5·6 cubic inches in 100 cubic inches of the water; which, as will be seen above, is a much larger quantity than existed in the water examined at the spring in 1847. As however sulphuretted hydrogen is generated when water containing sulphates with organic matter, is preserved in close vessels in warm weather, the large amount of this gas found by Dr. Wilson is not surprising. These two waters issue from rocks of the Niagara formation.

ASSUMPTION.

In the range of Assumption, called Point-du-Jour, is a saline mineral water of the second class, known as the Aurora Spring. It contains 7·36 parts of solid matter in 1000, including small portions of strontia. The spring disengages large volumes of carburetted hydrogen gas, and probably rises from the Lower Silurian limestones. Assumption.

BAIE DU FEBVRE.

Baie du Febvre. Several springs are known to exist in this seigniory, four of which have been examined. Of these, two are waters of the second class, both containing strontia. One of them, on the land of Antoine Loizeau, near the line of Nicolet, in the Grand Range, contains 5·44 parts of solid matter in 1000, and 4·54 parts of alkaline chlorids, of which 2·0 per cent. are chlorid of potassium. The other, in the same range, is on the land of Mr. Lefort, about a mile above St. Antoine church. It is more saline than the last, yielding 15·94 parts of solid matter to 1000, and contains a little boracic acid. Two other springs to be noticed, belong to the third class, both of which give off bubbles of carburetted hydrogen gas, and contain small portions of strontia. One of these is on the land of David Houlé, adjoining that of Antoine Loizeau above-mentioned, and contains 4·96 parts of solid matter in 1000. The other is on the land of Ignace Courchêne, about half a league east of the church. For its analysis, see Table III, 7. The chlorid of potassium in this water equalled 0·92 per cent. of the chlorids. All of these waters probably rise from the Hudson River formation.

BAY ST. PAUL.

Bay St Paul. A very bitter saline spring from the Lower Silurian limestones at Bay St. Paul, contains 20·68 parts of solid matter in 1000, and is to be referred to the first class. Several other mineral springs in the same vicinity contain only insignificant amounts of saline ingredients, and are at the same time feebly sulphurous. One of a similar kind, but more sulphurous, from Les Eboulemens, gave 0·42 of a cubic inch of sulphuretted hydrogen to 100 cubic inches of the water, and contained 0·70 parts of solid matter in 1000.

BELŒIL.

Belœil. A saline water, said to come from the seigniory of Belœil, belongs to the third class, and contains a notable proportion of strontia, besides undetermined amounts of iodids and bromids. It rises from the Hudson River formation. For its analysis, see Table III, 8.

BERTHIER.

Berthier. A copious saline spring of the second class occurs on the land of Charles Boucher, on the Bayonne, a league above the church of Berthier, and probably belongs to the Lower Silurian limestones. For its analysis, see Table II, 9. A spring regarded as chalybeate, near the manor-house at Berthier, contains a feeble proportion of iron, with earthy carbonates.

BRAMPTON.

A reputed mineral spring in the village of Brampton was found to contain 0·38 parts in 1000, of earthy and alkaline chlorids and sulphates, with a good deal of organic matter. Another copious spring on the river Etobicoke, a little below the village of Brampton, was also found to be very feebly saline. Brampton.

BRANT.

A copious spring of mineral water, belonging to the sixth class, occurs on the fifty-third lot of the township of Brant. It is described as filling a basin of eighty-eight by forty-five feet, having a depth of about forty feet, and situated upon a mound composed of calcareous tufa. From the clear blue color of the water in the basin, it has received the name of the Blue Spring. The flow from the spring is constant and copious, and the water is sulphurous to the taste and smell. No gas is evolved from the spring. A partial analysis of the water gave as follows for 1000 parts: Brant.

Sulphate of lime,	1·240
" magnesia,	·207
Carbonate of lime,	·198
	1·645

The carbonate of lime, which was precipitated by prolonged boiling, was without any carbonate of magnesia. The water held no trace of chlorids, but the amount of sulphuric acid obtained was a little more than is required to form the sulphates of lime and magnesia, and it is probable that a small portion of sulphate of soda exists in the water.

CALEDONIA.

Four springs are known at this watering place, three of which are very near to each other, and belong to the third class. One of these is known as the Gas Spring, from the quantity of carburetted hydrogen gas which it evolves, and which was roughly estimated at 300 cubic inches per minute. Another is called the Saline Spring, though less strongly saline than the first; and the third is known as the White Sulphur Spring. The amount of sulphuretted hydrogen in this was found not to equal a cubic inch in a gallon of the water, but it is said to have formerly been much more sulphurous. The supply of water from the first spring was estimated at about four gallons, and of the others at about ten gallons each, in a minute. The analyses of these waters will be found in Table III, 1, 2, 3. The fourth, known as the Intermittent Spring, on account of the intermitting discharge of carburetted hydrogen gas, is a water of the second class. Its analysis is given in Table II, 1. All of these waters issue from the Trenton group. Caledonia.

CAXTON.

Caxton. A saline spring of the second class rises from the Lower Silurian limestones in the township of Caxton, on the banks of the Yamachiche, and affords from six to eight gallons of water a minute, disengaging at the same time great quantities of carburetted hydrogen gas. Its analysis will be found in Table II, 3.

CHAMBLY.

Chambly. About a league north of the village of Chambly, in the Rang des Quarantes, upon the land of Mr. Cherrier, there are two saline springs belonging to the third class, and rising from the Hudson River formation. From one of these flows a considerable current of pleasantly saline water, containing 5·74 parts of solid matter in 1000. Baryta and strontia are present in it in considerable quantities. This spring, which evolves abundance of carburetted hydrogen gas, has a temperature of 53° F. The second spring, near to this, was slightly ferruginous, and had a feeble sweetish saline taste, but was not farther examined.

A remarkable spring occurs on the land of Antoine Jetté, on the Grand Coteau, where a well has been sunk eight or ten feet, and the water overflows in a small stream. A little carburetted hydrogen gas is evolved from the well, the temperature at the bottom of which was like that of the spring mentioned above, 53° F., shewing these waters to be slightly thermal. This water is feebly sweetish and saline to the taste, and belongs to the fourth class. The carbonate of soda forms more than one half of the solid contents of this water, which affords evidence of the presence of boracic acid, bromine, iodine, strontia, and baryta. Two analyses closely agreeing with each other, were made of portions of this water, collected in 1851 and 1852. The latter analysis is given in Table IV, 1.

CHAMPLAIN.

Champlain. There are two springs near the village of Champlain which have a local reputation. One of these, when visited, was full of surface water; the other was feebly saline and belonged to the second class.

CHARLOTTEVILLE.

Charlotteville. A remarkable sulphurous spring, belonging to the sixth class, occurs on the third lot of the twelfth range of Charlotteville. The water fills a natural basin, covering about a hundred square yards, from which the discharge was found to be about sixteen gallons a minute. The water rises through several holes in the mud at the bottom of the basin. This is covered with a layer of sulphur and carbonate of lime, a mixture of which incrusts leaves and twigs placed in the spring. The water is remarkable for the predominance of earthy sulphates, and for the great amount of sulphuretted hydrogen which it contains, amounting to 11·6 cubic inches in 100 cubic inches of water. This was determined at the spring, by precipitating it from the recent water by means of a solution of chlorid of arsenic. The temperature of this water in the basin was 45° F., its specific gravity 1002·7. It is limpid and sparkling, and pungent to the taste from the great amount of sulphuretted hydrogen which it contains. 1000 parts of the water yielded on analysis:

Sulphate of potash,	·0510
" soda,	·4718
" lime,	1·1267
" magnesia,	·4351
Chlorid of magnesium,	·0878
Carbonate of lime,	·3050
" magnesia,	·0179
" iron,	traces
Sulphuretted hydrogen,	·1776

The amount of solid matters is 2·495 parts in 1000. The carbonic acid was equal to ·273 parts, of which the carbonates require ·143, leaving ·130, or scarcely enough to form with them bicarbonates. This spring issues from the Corniferous formation.

FITZROY.

A saline spring belonging to the third class, and rising from the Chazy or the Calciferous formation, occurs on the tenth lot of the second range of Fitzroy, on the land of Mr. Francis Gillan. It contains traces of strontia, and a portion of phosphoric acid. For its analysis, see Table III, 6. Fitzroy

A spring on the twelfth lot of the sixth concession of the same township, is feebly saline and sulphurous to the taste, and belongs to the second class. It has not been quantitatively analyzed.

GLOUCESTER.

A water said to be from a spring on the land of Mr. Borthwick in Gloucester, belongs to the second class, and is strongly saline, giving 11·20 parts of solid matter in 1000. It contains a little strontia, and rises from the Lower Silurian limestones. Gloucester.

HALLOWELL.

Several wells have here been sunk in the Trenton formation, with a view of obtaining brine for salt-making, and have yielded bitter saline waters of the first class. On the eleventh lot of the second range, a portion of

Hallowell. water was taken from a well twenty-seven feet deep, on the land of Mr. Amos Hubbs. It was very bitter and saline, and gave only traces of potash salts, no sulphates, but bromids, and an unusually large proportion of iodids. Its analysis is given in Table I, 3. A similar water, but less strong, was afterwards received from Mr. Hugh McDonell of Hallowell. Its analysis is given in Table I, 4.

HAWKESBURY.

Hawkesbury. The water from a mineral spring said to be on the ninth lot of the sixth range of Hawkesbury, is both saline and strongly alkaline, belonging to the third class. A partial analysis gave for 1000 parts, chlorid of sodium 8·177, sulphate of soda ·083, carbonate of soda 1·200, carbonate of lime ·076, carbonate of magnesia ·063 = 9·599. It contains moreover, bromids, iodids, and boracic acid, with a little silica and oxyd of iron. The quantities of these ingredients were not determined.

HAMILTON.

Hamilton. In the Canadian Journal for 1853, page 153, Prof. Henry Croft, of Toronto, has described a mineral water said to be from Young's Spring at Hamilton. It belongs to the sixth class, and is distinguished by the very large proportion of sulphate of magnesia which it contains. The specific gravity of this water was found to be 1006·4, and its composition, according to Prof. Croft, was as follows, for 1000 parts:

Chlorid of sodium,	·5098
Sulphate of soda,	1·6985
" lime,	1·1246
" magnesia,	4·7799
	8·1128

HENRYVILLE.

Henryville. A sulphurous water belonging to the third or the fourth class, is found on the land of David Miller, about two miles south of Henryville. It contains a large proportion of carbonate of soda, with chlorids, and a trace of iodine, together with sulphuretted hydrogen equal to 1·6 cubic inches in 100 cubic inches of the water.

JACQUES CARTIER RIVER.

Jacques Cartier. A strongly sulphurous spring at Marcotte's Mills on the Jacques Cartier River, belongs to the fourth class. It rises from the Utica formation, and contains but a small amount of solid matter, of which carbonate of soda makes up the largest part. It appears to hold a considerable proportion of borates. The chlorid of potassium equals 2·95 per cent. of the alkalies estimated as chlorids. For the analysis of this water, see Table IV, 3.

JOLY.

In the township of Joly there is a sulphurous spring, issuing from the Hudson River formation, on the banks of a brook called the Maguenat, about five miles from Methot's Mills. The water, which is feebly saline, belongs to the fourth class, and contains a portion of boracic acid, besides sulphuretted hydrogen gas equal to 7·5 cubic inches to a litre. See the analysis, Table IV, 4. Joly.

KINGSTON.

In boring for water at Morton's distillery in Kingston, two mineral springs were met with. The waters of these are bitter and saline, partaking of the characters of the first class, but they are remarkable for the large proportions of sulphates and of earthy carbonates which they contain. In the presence of the latter elements, they approach in composition to the waters of the second class. These waters have been examined by the Rev. Professor Williamson, of Queen's College, Kingston, and the results of his analyses, as calculated for 1000 parts, are as follows: Kingston

	Upper well.	Lower well.
Chlorid of sodium,	29·864	5·216
" calcium,	12·894	4·010
" magnesium,	6·954	1·763
Sulphate of soda,	....	2·441
" lime,	·396	.....
" magnesia,	·492	.....
Carbonate of lime,	·370	·400
" magnesia,	1·287	.....
	52·257	13·830
Specific gravity,	1043·2	1010·0

The waters of the upper well contain, according to Dr. Williamson, both iodine and bromine, the latter being the more abundant. In the lower well, traces of sulphuretted hydrogen are met with. These waters are from the Lower Silurian limestones.

LANORAIE.

A saline spring, rising from the Lower Silurian limestones, and belonging to the second class, occurs about mid-way between the villages of Lanoraie and Industry. It gives off large volumes of carburetted hydrogen gas, and is remarkable for the considerable proportion of salts of baryta and strontia which the water contains. An analysis of it will be found in Table II, 5. Lanoraie.

NIAGARA.

Niagara A spring of acid water, belonging to the fifth class, is found in the south-west corner of Niagara, on the land of Mr. McKinley. The basin of the spring is about thirty inches deep, and three or four feet in diameter, and is in a yellow clay, which at a depth of three or four feet is underlaid by the red and green sandstone of the Medina formation. The basin, which had no visible outlet, was nearly full of water. This was in constant ebullition from the escape of inflammable gas, and had a decided taste and smell of sulphuretted hydrogen. A half dried-up pool, about twenty yards distant, contained a small quantity of very acid water. The water of the basin is slightly yellowish, turbid, and very styptic and acid to the taste. It contains sulphuric, but no hydrochloric acid, and portions of lime, magnesia, alumina, protoxyd of iron, and alkalies, besides an organic matter, which causes the residue of the evaporated water to blacken when heated. The specific gravity of this water is 1002·16, and the mean of two determinations gave 2·1376 parts of sulphuric acid (SO_3) to 1000. The same amount of water gave ·074 of lime, equal to ·180 of sulphate, while the residue from calcination, after evaporating the water, consisting of sulphates of lime and magnesia, with oxyd of iron and alumina, was only equal to ·600 ; so that in round numbers the water may be said to contain two parts of hydrated sulphuric acid in 1000. After being kept for some months in close vessels, a peculiar organic growth made its appearance in the water. This, under the microscope, seemed to consist of groups of filaments, each composed of a single chain of yellow translucent homogeneous globules.

Chippewa. About a mile and a half above Chippewa, near the Niagara River, is a similar spring, which has been described by Dr. Mack of St. Catherines. The water is very sour to the taste, and strongly impregnated with sulphuretted hydrogen. A qualitative analysis shows it to be similar in composition to the water described above, but somewhat stronger. This spring rises from the Onondaga formation ; but another similar water, said to be near St. Davids, rises, like that of Niagara, from the Medina formation. For farther particulars about these acid waters, see the description of the spring of Tuscarora.

NICOLET.

Nicolet. In the concession of the Quarante Arpents, in Nicolet, and near to the line of St. Gregoire, upon the farm of the widow Honoré Hébert, is a small area destitute of vegetation, and impregnated with water, which was collected by digging a hole in the earth. The color of the water, which belongs to the fourth class, was brownish-yellow, and its taste was alkaline, but scarcely saline. An analysis of the soluble salts of this water will be found in Table IV, 5.

Another similar spring occurs on the land of Olivier Roy in Nicolet, not far from the line of the Baie du Febvre. When evaporated, the water becomes strongly alkaline to the taste. These two springs rise from the Hudson River formation.

PLANTAGENET.

Three saline waters, belonging to the second class, and issuing from the Lower Silurian limestones, have been examined from this township. The first is that of Larocque, generally known as the Plantagenet Spring, of which the analysis will be found in Table II, 4. The second is the so-called Georgian Spring, and differs from the last in containing a small proportion of sulphates. Its analysis is given in Table II, 6. The third is a water similar to the first, and was furnished by Mr. Peter McIntosh. It contains 10·16 parts of solid matter to 1000, and yields traces of boracic acid, and a comparatively large amount of strontia. Plantagenet

The water of a saline and alkaline spring, containing no sulphates, received from Mr. Sheriff Treadwell, is said to occur on the twelfth lot of the first concession of Plantagenet. The specimen was diluted with surface water, but evidently belonged to the third class.

QUEBEC.

A sulphurous water, which was formerly in some repute, rises from the rocks of the Quebec group, in St. John's suburb, Quebec, on the property of Mr. Joseph Hamel. It contains, besides common salt and carbonate of soda, a portion of sulphates, and apparently belongs to the fourth class, but when examined was diluted with surface water. Quebec.

RAWDON.

Two springs have been examined from the township of Rawdon. One of the third class from the twenty-fifth lot of the third range, is somewhat strongly saline, containing 4·96 parts of solid matter in 1000, and yielding the reactions of baryta, boracic acid, bromine, and iodine. The other, from the twenty-seventh lot of the same range, is an abundant spring of slightly sulphurous water, belonging to the fourth class, which yields only 0·32 parts of solid matter in 1000, and contains portions of sulphates and borates, with a trace of bromine. These springs apparently rise from the Potsdam formation. Rawdon.

RIVIERE OUELLE.

A saline spring occurs on the south side of the river, in the third concession of this seigniory, on the land of Mr. Charles Rocheford, and issues from the rocks of the Quebec group. An area of about half an acre of clayey soil is here impregnated with salt water, which collects in four basins, the largest being four or five feet in diameter and three or four feet deep, the others somewhat smaller. The streams issuing Rivière Ouelle.

from these unite to form a small rivulet. The water of all these basins is apparently alike, and strongly saline and bitter. A portion from the largest gave 13·36 parts of solid matter to 1000. It contained a small amount of earthy carbonates, a very large proportion of chlorids of calcium and magnesium, besides some sulphates, and distinct reactions of bromine and iodine. This water belongs apparently to the first class.

SABREVOIS.

Sabrevois. Near to the village of Pike River, in Sabrevois, are several mineral springs near to each other, the waters of two of which, known as the Saline and Sulphur Springs, have been examined. Both are feebly saline and sulphurous waters, of the second class, and rise from the Utica or the Hudson River formation. The first contains salts of baryta and strontia; the second, and the stronger of the two, holds, on the contrary, soluble sulphates. Both of these waters are very slightly impregnated with sulphuretted hydrogen.

SCARBOROUGH.

Scarborough. Two springs on the sixteenth lot of the fourteenth range of Scarborough have a local reputation as mineral springs. Their waters give by boiling a small amount of earthy carbonates; but even when evaporated to one tenth, they have no marked taste. They contain, besides, only sulphate of lime, with traces of chlorids.

The water of a well at the Bank of Upper Canada in Toronto has a similar composition, while that of a spring at Spadina, which deposits a large amount of carbonate of lime in the form of calcareous tufa, contains in solution only traces of chlorids, and no sulphates.

STE. ANNE DE LA POCATIERE.

Ste Anne. In the second concession of this seigniory, on the land of Nicholas Rouleau, is a copious spring of slightly sulphurous water, which issues from a hill of sandstone of the Quebec group, and has a temperature of 44°·5 F. It gives by evaporation only 0·36 parts of solid matter to 1000: the residue is strongly alkaline to the taste, and contains a small portion of sulphates. This water belongs to the fourth class. In the same concession, about a mile to the north-east of the last, and a mile south of the college, is a small spring of bitter saline water, which contains, besides chlorids, an abundance of sulphates of lime and magnesia, and a small portion of carbonates. It belongs to the second class, and yields 5·06 parts of solid matter to 1000.

ST. BENOIT.

A spring nearly opposite to the old church of St. Benoit rises through the clays, which here overlie the Potsdam formation. The specific gravity of the water is 1004·3, and it contains about 6·0 parts of solid matter to 1000. This water, which may be referred to the first class, contains traces of carbonates, and large amounts of calcareous and magnesian salts, both chlorids and sulphates. St. Benoit.

ST. CATHARINES.

A well was sunk some years since in the town of St. Catharines in the hope of obtaining brine for the manufacture of salt. A boring, five inches in diameter, was carried to a depth of about 500 feet, and after traversing the red strata of the Medina formation, is said to have penetrated fifty or sixty feet into the schists of the Hudson River formation. The well is stated to yield about twenty-two gallons of water per minute. The brine is so much charged with lime and magnesia salts as to be unfit for the manufacture of salt; but it has acquired a considerable reputation in the treatment of many diseases. It is used at the well, both internally and externally, and is also evaporated to a small volume, and sent over the country in a concentrated form. This water, which belongs to the first class, was analysed a few years since by Prof. Croft of Toronto, whose analysis is given below (I). Its specific gravity was 1036·0. St. Catharines.

A second boring, made in the town of St. Catharines by Mr. E. S. Adams in 1861, has resulted in the discovery of a saline water similar to that of the old well, but somewhat less strong. The composition of this last seems subject to some variation, as will be seen by comparing with the analysis of Prof. Croft, the results of a partial examination of a specimen of the water obtained from the old well, in December, 1861, (II), at the same time with the water of the new well (III). In these analyses the chlorid of potassium and the iodid of sodium were not determined. These waters gave for 1000 parts as follows:

	I.	II.	III.
Chlorid of sodium, ...	29·8034	23·00	19·94
" potassium, ...	·3555	.....	.....
" calcium, ...	14·8544	9·66	6·49
" magnesia, ...	3·3977	2·40	1·95
Iodid of sodium, ...	·0042	.....	.....
Sulphate of lime, ...	2·1923	1·75	1·77
	50·6075	36·81	30·15

ST. EUSTACHE.

About two leagues beyond the church of St. Eustache, on the land of Joseph Laurin, is a feebly saline spring belonging to the second class, and yielding 1·88 parts of solid matter to 1000 of the water. It contains a portion of sulphates, and issues from the Lower Silurian limestones. St. Eustache.

STE. GENEVIEVE.

Ste. Geneviève — Ste. Geneviève, on the Batiscan River, offers several strongly saline springs of the second class, two of which have been analysed, and are remarkable for the large proportion of iodids which they contain. The first is on the land of Olivier Trudel, a league above the church, and disengages bubbles of carburetted hydrogen gas; the supply of water is abundant. Another spring occurs at the ferry, directly opposite to the church. These waters rise from the Lower Silurian limestones. The analyses of both of them are given in Table II, 7 and 8.

ST. HYACINTH.

St. Hyacinth. — The so-called Providence spring of St. Hyacinth, is a saline water of the third class, issuing from the Hudson River formation. It is strongly alkaline, and contains a portion of strontia. The solid matters of the water equalled 5·16 parts in 1000.

ST. LEON.

St. Léon — A strongly saline spring is met with in the valley of the Rivière à la Glaise, about a mile from the church of St. Léon. It rises from the Hudson River formation, or from the Lower Silurian limestones. The volume of water discharged is considerable, and it is accompanied with large quantities of carburetted hydrogen gas. This water belongs to the second class, and, besides small portions of baryta and strontia, contains sufficient carbonate of iron to give it a chalybeate taste. Its analysis is given in Table II, 2.

STE. MARTINE.

Ste. Martine — A feebly saline water from the parish of Ste. Martine, in Beauharnois, belongs to the third class, and probably rises from the Calciferous formation. It gives 1·98 parts of solid matter to 1000, and contains a small portion of sulphates. This spring is said to be sulphurous.

ST. OURS.

St. Ours — In constructing a lock on the Richelieu River, at St. Ours, a mineral spring was found, which was inclosed in such a manner as to make it accessible from above by a pump. The water, which rises from the Hudson River formation, and belongs to the fourth class, contains only ·53 parts of solid matter to 1000, among the soluble parts of which carbonate of soda predominates, with chlorids and small portions of borates. Its analysis is given in Table IV, 2. The large proportion of potash salts is remarkable. 1000 parts of this water gave ·2250 of alkalies, estimated as chlorids, of which ·0565 parts, or 25·11 per cent, were chlorid of potassium. Another determination gave 24·52 per cent of chlorid of potassium. A portion of water taken from the spring several weeks previously, gave a larger amount of alkalies, equal to ·3400 of chlorids in 1000 parts, of which ·0596, or 17·53 per cent. were chlorid of potassium; apparently showing an admixture of a more saline water, richer in soda salts.

TUSCARORA.

What is known as the Sour Spring of Tuscarora is upon the Indian Reserve, about nine miles south of Brantford, and three miles south of the bank of the Grand River. The water issues from a small mound around the roots of a decaying pine tree, whose ruins constitute the soil. This for some distance around is saturated with acid water, and destitute of vegetation. Several depressions at the foot of the mound are filled with acid water, the largest being about eight feet in diameter, three or four feet deep, and nearly full, but without any visible discharge. The water is kept in constant agitation by a discharge of inflammable gas. It is slightly turbid and brownish, and has a styptic, acid and sulphurous taste. The presence of sulphuretted hydrogen is also evident from the odor, and from the ready blackening of bright silver when immersed in the water. Its amount was determined on the spot, by a solution of arsenic, and was found equal to only one fourth of a cubic inch in 100 cubic inches of the water. The specific gravity of the water was 1005·58. It contained no trace of chlorids, but gave by analysis as follows for 1000 parts: Tuscarora.

Sulphate of potash,	·0608
" soda,	·0502
" lime,	·7752
" magnesia,	·1539
" protoxyd of iron,	·3638
" alumina,	·4681
Phosphoric acid,	traces
Hydrated sulphuric acid (SO_3 HO),	4·2895
	6·1615

A portion of organic matter is present, which causes the water to blacken when evaporated to a small volume. No traces of zinc, manganese, cobalt, or nickel could be detected in this water; and the presence of free sulphuretted hydrogen is evidently incompatible with the existence, in solution, of most of the other metals occasionally found in mineral springs, such as tin, lead, copper, antimony, and arsenic.

The above analysis was made with water taken from the spring in October, 1847. A portion of the water, collected in April, 1846, had been previously submitted to a partial analysis by Prof. Croft of Toronto, whose results show a considerable change in the composition of the water. His determinations are here given (I), and are compared with those obtained in the analysis already given above.

	I.	II.
Sulphuric acid (SO_3),	2·9069	4·6350
Potash,	——	·0329
Soda,	——	·0219
Lime,	·4798	·3192
Magnesia,	·2036	·0524
Peroxyd of iron and alumina,	·5148	·3315
	4·1051	5·3929

The water examined by Prof. Croft is more dilute, but contains a greater amount of bases than that collected eighteen months later. In the former, the sum of the bases is to the amount of sulphuric acid as 412 : 1000, and in the latter, as 152 : 1000. The proportion of the lime to the acid is about as 1 : 6, by weight, in the first, and as 1 : 15 in the second.

The proportions between the magnesia and the sulphuric acid in the two are respectively as 1 : 15 and 1 : 90. If it be supposed that the water at its source contained only sulphuric acid, and dissolved the various bases in its way through the strata, it would follow, that, as these gradually become exhausted of their soluble elements, the proportion of saline matters in the waters of the spring must diminish.

VARENNES.

Varennes. The two saline springs of Varennes rise through the clays which overlie the Utica, or the base of the Hudson River formation, and belong to the third class. They are situated about a mile and a half below the church, not far from the St. Lawrence, and are about 100 rods apart. The one enclosed within the house is known as the Gas Spring, from the large volume of carburetted hydrogen gas which it gives off. This was formerly collected in a gas-holder, and employed in lighting the house. The outer one is known as the Saline Spring, and is generally resorted to for drinking. It affords, from time to time, a few bubbles of carburetted hydrogen, and yields two or three gallons of water in a minute. The temperature of the Saline Spring, on the 20th of November, 1847, was found to be 47° F., and that of the Gas Spring only 40°, the air being 19°. On the 18th of October, 1848, the air being 44°, the Saline Spring was 47°·5, and the Gas Spring 45°·5. While the former spring, although uncovered, scarcely freezes, it is said that in winter the latter becomes filled with ice. This difference may be in part due to a less abundant supply of water in the Gas Spring, rendering it more affected by atmospheric influences. At the same time, the escape and rarefaction of large volumes of carburetted hydrogen gas, from a state of compression in the strata below, may be supposed to diminish the temperature of the Gas Spring, from the waters of which gas is constantly escaping. The analyses of these two waters are given in Table III, 4 and 5.

WESTMEATH.

On the thirteenth lot of the sixth range of Westmeath is a spring which deposits a considerable amount of calcareous tufa, and is known as the Petrifying Spring. The water contains, besides carbonate of lime, small quantities of chlorids, and is feebly sulphurous. On the twenty-third lot of the same range, a copious spring, similar to the last, occurs on Tucker's Creek. It contains a large amount of carbonate of lime, and a little iron; besides which, it holds only traces of sulphates and chlorids. Westmeath.

WHITBY.

At Bowerman's Mills, on the thirty-second lot of the third range of Whitby, there is a copious saline spring of the first class, containing an abundance of bromine, but only traces of iodine. It yields also minute portions of strontia and oxyd of iron, and very small quantities of potash salts. The analysis of this water is given in Table I, 2. Whitby.

TABLE I.—WATERS OF THE FIRST CLASS.

	1.	2.	3.	4.
Chlorid of sodium,	17·8280	18·9158	38·7315	17·4000
" potassium,	·0920	traces	traces	......
" calcium,	12·8027	17·5315	15·9230	9·2050
" magnesium,	5·0737	9·5437	12·9060	9·4843
Bromid of sodium,	·1178	·2482	·4685	undet.
Iodid of "	......	·0008	·0133	"
Sulphate of lime,	·7769	......	......	......
Carbonate of lime,	traces	·0411	......	......
" magnesia,	......	·0227	......	......
" strontia,	......	traces	......	......
" iron,	......	traces	......	......
In 1000 parts of water,	36·6911	46·3038	68·0423	36·0893
Specific gravity,	1029·1	......	1053·11	......

1. Ancaster. 2. Whitby. 3. Hallowell, Amos Hubbs. 4. Hallowell, H. McDonell.

TABLE II.—WATERS OF THE SECOND CLASS.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Chlorid of sodium,	12·2500	11·4968	11·7750	11·6660	11·1400	9·4600	17·2671	11·5094	8·0454
" potassium,	·0305	·1832	·0800	·1040	·1460	·1040	·2409	undet.	undet.
" barium,	......	·0019	......	......	·0303	......	......	......	......
" strontium,	......	·0019	......	......	·0185	......	......	......	......
" calcium,	·2870	·0718	·0503	·1364	·2420	·0443	·6038	·2264	·0466
" magnesium,	1·0338	·6636	·3743	·2452	·2790	·4942	2·0523	·8942	·0856
Bromid of "	·0238	·0091	·0342	·0080	·0283	·0029	·0587	·0273	undet.
Iodid of "	·0021	·0046	·0039	·0052	·0052	·0017	·0133	·0183	traces
Sulphate of lime,	......	......	......	......	......	·1929	......	......	......
Carbonate of baryta,	......	......	......	......	·0106	......	......	......	......
" strontia,	......	......	......	......	·0137	......	......	......	......
" lime,	·1264	·3493	·2160	·0330	·4520	·2980	·0120	·0180	·0470
" magnesia,	·8632	·9388	1·0593	·8904	·4622	·3629	·7506	·4464	·8354
" iron,	traces	·0145	·0054	·0096	traces	traces	traces	traces	......
Silica,	·0225	·0865	·0479	·0700	·0552	·0205	undet.	undet.	......
Alumina,	traces	·0145	·0050	traces	undet.	undet.	"	"	......
In 1000 parts of water,	14·6393	13·8365	13·6513	13·1678	12·8830	10·9814	20·9987	13·1400	9·0600
Specific gravity,	1010·9	1011·23	1010·36	1009·39	1009·42	1008·78	......	......	......

1. Caledonia, Intermittent Spring. 2. St. Léon. 3. Caxton. 4. Plantagenet, Larocque's Spring. 5. Lanoraie. 6. Plantagenet, Georgian Spring. 7. Ste. Geneviève, Trudel's Spring. 8. Ste. Geneviève, Ferry Spring. 9. Berthier, Boucher's Spring.

TABLE III.—WATERS OF THE THIRD CLASS.

	1.	2.	3.	4.	5.	6.	7.	8.
Chlorid of sodium, ...	6·9675	6·4409	3·8430	9·4231	8·4286	6·5325	4·8334	5·9662
" potassium, ...	·0309	·0296	·0230	·1234	·0382	·1160	·0610	undet.
Bromid of sodium, ...	·0150	·0169	·0100	·0126	·0046	·0217	undet.	undet.
Iodid of "	·0005	·0014	traces	·0054	·0085	·0032	undet.	undet.
Sulphate of potash, ...	·0053	·0048	·0183	......	......	......	......	......
Phosphate of soda, ...	......	......	......	......	......	·0124	......	......
Carbonate of "	·0485	·1762	·4558	·1705	·3260	·5885	1·5416	·6082
" baryta, ...	......	......	......	·0226	·0123	traces	traces	......
" strontia, ...	......	......	......	·0140	·0096	"	"	·0250
" lime, ...	·1480	·1175	·2100	·3540	·3490	·1500	·2180	·1440
" magnesia, ...	·5262	·5172	·2940	·5433	·3559	·7860	·4263	·4756
" iron, ...	traces	traces	traces	·0048	traces	traces	......	traces
Alumina, ...	·0044	undet.	·0026	traces	"	·0040	undet.	undet.
Silica, ...	·0310	·0425	·0840	·0465	·0540	·1330	·2120	·1140
In 1000 parts of water, ...	7·7773	7·3470	4·9407	10·7202	9·5868	8·3473	7·2923	7·3330
Specific gravity, ...	1006·2	1005·8	1003·7	1008·15	1007·7	1006·24	......	......

1. Caledonia, Gas Spring. 2. Caledonia, Saline Spring. 3. Caledonia, Sulphur Spring. 4. Varennes, Saline Spring. 5. Varennes, Gas Spring. 6. Fitzroy, Gillan's Spring. 7. Baie du Febvre, Courchêne's Spring. 8. Belœil.

TABLE IV.—WATERS OF THE FOURTH CLASS.

	1.	2.	3.	4.	5.
Chlorid of sodium, ...	·8387	·0207	·0347	·3818	·3290
" potassium, ..	·0324	·0496	·0076	·0067	·0318
Sulphate of potash, ...	......	·0081	traces	·0215	traces
Carbonate of soda,.....	1·0604	·1340	·1952	·2301	1·1353
" strontia, ..	·0045	......	......	......	.....
" lime, ...	·0380	·1740	·0710	·0620	undet.
" magnesia,.	.0765	·1287	·0278	·0257	"
" iron,......	·0024	traces	......	......	"
Alumina,..............	·0063	undet.	undet.	undet.	"
Silica,................	·0730	·0160	·0110	·0245	"
In 1000 parts of water,.	2·1322	·5311	·3473	·7523	1·5591

1. Chambly. 2. St. Ours. 3. Jacques Cartier. 4. Joly. The ·0215 in this analysis is sulphate of soda. 5. Nicolet, Hebert's Spring.

ON THE CHEMICAL COMPOSITION OF THE PRECEDING WATERS.

The results obtained during the long series of analyses which have been given above, offer many points of interest, which will now be indicated in discussing successively the principal constituents of the mineral waters, and their chemical history.

SALTS OF SODA AND POTASH.

Potash and soda. The compounds of soda generally predominate in saline waters, and it is only in rare cases that the saline ingredients of these consist chiefly of the salts of lime and magnesia. By a reference to the Tables II and III, it will be seen that the chlorid of sodium, or common salt, forms the greater portion of the solid matter of these saline waters, and that it is only among the waters of the fourth class that the alkaline carbonates constitute a large portion of the soluble salts present. The relative proportions of soda and potash are subject to considerable variations. In the waters of the ocean the potash does not form more than two or three per cent. of the alkalies, calculated as chlorids; while in the various brine springs of England, Germany, and Canada, it is still less; often amounting, as in the waters of the first class, to traces only. In the waters of the second class, its proportion becomes somewhat greater; and in those of the third class, and more especially in the fourth, where alkaline carbonates predominate, the proportion of potash salts is sometimes worthy of especial notice. The alkaline chlorids of the water of Nicolet yield 1·89 per cent. of chlorid of potassium, those of Jacques Cartier 2·95, and those of St. Ours not less than 25·0 per cent. There does not, however, appear to be any constant relation between the proportion of alkaline carbonates and the potash, since the Nicolet and Jacques Cartier waters are more alkaline than the water of St. Ours, while the salts from the spring of Joly contain less than one per cent. of potash.

SALTS OF LIME AND MAGNESIA.

The waters of the first class are characterized by the presence of great quantities of chlorids of magnesium and calcium; amounting, in several cases, to more than one half the solid contents of the water. This composition is altogether unlike that of any waters hitherto studied. The bittern left after the partial separation of the salt from sea-water by evaporation, contains a large amount of chlorid of magnesium, but lime salts are altogether wanting in it. These have been separated during evaporation in the form of sulphate, in which state a portion of magnesia still exists in the bittern, showing an excess of sulphuric acid over that required to combine with the lime. In the waters of the first class, on the contrary, lime abounds, while sulphates are absent, or are present only in small quantities. The water of the Dead Sea offers some resemblance to these curious brine springs, in its large amount of chlorid of magnesium; but it differs in containing a much smaller proportion of chlorid of calcium, and a larger quantity of chlorid of potassium; resembling in this respect the bittern of sea-water, in which, from the separation of the chlorid of sodium, the potash has accumulated. The occasionally large proportion of iodine in these brine springs, is especially worthy of notice. The stratigraphical relations of these waters, which issue from the limestones near the base of the palæozoic series, will be considered farther on.

Lime and magnesia.

Earthy chlorids

While the waters of the first class are destitute of earthy carbonates, or, like sea-water and most true brine springs, contain them only in small amounts, those of the second, third, fourth, and sixth classes deposit, by boiling, considerable quantities of the carbonates of lime and magnesia. The relative proportions of these carbonates vary. In the precipitate from the waters of the second class, which contain chlorids of calcium and magnesium, the carbonate of magnesia greatly predominates over the carbonate of lime, and sometimes exceeds seven or eight per cent. of the solid matters present, as in the St. Léon and Caxton springs. A similar predominance of carbonate of magnesia is observed in the precipitates obtained by boiling the alkaline saline waters of the third class; while in the more alkaline waters of the fourth class, these proportions are reversed, and the carbonate of lime predominates; as is likewise the case in those of the sixth class.

Earthy carbonates.

At the temperature of boiling water, carbonate of lime slowly decomposes a solution of chlorid of magnesium, with the production of carbonate of magnesia and chlorid of calcium; so that the proportions of the two bases in the precipitated carbonates will depend upon the length of time which the water has been boiled. Thus in the analysis of the water of Ste. Geneviève (II, 7), the proportion of the two carbonates is given as 12 : 750. When, however, another portion of the same water was boiled to one sixth of its volume, in contact with the separated carbonates, the lime had entirely disappeared from the precipitate, which was only carbonate of magnesia. From this, it follows that the proportions in which the chlorine is divided between the calcium and magnesium in a mineral water, cannot be determined from the results of analysis. In some experiments made with the intention of elucidating this question, it was found that from an artificial mineral water, containing chlorids of calcium and magnesium, besides bicarbonates of the same bases, there was separated, by thirty minutes' boiling, a precipitate which contained ·173 of carbonate of magnesia and ·666 of carbonate of lime; while by spontaneous evaporation, a portion of the same liquid gave ·805 carbonate of lime, without any carbonate of magnesia. This same fact is curiously illustrated in the case of the Plantagenet water (Table II, 4), whose analysis gives chlorid of calcium ·1364, chlorid of magnesium ·2452, with carbonate of lime ·0330, and carbonate of magnesium ·8904: the latter numbers being deduced from the precipitate obtained by ebullition. When however this water is left to spontaneous evaporation, the whole of the lime is deposited as carbonate, and the solution remains, for a time, charged with sesqui-carbonate of magnesia. This compound, even in closed vessels, is spontaneously decomposed, with the precipitation of a portion of crystalline hydrated carbonate of magnesia, equal to ·772 parts of carbonate of magnesia to 1000 parts of the liquid, while bicarbonate of magnesia and chlorid of magnesium remain in solution.

Two types of saline waters.

The various saline waters of the Lower Silurian rocks may be looked upon as derived from two types, the one of which is represented by the waters of the first class, derived from the limestones, and the other by those of the fourth class, which apparently have their origin in the shales and sandstones. In some cases, the brines of the first class appear to pass unchanged through the overlying formations, as at Ancaster; but more frequently they become mingled with the alkaline waters of the fourth class. In order to make known the reactions which would result from this admixture, a series of experiments was made, with the following results. When to an artificial water, resembling in composition that of Whitby or of Hallowell, there is added a dilute solution of carbonate of soda, a precipitate is formed, which consists of carbonate of lime, with about sixteen per cent. of carbonate of magnesia. The solution, evaporated at a gentle heat, afterwards deposits carbonate of magnesia, with only sixteen per cent. of carbonate of lime. When a solution of bicarbonate of soda is substituted, the precipitate of carbonate of lime does not contain more than two or three per cent. of carbonate of magnesia, and the liquid retains, in the form of bicarbonate, a portion of lime, which may be separated by evaporation at the ordinary temperature; but at a boiling heat, as already stated, it reacts on the chlorid of magnesium present, and gives rise to a precipitate of carbonate of magnesia. In this way, may be explained the generation of the waters of the second and third classes from the admixture of the carbonated alkaline waters of the fourth with those of the first class. It will be observed, that the waters of the third class contain less solid matter than those of the second, showing apparently a greater admixture of the more dilute alkaline waters of the fourth class.

SALTS OF BARYTA AND STRONTIA.

The presence of baryta and strontia has been detected in a great number of the saline waters of Canada; and it is probable that in most cases the two bases will be found together. In several of the analyses given above, the formation of a precipitate by a solution of gypsum, in the concentrated and acidulated water, was regarded as sufficient evidence of the presence of one or both of these bases; but in the waters of Varennes, St. Léon, and Lanoraie, the precipitate of sulphates thus obtained was submitted to further examination, and found in each case to consist of a mixture of the sulphates of baryta and strontia. In the waters of the second class, a portion of these bases was found in the precipitate of carbonates obtained by boiling, while another portion remained in solution as chlorids. It is probable that the carbonates of baryta and strontia react with the chlorid of magnesium like the carbonate of lime, so that the remarks already made about the salts of magnesia and lime will equally apply to the present case. Baryta and strontia.

SALTS OF IRON, MANGANESE, AND ALUMINA.

Traces of iron are seldom or never wanting in those waters which contain earthy carbonates. The proportion is ordinarily very small; but the waters of St. Léon, Caxton, Plantagenet, and the Saline Spring of Varennes may be regarded as slightly chalybeate. In every case when a portion of one of the saline or alkaline waters, or the precipitate obtained from it by boiling, is evaporated to dryness with an excess of hydrochloric acid, and the residue treated with dilute hydrochloric acid to separate silica, the solution will be found to yield with ammonia a precipi- Iron.

Alumina. tate. This, which is often colorless, is partly soluble in potash, and contains a portion of alumina. When dissolved in hydrochloric acid, it gives with a sulphocyanid the reaction of iron, and with molybdate of ammonia, indications of phosphoric acid. When heated with a little caustic soda on silver foil, the precipitate rarely, if ever, fails to give evidence of the presence of manganese. The small portion of alumina which these waters contain, is not derived from suspended argillaceous matters, but appears to be in a state of solution.

Manganese.

CHLORIDS, BROMIDS, AND IODIDS.

Chlorids. The characteristic element of the saline waters is chlorid of sodium, with variable proportions of chlorid of potassium, and in the first and second classes, with chlorids of the earthy bases. These chlorids are accompanied by portions of bromids and iodids. The proportion of the bromids to the chlorids however appears to be less in these springs than in the sea-water of the present day. Thus, according to Usiglio, 100 parts of the salts of the Mediterranean contain 1·48 of bromid of sodium; and ten analyses, by Von Bibra, of the waters of different oceans, give from ·86 to 1·46 parts, affording for 100 parts of salts, an average of 1·16 parts of bromid of sodium, equal to 1·04 parts of bromid of magnesium. The waters of Whitby and Hallowell, on the contrary, which are the richest in bromids, give only ·54 and ·69 parts of bromid of sodium to 100 parts of solid matters; while the two springs of Ste. Geneviève contain respectively only ·28 and ·21 parts of bromid of sodium (or magnesium), and that of Lanoraie ·22 parts of bromid of magnesium. The proportion of bromids in many other saline springs of the country is still smaller.

Bromids.

Iodids. The variations in the amount of iodine are not less remarkable. In the waters of the modern ocean, it is well known that iodine is present only in minute traces; and in some strongly saline springs, like that of Whitby, it is only in the alcoholic extract of the evaporated residue that iodine can be detected. The Hallowell water (Table I, 3), which closely resembles this in its general composition, and in its proportion of bromine, contains however so much iodine that its presence can readily be discovered without evaporation. It suffices to add to the recent water, acidulated by hydrochloric acid, a little solution of starch, and a few drops of nitrite of potash, to obtain an intense blue color. The iodid of sodium in the first water was found equal to ·0017 parts of the solid matter; and in the second to ·019, or nearly twelve times as much. The saline waters of Ste. Geneviève give as marked a reaction for iodine as that of Hallowell, and when acidulated with hydrochloric acid, without previous evaporation, yield, with a salt of palladium, an insoluble precipitate of iodid, after a few hours. The spring II 7 contains ·063 parts, and II 8 yields ·138 parts of iodine for 100 of solid matters; so that there appears to be no constant proportion between the chlorids, bromids, and iodids of these saline waters. The springs of Ste. Geneviève are remarkably rich in iodine, as will be seen by comparing them with the various saline waters of Canada and of other regions. The Congress Spring of Saratoga, which is an alkaline saline resembling that of Varennes, but charged with carbonic acid gas, gives, according to Schweitzer's analysis, for 100 parts of solid matters ·464 parts of bromid of sodium, and ·013 parts of iodid of sodium.

SULPHATES, SULPHURETS, AND SULPHURIC ACID.

A great number of the saline and alkaline waters of Canada contain soluble salts of baryta, whose presence is incompatible with the existence of sulphates in solution. These are however met with in the waters of the third class, from Caledonia, and in all those of the fourth class which have been examined, that from Chambly excepted. In all of these waters, however, chlorids or carbonates of soda predominate, and the sulphates are present only in comparatively small quantities. In the waters of the sixth class, on the contrary, the chlorids are present in small amounts, and the sulphates of lime and magnesia are the characteristic ingredients, the former salt predominating in the springs of Brant and Charlotteville. The water of Young's Spring, from Hamilton, differs from these; inasmuch as, according to Prof. Croft's analysis, more than one half of the saline contents of the water consists of sulphate of magnesia. Such waters are but rarely met with; but a spring near Crown Point, in Essex County, New York, according to Dr. Emmons, contains in 1000 parts, 18·78 parts of solid matter, which consists principally of sulphate of magnesia, with a little sulphate of lime. It is probable that mineral waters of this kind are directly connected with the sulphate of magnesia which has already been described as incrusting the dolomites of the Clinton formation in western Canada, and efflorescing elsewhere upon Lower Silurian shales (page 460).

Sulphates.

Magnesian sulphate.

The origin of the sulphate of magnesia, which is often found in similar conditions upon magnesian rocks, is, upon the authority of Mitscherlich, ascribed to the decomposition of sulphate of lime by the carbonate of magnesia of dolomite. A series of experiments has, however, shown that, although a solution of gypsum is readily decomposed by hydrated carbonate of magnesia, it may remain for months in contact with dolomite without change. It is probable that the sulphate of magnesia which now impregnates mineral springs, or effloresces from the surface of certain rocks, existed, like other saline elements, disseminated in the strata; except in those cases where, as at Marmora, it is produced from magnesian rocks by the sulphuric acid from oxydizing pyrites.

Its source.

The waters of Brant and Charlotteville closely resemble in composition the well-known sulphur springs of Sharon and of Avon, in New York. In all of these, the sulphuretted hydrogen has doubtless been formed by the

Sulphuretted hydrogen. reducing action of organic matter, which converts the sulphates into sulphurets; these, in their turn, are decomposed by carbonic acid, with the separation of sulphuretted hydrogen. This reaction is probably the source of all sulphuretted waters; and it may be, in some cases, carried so far as to decompose the whole of the soluble sulphates in a water, converting them into carbonates. An example of this is seen in the saline water of the second class from Sabrevois, which contains no sulphates, but holds in solution sulphuretted hydrogen and a portion of baryta.

Sulphuric acid. The origin of the sulphuric acid in the waters of the fifth class is not easily explained. A few similar springs are known elsewhere, in volcanic countries; and the origin of the acid in these cases is ascribed, either to the oxydation of the sulphurous acid formed by the combustion of sulphuretted hydrogen, or to the slow and direct oxydation of the latter gas, in the presence of air and moisture, at ordinary temperatures. Neither of these reactions, however, can explain the origin of the acid in the springs of Tuscarora and Niagara, or the similar ones in Western New York. These waters are not thermal, and rise from undisturbed and unaltered Silurian rocks, far removed from any volcanic region. They contain from two to four thousandths of sulphuric acid, with small portions of soluble sulphates, and are accompanied with carburetted and sulphuretted hydrogen gases. It is possible that the origin of the sulphuric acid in these waters is due to the decomposition of a sulphate, such as gypsum, by the action of silica and water, under the influence of an elevated temperature, and at a great depth. The sulphuric acid would either be set free without decomposition, or be resolved into sulphurous acid and oxygen, which would re-combine in their upward progress through the strata.

CARBONATES AND CARBONIC ACID.

The most interesting facts connected with the carbonates of lime and magnesia in mineral waters, have already been mentioned in speaking of these bases. The absence of free carbonic acid from the mineral springs of Canada, is remarkably evident in the want of dissolved carbonate of lime in the waters of the first class, which flow from limestone rocks; nor do any of the other waters offer that excess of carbonic acid, which gives to certain springs, like those of Saratoga, their acidulous taste and sparkling appearance. The waters of the St. Léon Spring gave, by direct determination, 1·224 of carbonic acid for 1000 parts. Of this, ·651 were required to form the neutral carbonates obtained in the analysis; leaving ·673 parts of carbonic acid, or very little more than is required to convert them into bicarbonates. The Caxton Spring gave, in like manner, 1·126 of carbonic acid; of which, ·651 are required for the neutral carbonates, leaving only ·475 of carbonic acid in excess. Of alkaline waters, the Saline Spring of Varennes yielded ·920 parts of

Carbonic acid.

carbonic acid; of which, ·451 parts, or very nearly one half, is required to form neutral carbonates. The Gas Spring of Varennes shows, like the Caxton Spring, a deficiency of carbonic acid.

Of the waters of Caledonia, in which the carbonic acid was determined with great care at the springs, the Gas Spring contained in 1000 parts, ·705 of carbonic acid; of which, ·356, or a little more than one half, is combined in the form of neutral carbonates. The Saline Spring gave ·648 of carbonic acid, being an excess of ·292 over that required to form neutral carbonates; while in the Sulphur Spring, which contained in 1000 parts, only ·590 of carbonic acid, ·349 parts are combined as carbonates, leaving only ·141 parts for the formation of bicarbonates. In the latter water, as well as in the Gas Spring of Varennes, there is, then, a deficiency in the amount of carbonic acid, so that the bases represented as carbonates cannot all exist in the form of bicarbonates. This deficiency is most marked in the waters which contain the greatest amount of carbonate of soda. It is well known, however, that an excess of carbonic acid is not necessary to retain carbonate of magnesia in solution. Carbonate of magnesia is soluble to a considerable extent in an excess of carbonate of soda, or of chlorid of magnesium; and a large quantity of magnesia may be held in solution in the form of a sesqui-carbonate, as shown in the case of the Plantagenet water submitted to spontaneous evaporation (page 552). The small amount of carbonic acid in these waters is explained, when it is considered that the earthy carbonates have been derived from the decomposition of the chlorids in the waters of the first class, by the action of the carbonate of soda contained in the waters of the fourth class. The alkaline salt having been formed from the decomposition of feldspathic matters in the presence of earthy carbonates, probably contains no excess of carbonic acid. It will still be desirable to determine the amount of carbonic acid in some of the waters of the fourth class, like those of Chambly and of St. Ours. Bicarbonates

The amount of carbonate of soda, as given in the analyses of the alkaline waters, is calculated from the excess of soda over that required to combine with the chlorine and sulphuric acid. Attempts were made to control these determinations by evaporating the water to dryness to separate the earthy salts, dissolving the residue, and precipitating the alkaline solution with chlorid of barium. From the weight of the carbonate of baryta thus obtained, the amount of carbonate of soda in the liquid was then calculated. As thus determined, however, it was always found to be somewhat less than that deduced from the excess of soda. The following results were obtained for the amounts of carbonate of soda in certain waters whose analyses are given in tables III and IV, when calculated by the two methods above described; — A, by the excess of soda over the chlorine and sulphuric acid; B, by the amount of carbonate of baryta: Carbonate of soda

	III, 3.	III, 6.	IV, 1.	IV, 2.	IV, 3.	IV, 5.
A............	·4558	·5885	1·0604	·1340	·1952	1·135
B............	·2540	·5466	1·0156	·1125	·1470	1·078

It would appear from these results that a portion of the excess of soda must be combined with some other acid, capable of forming a soluble salt with baryta. It was found in the case of the Chambly water, that the precipitate of carbonate contained a sparingly soluble baryta-salt, which was not entirely removed even by long continued washing with water. This was probably a borate of baryta, since salts of boracic acid are now known to be present in all of these alkaline waters.

SILICA AND SILICATES.

Silica.

It will be seen by reference to the tables of analyses, that the mineral waters of the second class always hold in solution small portions of silica, varying from ·15 to ·60 parts for 100 of solid matters; and that in those of the third class, there is a larger quantity of the same element, which, up to a certain point, augments with the amount of carbonate of soda. In the following table, the proportions of carbonate of soda and of silica in 100 parts of solid matters, are given for certain springs, whose analyses will be found in Tables III and IV:

	III, 1.	III, 4.	III, 2.	III, 5.	III, 6.	III, 8.	III, 3.	III, 7.	IV, 2.	IV, 4.	IV, 1.	IV, 3.
Carb. Soda.	·6	1·6	2·4	3·4	7·0	8·0	9·2	21·0	25·0	30·0	50·0	56·0
Silica......	·4	·4	·6	·6	1·6	1·5	1·7	2·9	3·0	3·2	3·4	3·2

Silicate of soda.

The amount of silica which these waters contain, does not in any case exceed one or two ten-thousandths; and it is well known that water at the ordinary temperature may dissolve very much more than this amount of silica, even in presence of alkaline chlorids and bicarbonates. Carbonic acid expels silica from its combination with soda, at ordinary temperatures; but at the boiling-point the affinities are reversed, and silicate of soda is regenerated. At that temperature, however, a mutual decomposition takes place between the silicate of soda, and the carbonates of lime and magnesia, giving rise to silicates of these bases, which are sparingly soluble in water. Hence it happens that when a water, like those of the third and fourth classes, containing dissolved silica, with carbonates of lime, magnesia, and soda, is boiled, there is deposited, with the earthy carbonates, a portion of silicates. In the case of the Belœil water, the precipitate obtained by boiling, gave with hydrochloric acid a clear solution, from which gelatinous silica was afterwards separated. A portion of the earthy silicates is, however, retained in solution, even to an advanced stage of the evaporation. It was found that the water from Gillan's Spring in Fitzroy, which had been evaporated to one tenth and filtered, became turbid by farther boiling, and gave a flocculent precipitate, which consisted of silica combined with lime and magnesia. A similar reaction was observed with the Varennes and other saline waters; and likewise with the waters of the St. Lawrence and Ottawa Rivers, to be described farther on.

Silicates of lime and magnesia.

The proportion of silica thus held in solution, in combination with the earthy bases, is considerable. In the water of Gillan's Spring, 1000 parts of which contain ·133 parts of silica, the precipitate obtained by evaporating to one tenth, contained ·088 parts of silica, leaving ·045 parts still in solution, together with portions of lime and magnesia. 1000 parts of the Belœil water, treated in the same way, deposited ·050 parts of silica with the carbonates, retaining ·064 in solution. When the water was evaporated to complete dryness in contact with the earthy precipitate, the whole of the silica was obtained in an insoluble form; but when the carbonates were removed from the concentrated alkaline liquid, it was found that by evaporation to dryness, a reaction took place, by which the precipitated silicate of lime was partly decomposed, and the silica was re-dissolved by the alkaline carbonate; a result which did not happen when an excess of earthy carbonates was present. When 1000 parts of the Chambly water, containing ·073 of silica, were evaporated to one twentieth, ·042 parts of silica remained in solution.

There are not wanting observations which confirm the above results. Dr. J. Lawrence Smith noticed the existence of a dissolved silicate of lime, apparently combined with soda, in the concentrated alkaline waters of Broosa; and a silicate of lime is deposited from the thermal springs of Weisbaden. The existence of proto-silicates of iron and manganese has been observed in several mineral waters, and the separation of gelatinous silica from certain limonites and ochres, as already described (pages 511 and 512), shows the existence of a silicate of iron in these ores. Berzelius observed that a silicate of magnesia separates during the evaporation of the hot alkaline waters of Carlsbad; and according to Kersten, the carbonated waters of Marienbad, when evaporated either at ordinary or elevated temperatures, deposit at first carbonates, and then silicates of lime and magnesia, which gelatinize with acids, like the silicates separated from the Belœil water (Bischof, Chem. Geol., i, 4 and 5). This production of silicates of lime and magnesia by the evaporation of natural waters, is highly interesting in a geological point of view, since it explains the formation of many natural silicates, such as, for example, the deposits of hydrous silicate of magnesia, which occur interstratified with unaltered fresh-water tertiary strata in France and elsewhere. To the metamorphism of such silicates may be due the formation of steatites, serpentines, and many allied minerals.

BORATES AND PHOSPHATES.

Boracic acid.

The frequent occurrence of small portions of boracic acid in natural waters has only been made known within a few years; and since that time, all the alkaline waters of Canada which have been examined, have shown the presence of borates, by the power of the evaporated water to redden turmeric paper in the presence of free hydrochloric acid. This reaction is particularly marked with the waters of the fourth class; but it has also been observed with some of those of the second class, as in Lefort's Spring from Baie du Febvre. In speaking of the alkaline carbonates (page 558), allusion has already been made to the fact, that a portion of the soda which is represented as carbonate, in these waters, appears to be in combination with boracic acid. As no direct process for separating this acid is known, its determination must be effected by indirect means. The alkaline water of Joly gives a strong reaction of boracic acid; and having, by evaporation, obtained a quantity of its saline matters, the silica was separated by carbonate of ammonia, and the chlorine by carbonate of silver. There was thus obtained a mixture of salts of soda and potash, combined only with carbonic, sulphuric, and boracic acids. By directly determining all the other ingredients, the boracic acid was calculated from the loss, and was found equal to ·028 parts in 1000 parts of the water, which contained ·752 of solid matter. By the use of bicarbonate of baryta to separate the sulphuric acid from the mixed salts, the above process of analysis might be simplified.

Phosphoric acid.

The presence of traces of phosphates in these waters has been alluded to on page 554. They are probably never absent; and in some of the alkaline waters, they may exist in larger quantities than has been supposed. In the case of Gillan's Spring in Fitzroy, the amount of phosphoric acid was found to be equal to ·0087 parts in 1000 of the water.

ORGANIC MATTERS.

Organic matters.

The alkaline waters, although colorless when recent, generally become of a brownish-yellow color when boiled. This change appears to be due to the presence of some organic matter, which is modified by the action of the alkaline carbonate. When a litre of the Chambly water was evaporated to one sixth, and separated by filtration from the earthy salts, it had a clear bright brown color, which the addition of a slight excess of acetic acid rendered paler, without causing any precipitation. Acetate of copper then threw down a brown precipitate, having the characters of apocrenate of copper, and corresponding to ·0043 of apocrenic acid. The filtrate, treated with carbonate of ammonia, gave no evidence of crenic acid.

GEOLOGICAL DISTRIBUTION OF MINERAL SPRINGS.

The great palæozoic area of Canada has been shown to be divided into two secondary basins, by an axis extending from Deschambault on the St. Lawrence, in a south-west direction, to Lake Champlain. The eastern part of the western basin is more or less affected by undulations, which are subordinate to the great fault that brings up the Quebec group against the Hudson River formation, and by others of minor importance. It is in this disturbed region that by far the greater number of the mineral springs occur; and although it is often difficult to establish the presence, or to trace the extent of the faults in the stratification, on account of the alluvial deposits which generally cover the Lower Silurian rocks of the region, it is evident that in a great number of cases the mineral springs occur along the lines of disturbance, and it is probable that a constant relation of this kind exists. Geological position.

As the south-eastern limit of the western basin is approached, the mineral springs become more numerous; but this boundary once passed, a region is soon reached where the rocks have become profoundly altered, and furnish no more mineral waters. The great western portion of the occidental basin, which is less disturbed, presents but very few mineral springs; although the wells which have been sunk at Kingston, Hallowell, St. Catherines, and elsewhere, show that the rocky strata of this region are charged with saline waters. Of the waters of Western Canada, those of Ancaster rise from the Niagara, and those of Brant and Charlotteville from the Corniferous formation. Of the acid springs of the fifth class, those of Tuscarora and Chippewa issue from the Onondaga formation, and those of Niagara and St. David's from the Medina. With these exceptions, all of the mineral waters noticed in the preceding descriptions, issue from Lower Silurian rocks. Of the alkaline waters of the third and fourth classes, of which twenty-one have been examined, those of Caledonia rise from the Trenton group, and that of Fitzroy from the Chazy or the Calciferous formation; to which last, or to the Potsdam formation, the waters of Ste. Martine, and those of Rawdon, are probably to be referred. All the others of these classes belong to the Hudson River formation; except those of Varennes and Jacques Cartier, which appear to rise from the Utica formation, and those of Ste. Anne and Quebec, which issue from the Quebec group of rocks. Western Canada. Eastern Canada.

Of the waters of the second class, of which more than thirty have been examined, those of La Baie, Sabrevois, and perhaps St. Léon and Assumption, rise from the Utica or the Hudson River formation; while the others issue from the Trenton, Chazy, Calciferous, or Potsdam formation. The neutral saline waters of Ste. Anne and Rivière Ouelle, and several similar saline springs at Cacouna and Green Island, rise from the rocks of the Quebec group.

Origin of the various waters.

Setting aside for the moment the waters of the Quebec group, it would appear, that, for the other springs of the first four classes, the source of the neutral salts, consisting of alkaline and earthy chlorids, is in the limestones and the other strata, from the Potsdam to the Trenton group inclusive; while the alkaline carbonates are derived from the argillaceous sediments which make up the Utica and Hudson River formations. These sediments are never deficient in alkaline silicates, whose slow decomposition yields to infiltrating waters the alkaline carbonates and silicates which characterize the waters of the fourth class. These, mingling in various proportions with the brines which rise from the limestones beneath, produce the waters of the second and third classes, in the manner already explained while speaking of the calcareous and magnesian carbonates of these waters. The occurrence of several springs of the third class, like those of Caledonia and Fitzroy, rising from the Lower Silurian limestones, is not surprising, when it is considered that the Chazy formation in the Ottawa valley includes a considerable thickness of shales, sandstones, and argillaceous limestones, approaching in composition to the sediments of the Hudson River formation. That great mass of strata which constitutes the Quebec group, and is regarded as the equivalent of the Potsdam and Calciferous formations, offers, in its lithological composition, successions of limestones and shales similar to those of the higher portions of the Lower Silurian series, and furnishes the same variety of saline and alkaline waters.

Association of unlike springs.

As an evidence that the different classes of waters have their origin in different strata, may be cited the fact that springs very unlike in composition are often found in close proximity, and apparently rising from a common fissure or dislocation. Thus at Caledonia, three waters of the third class are found within a few feet of each other; one of them being sulphurous, while the others are not so, and are much more strongly saline. Not far from these rises a very different water, belonging to the second class. At Ste. Anne de la Pocatière, a spring of the second class, and another of the fourth class, are found not far apart. In Sabrevois, of two springs of the second class, very near together, one contains salts of baryta and strontia, and the other soluble sulphates; while in the seigniories of Nicolet and Baie du Febvre, six springs have been described, which rise through the Utica formation, along a line, in a distance of three or four leagues. Of these springs, two belong to the second, two to the third, and two to the fourth class; these last being probably derived entirely from the shales, while the others have their source in the underlying limestones. The great rarity of mineral springs in the uncomparatively undisturbed region of Western Canada has already been alluded to. The waters of Scarborough and of Brampton probably do not rise from the palæozoic rocks, but derive their feeble saline impregnation from the overlying clays and sands.

The extended series of analyses here given, offers many points of interest. Nowhere else, has such a complete systematic examination of the waters of a region, and of a great geological series been made ; and an additional importance is given to the results from the fact, that the waters are derived from palæozoic strata, which prepares us to find certain points of difference between these waters and those of other countries, for the most part belonging to more recent geological formations. The brine springs of the first class are altogether unlike those of England, Germany, and the state of New York. In all of these, common salt greatly predominates, and the earthy chlorids form but a very small portion of the solid contents; while in the waters of the first class, these chlorids constitute more than one half of the saline ingredients. The brine springs of other regions are supposed to arise from the solution of rock salt, which occurs in beds, or in crystals disseminated through the strata, as in the saliferous marls of the Onondaga formation. In the process of crystallization the common salt separates from the earthy chlorids; and hence the brine springs of New York, which have their source in this formation, are solutions of chlorid of sodium, with but very little impurity. The brine springs of the Lower Silurian limestones, on the contrary, may be supposed to represent the composition of the ancient ocean in which these early strata were deposited. The action of the carbonate of soda from feldspathic rocks, through long ages, has since decomposed the greater part of the chlorid of calcium of the ocean, replacing it by chlorid of sodium, and forming the carbonate of lime of which vast limestone formations have been built up. The analyses by Lenny, of some waters from deep wells in the Carboniferous series on the Alleghany river, show the existence of brines which resemble those of Whitby and Hallowell, in containing large amounts of chlorids of calcium and magnesium, and traces of baryta, sulphates being invariably absent. (Bischof, Chem. Geology, i, 377.) Brine springs.

The mineral waters of the second class, which are distinguished by containing a large proportion of carbonate of magnesia, and but very little carbonate of lime, seem, from the numerous analyses of Berzelius and Struve, to be very rare in Germany. The relations of these lime and magnesia salts have already been discussed. Since it has been suggested that these waters have been formed by the action of alkaline salts upon waters of the first class, it may be asked why more examples have not been given of springs which contain, at the same time, large amounts of earthy carbonates, and considerable portions of chlorids of the same bases, indicating a composition intermediate between the waters of the first class, and those of St. Léon, Plantagenet, and Lanoraie. To this, it is to be said, that the object of these analyses having been primarily the examination of those springs which had attracted attention as medicinal waters, the more bitter saline springs have been to a great extent neglected. The Whitby Spring, however, contains a portion of carbonates; and the bitter salines of Rivière Ouelle and of Kingston apparently represent waters intermediate between the first and second classes. It should here be observed, that the springs which have been examined make but a small portion of those which are known or reported to exist in the country.

Economic uses.

The saline springs of the first class are too much charged with earthy chlorids to be suited to the manufacture of common salt; while those of the second class contain too small a proportion of salt to be employed with advantage. It is not impossible that the large amount of alkaline carbonates in some of the springs of the fourth class might be made economically available, provided that the waters were concentrated, during the heats of summer, by solar evaporation. The supplies of dilute sulphuric acid furnished by the waters of the fifth class might also be found of value, in their vicinity, for manufacturing purposes.

Medicinal value.

In a medicinal point of view, the mineral waters of Canada are already known to a considerable extent; but they are generally employed without much reference to the great variations in their composition. Among saline waters, those containing considerable quantities of earthy chlorids must evidently possess medicinal properties very different from those in which large amounts of carbonate of soda are present. The salts of iodine, which are rarely absent, and are found in such unusually large quantities in the saline waters of Ste. Geneviève, and the salts of baryta and strontia which occur those of St. Léon, Lanoraie, Varennes, and many other springs, are also especially worthy of consideration in a therapeutic point of view.

Thermal waters.

None of the mineral springs of Canada, so far as they have yet been examined, offer any considerable elevation of temperature above the mean of the region in which they occur. Few of these springs are very copious, and the water in their basins is consequently subject to more or less modification from atmospheric influences. The annual mean temperature of Montreal, as deduced from the observations of twenty-seven years, is, according to Dr. Archibald Hall, 44°·6 F.; while the temperature of the Caledonia springs was found to vary from 44°·5 to 46°, that of St. Léon being 46°, and Caxton 49°. The temperature of the Varennes springs has already been noticed, of which the saline was 47°·5. The two springs of Chambly, taken under favorable conditions, gave each a temperature of 53°; so that many of these waters are to be regarded as slightly thermal.

WATERS OF THE ST. LAWRENCE AND OTTAWA RIVERS.

Analyses of the waters of the St. Lawrence and Ottawa Rivers were made in 1854, with reference to the supply of water for Montreal. Independent of their local value, the results are important as showing the composition of two immense rivers, which drain a large portion of the continent. These waters were collected in the month of March, before the melting of the snows had commenced. That of the Ottawa was taken on the 9th of March, at the head of the St. Anne lock, and was remarkably free from any sediment or mechanical impurity. Its color was of a pale amber-yellow, very distinct in layers of six inches. When heated, the color deepens, and by boiling, a bright brown precipitate appears, which, when the water is reduced to one tenth, is seen to consist of small brilliant iridescent scales, and consists of carbonates, with silica and organic matter. Meanwhile the water becomes much darker colored, and has an alkaline reaction. A portion was reduced to one fortieth, filtered, and being still farther evaporated, deposited an opaque film, which was imperfectly soluble in hydrochloric acid. The concentrated liquid was now dark brown and alkaline, reddening turmeric paper. It was evaporated to dryness, and gave a deep brown residue, which carbonized without deflagration, giving off an agreeable vegetable odor, and leaving a little carbon. The soluble portion of the ignited residue was alkaline to the taste. The insoluble portion did not effervesce with hydrochloric acid, which removed from it a portion of lime, but no magnesia, leaving a residue of pure silica, and showing it to be a silicate of lime. Water of the Ottawa.

The precipitate obtained from the water by ebullition, gives up its coloring matter when boiled with a dilute solution of potash, which assumes a bright brown color from the organic substance. This seems to consist in part of crenic acid. When the same precipitate is boiled with hydrochloric acid and a little chlorate of potash, and evaporated to remove silica, the acid solution gives with ammonia a colorless precipitate, which consists in large part of alumina, but contains, besides, an abundance of phosphoric acid, and small portions of iron and manganese. When the concentrated water, with its precipitate, is evaporated to dryness with an excess of hydrochloric acid, and the residue treated with a dilute acid, a large amount of silica is obtained, which after ignition is perfectly white, and equals one third of the solid contents of the water. Examined under the microscope, it is amorphous, like chemically separated silica. Organic matter. Silica.

The recent water gives, with the ordinary tests, only traces of sulphates and chlorids. The proportions of these, and of the other elements, were ascertained by two or more concordant determinations, made upon quantities of two and four litres of the water. The experiments already detailed

Silicate of lime. show that the concentrated water holds in solution a portion of silicate of lime. Ten litres of the water evaporated to one thirtieth, still retained, thus dissolved, ·046 grams of silica, and ·013 of lime. The chlorine and sulphuric acid are sufficient to neutralize only about one half of the alkaline bases present. The remaining portion, which is represented below as carbonate of soda, may be considered as in part combined with silica and with an organic acid.

Water of the St. Lawrence. The water of the St. Lawrence was collected on the 30th of March, on the south side of the Pointe des Cascades, Vaudreuil. It was clear and transparent, and, unlike the water of the Ottawa, exhibited no color when in layers of several inches in thickness. When boiled, it lets fall a white crystalline precipitate, which adheres to the sides of the vessel; and the liquid, which is turbid from a little suspended yellow matter, is but slightly colored. The reactions for chlorine and sulphuric acid were much more distinct with this than with the Ottawa water, and the dried residue contains much less organic matter. The residue from two litres sufficed to give the reactions of iron and manganese: the ammoniacal precipitate was however chiefly alumina, with some phosphoric acid. Like the Ottawa water, this retains in solution a portion of silicate of lime. When evaporated to one fortieth, ten litres contained ·075 grams of silica, and ·028 of lime. The determinations for the two waters are given below, the alkalies being represented as chlorids. They are as follows for 10,000 parts:

	Ottawa.	St. Lawrence.
Carbonate of lime,	·2480	·8033
" magnesia,	·0696	·2537
Chlorine,	·0076	·0242
Sulphuric acid,	·0161	·0687
Silica,	·2060	·3700
Chlorid of sodium,	·0607	·1280
" potassium,	·0293	·0220
Residue dried at 300° F.,	·6975	1·6780
" ignited,	·5340	1·5380

In the following table are given the results, calculated in like manner for 10,000 parts, the excess of soda being represented as carbonate:

	Ottawa.	St. Lawrence.
Chlorid of potassium,	·0160	·0220
" sodium,	....	·0225
Sulphate of potash,	·0122	....
" soda,	·0188	·1229
Carbonate of "	·0410	·0061
" lime,	·2480	·8083
" magnesia,	·0696	·2537
Silica,	·2060	·3700
Alumina and phosphoric acid,	traces	traces
Oxyds of iron and manganese,	"	"
	·6116	1·6055

In the water of the Ottawa the amount of chlorine is not sufficient to saturate the potash, and the excess of this base is therefore given as sulphate. In the water of the St. Lawrence, on the contrary, the chlorine suffices not only for the potash, but for a portion of the soda.

The difference in the color of the waters of the two rivers is very distinctly marked in front of the island of Montreal, a long distance below their junction; but in the amber-colored waters before the city, the current of the Ottawa has already become mingled with a large proportion of the St. Lawrence water. This is shown by some analyses made in 1854. In I are given the determinations made of the water taken at Lower Lachine, about thirty feet from the shore, and opposite to the entrance to the present aqueduct, on the 9th of March, the same day as the Ottawa water whose analysis is given above. II is the water which was, at that time, raised by pumping from the river in front of the city. It was taken on the 15th of March. III was also from the city supply in April, 1850, when the spring floods had increased the volume of the Ottawa river, and consequently the proportion of its water in front of the island. These are given, as before, for 10,000 parts.

	I.	II.	III.
Carbonate of lime, ...	·6440	·7400	·4228
" magnesia, ...	·1970	·2160	·0989
Chlorine, ...	·0183	·0296	·0296
Sulphuric acid, ...	·0487	·0498	·0447
Silica, ...	·3250	·3450	undet.
Residue dried at 300° F., ...	1·4150	1·5600	"
" ignited, ...	1·2020	1·3750	"

The amount of chlorine in the city supply on the 14th of April, 1854, was ·0284. The proportion of chlorine found in the water before the city, being greater than that of the unmixed St. Lawrence water, indicates a local source of this element, which was probably due to the sewerage of the town, whose waters, impregnated with alkaline chlorids, were carried near to the supply-pipe for the old water-works.

The comparison of the waters of the two rivers shows the following differences: the water of the Ottawa, containing but little more than one third of the solid matter of the St. Lawrence, is impregnated with a much larger quantity of organic matters, and contains a large proportion of alkalies uncombined with sulphuric acid or chlorine. Of these bases, determined as chlorids, the chlorid of potassium in the water of the Ottawa forms thirty-two per cent., and in that of the St. Lawrence only sixteen per cent. In the former, the silica equals thirty-four per cent., and in the latter twenty-four per cent., of the mineral matter. Comparison of the two waters.

The Ottawa flows through a region of crystalline rocks, and receives from them the greater part of its waters. It also drains great areas of forest and of marsh, and from the decomposition of the vegetation derives the organic matters, and the great proportion of potash salts which it contains. The St. Lawrence, at its source, in Lake Superior, drains a region of ancient sandstones and crystalline rocks; but it afterwards passes through lakes whose basins are composed of palæozoic strata abounding in limestones, which are rich in gypsum and salt. It is these rocks that give to the waters of the river that predominance of soda, sulphuric acid, and chlorine which distinguishes it from the Ottawa. Both of these great rivers flow through a series of lakes, in which the waters are enabled to deposit their suspended impurities, and are thus rendered remarkably clear and transparent.

Silica and potash

The great proportion of silica and of potash carried down to the ocean by these rivers,—the latter amounting, even in the St. Lawrence, to one sixth of the alkaline salts,—is particularly worthy of consideration, in connection with the small proportion of these elements which the ocean waters contain. Silica is doubtless never wanting in river waters, though it has hitherto been, in most cases, wholly or in great part overlooked, except by Deville, in his analyses of the river waters of France. It is interesting to contrast this large proportion of silica in the Ottawa and the St. Lawrence, with the small amount of it found in the mineral waters of the second, third, and fourth classes. The soda from the decomposition of the feldspars in sedimentary strata, is liberated in the form of a silicate, which is decomposed, in its passage towards the surface, by compounds of lime and magnesia; giving rise, in this manner, to insoluble silicates of these bases, which remain behind, and to soluble soda-salts.

CHAPTER XIX.

ON SEDIMENTARY AND METAMORPHIC ROCKS.

GENERAL CONSIDERATIONS; DECOMPOSITION OF ROCKS; ACTION OF WATERS; VEGETATION; SOLUTION OF IRON; PROCESS OF REDUCTION; DEPOSITION OF SILICA; CARBONATES OF LIME AND MAGNESIA; GYPSUMS; CLASSIFICATION OF SEDIMENTS; NATURE AND THEORY OF THE METAMORPHISM OF ROCKS.—LAURENTIAN ROCKS.—HURONIAN ROCKS; PALÆOZOIC ROCKS OF THE EASTERN DISTRICT; PALÆOZOIC ROCKS OF THE WESTERN DISTRICT.—CLAYS AND SOILS; PEATS.

It is proposed in the present chapter to consider the chemical and mineralogical composition of the stratified rocks of the province, and the nature of that metamorphism to which portions of them have been subjected. The distribution and the general characters of these rocks have been given in the preceding part of this volume, and, in another chapter, the principal mineral species which they contain have been noticed in detail. The stratified rocks of Canada are especially interesting, inasmuch as they include crystalline or metamorphic strata belonging to three great geological periods. These are distinguished by remarkable mineralogical differences, which are apparently connected with the greater or less antiquity of the formations.

Metamorphic strata

So long as all crystalline stratified rocks were classed together under the designation of primitive, and were supposed to belong to a period anterior to the fossiliferous formations, the studies of the lithologist were confined to descriptions of the various species of rocks, without any reference to their stratigraphical or geological distribution. Since however the fossiliferous strata have been studied with reference to the great principle of the succession of organic life, the palæontologist has learned that the fossils of each formation furnish a guide to its age and stratigraphical position. Investigations have also shown that sedimentary strata of all ages, up to the tertiary inclusive, may undergo such changes as to obliterate the evidences of organic life, and give to them the mineralogical characters once assigned to primitive rocks. The question now arises, whether, in the absence of organic remains, or of stratigraphical evidence, there exists any means of determining, even approximately, the geological age of a given series of crystalline stratified rocks, or the date of its metamorphism;—in other words, whether the chemical conditions which have presided over the formation of sedimentary rocks, have so far varied, in the course of ages, as to impress upon these rocks marked chemical and mineralogical differences.

Chemical forces. It cannot be doubted, that in the earlier periods of the world's history, chemical forces of certain kinds were much more active than at the present day. Thus, the decomposition of earthy and alkaline silicates under the combined influences of water and carbonic acid, would be greater when this acid gas was more abundant in the atmosphere. The larger amounts of alkaline and earthy carbonates then carried to the sea from the decomposition of these silicates, would furnish a greater abundance of calcareous matter to the sediments; and the chemical effects of vegetation, both on the soil and the atmosphere, must have been much greater during the carboniferous period than at present.

Decomposition of feldspars. In the decomposition of the feldspars, which may be represented as silicate of alumina combined with silicates of potash, soda, and lime, the alkali or lime is removed in combination with a portion of silica; and there remains, as the final result of the process, a hydrated silicate of alumina, or clay. The potash feldspar, orthoclase, is, under ordinary conditions, much less subject to such a decomposition than the soda feldspar, albite, or those which, like labradorite, contain both lime and soda. Both Mitscherlich and Bischof have remarked that where albite and orthoclase are associated, the former may be found decomposed and friable, while the latter is still unaltered. This change of feldspar is favored by mechanical division, which multiplies the surfaces exposed; so that when a feldspathic rock is triturated with water, small portions of silica and of alkalies are taken into solution. If the decomposing rock contains, like many granites, both potash and soda feldspar, the latter, being first attacked, will be rendered friable, and eventually reduced to the condition of clay, with the loss of more or less of its alkali, and, being readily held in suspension in the water, will become mechanically separated from the heavier portions. These, consisting of grains of unaltered orthoclase, with quartz, will form a sandy sediment, apart from the lighter clays; while the soda and lime, with the dissolved silica, are removed by the water. Such a separation is necessarily but a partial one; for the feldspar, thus broken up and reduced to a clay, still retains a considerable portion of alkali, and is moreover mingled with the more finely divided parts of the orthoclase and quartz. This process is evidently that which must go on in the wearing of rocks by the agency of water; and, explains the fact, that while quartz, or an excess of silica, is for the most part wanting in rocks which contain a large proportion of alumina, it is generally abundant in those where potash feldspar predominates. Daubrée has remarked, that by the prolonged attrition of fragments of granite under water, the feldspar, being softer and more readily divisible, is eventually in great part reduced to an impalpable powder, which remains for some time suspended in the water, while the grains of quartz are only rounded, and form a readily subsiding sand; which will however retain some portions of the feldspar.

Alkaline waters.

The decomposition of aluminous and alkaline silicates goes on, not only at the earth's surface and in sediments still suspended in water, but in stratified sedimentary rocks. The evidence of this is seen in the silica and the alkaline carbonates held in solution by the waters of many mineral springs. Atmospheric waters, permeating strata composed of the ruins of argillaceous rocks, dissolve from them large portions of carbonate of soda, giving rise to alkaline springs and to natron lakes. In these waters, it is found that soda greatly predominates, sometimes almost to the exclusion of potash. This is due not only to the fact that soda feldspars are more readily decomposed than orthoclase, but to the power of argillaceous sediments to abstract from water the potash salts which it already holds in solution. Thus when a solution of silicate, carbonate, sulphate, or chlorid of potassium is filtered through common earth, the potash is taken up, and replaced by magnesia, lime, or soda, by a double decomposition between the soluble potash salt, and the insoluble silicates of the latter bases. Soils in the same way remove from infiltrating waters, ammonia, and phosphoric and silicic acids; the bases which were in combination with these acids being converted into carbonates. The drainage-water of soils, like that of mineral springs, contains only carbonates, chlorids, and sulphates of lime, magnesia, and soda; all the potash, ammonia, phosphoric and silicic acids being retained by the soil.

Elements removed from waters.

Action of plants.

The elements which the earth extracts from waters are precisely those which are removed from it by growing plants. These, by their decomposition under ordinary conditions, yield their mineral matters again to the soil; but when plants decay in water, these become dissolved, and hence the waters of peat bogs and marshes are remarkable for the large amounts of potash and of silica which they contain. The considerable extent of such lands drained by the Ottawa River explains the predominance of these elements in its waters (page 568). The result of such a process is, through the decomposition of terrestrial vegetation, to carry large amounts of potash salts and silica to the sea; but here the agency of organic life prevents their accumulation. While foraminifera appropriate the silica for the formation of their shields, marine plants take up the potash. According to the analyses of Forchammer, these are very rich in mineral matters, in which potash salts predominate; and the same appears to be true of fresh-water plants, like duck-weed. When these aquatic plants are thrown upon the shores, or sink, and become buried beneath the mud in the ocean's bottom, the potash set free during their decay will be taken up by the argillaceous matters, and rendered insoluble. Thus, as Forchammer has shown, the fucoidal shales of the palæozoic series of Scandinavia are peculiarly rich in potash, which has doubtless in part been derived from the sea-water, through the agency of marine vegetation. The formation of glauconite or green-sand, which is essentially a hydrous silicate of iron and potash, is still going on in the sea, in virtue of reactions as yet unknown (page 486), and must, in like manner, be continually abstracting potash from the sea-water.

Fire-clays. The fire-clays (under-clays) of the coal formation, which are beneath each bed of coal, are argillaceous sediments almost entirely devoid of alkalies, and represent the ancient soil in which the luxuriant coal vegetation flourished, and apparently deprived it of the greater part of its potash. From the coal itself, as from modern peats, the alkalies appear to have been almost entirely removed by the action of water. These fire-clays, which still retain the traces of their ancient vegetation, in the stigmariæ which they enclose, are not to be confounded with those deposits of kaolin which in certain cases result from the direct and rapid decay of feldspathic rocks, under conditions as yet imperfectly understood. The products however do not differ essentially from those of the process above considered.

The coarser sediments, in which quartz and orthoclase prevail, are necessarily more readily penetrated by water than the finer argillaceous deposits, which are nearly impermeable. Hence, while the latter retain all the alkalies, the lime, magnesia, and iron-oxyd which they carried down with them, these elements, with the exception of the potash, are gradually removed by solution from the coarser sediments. But when once these mechanical deposits have been rendered crystalline by metamorphism, both their permeability and their alterability are greatly diminished; and it is only when they are again broken down by mechanical agencies to the condition of soils and sediments, that they become once more subject to the chemical changes which have just been described. Alkalies and alumina. Hence the mean composition of the argillaceous sediments of any geological epoch, or, in other words, the proportion between the alkalies and the alumina, will depend not only upon the age of the formation, but upon the number of times which its materials have been broken up, and the length of the periods during which these have remained unmetamorphosed, and exposed to the action of infiltrating waters. Thus, for example, that portion of the argillaceous rocks of the Lower Silurian series in Canada which became metamorphosed before the close of the palæozoic period, will have lost less soluble matter than that part which still remains in the form of unaltered shales and sandstones. Of these, again, such portions as remain undisturbed by folds and dislocations will preserve a larger portion of alkalies than those strata in which such disturbances have favored the formation of mineral springs, which, even now, are active in removing the soluble matters from these rocks. The crystalline Lower Silurian rocks in Canada may be compared with those of the Laurentian series on the one hand, and with the Upper Silurian or Devonian on the other; but when these are to be compared with the crystalline rocks of secondary or of tertiary age in the Alps, it cannot be determined whether the material of which these were formed, and which may be supposed, for illustration, to have been directly derived from palæozoic strata, existed, up to the time of its translation, in a condition similar to that of the altered, or to that of the unaltered Lower Silurian strata of Canada.

The proportion between the alkalies and the alumina, throughout the aluminous silicates of any given formation, is not therefore in direct relation to its age, but indicates the extent to which it has been subjected to the action of water, carbonic acid, and vegetation. If however it may be assumed that this action, other things being equal, has, on the whole, been proportionate to the newness of the formation, it is evident that the chemical and mineralogical composition of different systems of rocks must furnish some guide to their relative ages. In the case of unaltered sediments, it would be difficult to arrive at any conclusion, without greatly multiplied analyses; but in these same rocks, when altered, the crystalline minerals which are formed, being definite in their composition, may to a certain extent become to the geologist, what organic remains are in the unaltered rocks, a guide to the geological age and succession. **Variations in composition.**

In considering the influence exercised by vegetation, in its growth and decomposition, upon the composition of sedimentary rocks, the reducing power of decaying organic matter must not be overlooked. In this way, peroxyd of iron is reduced to the state of protoxyd, and then, being dissolved by carbonic acid, or by some organic acid, is removed from a sedimentary deposit, to be again precipitated by oxydation, or by the loss of carbonic acid, either as carbonate of protoxyd of iron, or as a sesquioxyd combined with water, and often with a portion of organic matter, in the forms of iron-stone, ochre, and limonite. Peroxyd of iron being insoluble, the infiltrating waters which take up the soda, lime, and magnesia from sediments, cannot remove this metal unless they contain organic matter. The evidence of this reducing and dissolving action of organic matter is met with, not only in the fire-clays and iron-stones of the Carboniferous system, and among secondary, tertiary, and modern deposits, but on a gigantic scale in the Laurentian series, where great thicknesses of sediments are found almost destitute of iron; while beds of iron ore, more extensive than any in subsequent periods, are evidences of the abundance of organic matters at that period. If these have not been more frequently preserved in the forms of anthracite and graphite, it is because the amount of peroxyd of iron diffused **Action of organic matters.** **Solution of iron oxyd.**

through the sediments of the period, furnished the oxygen necessary for the oxydation of the carbon. Inasmuch as the iron ores of these old rocks, in their present forms of magnetite and hematite, are very insoluble, and are so much iron withdrawn from the terrestrial circulation, it is evident that the proportion of this element existing in a diffused state in recent sediments must be less than in those of more remote times. The solution and precipitation of oxyd of manganese probably takes place under conditions similar to those of oxyd of iron (page 507).

Metallic sulphurets. The chemical agency of organic matters is also apparent in the production of metallic sulphurets. These indicate a reduction of the soluble sulphates of the waters to the state of sulphurets, which precipitated, in an insoluble form, not only iron, but the zinc, lead, and copper which appear to have been in solution in the waters in earlier geological periods. In this way may be explained the origin of the *fahlbands*, and of the beds of metallic sulphurets, which appear to be more abundant in the earlier rocks. These sulphurets, being insoluble, except under the influence of atmospheric oxygen, the metals thus combined are now removed from the terrestrial circulation. All analogies lead to the conclusion that the primeval condition of the metals, and of sulphur, having been, like that of carbon, one of oxydation, vegetable life has been the only agent of their reduction.

Agent of reduction.

Dissolved silica. The silica is set free from decomposing feldspars, chiefly as silicate of soda. This is in many cases decomposed by carbonates of lime and magnesia, giving rise to silicates of these bases, which, being sparingly soluble, are in great part retained by the sediments, and to carbonate of soda. Hence alkaline mineral waters, even though containing much carbonate of soda, bring comparatively little silica to the surface; unless they are thermal, when they are sometimes highly charged with it, and give rise to silicious deposits. The case is different in rivers, where the decomposition of minerals and of plants, at the surface, gives rise to waters, in which, like those of the Ottawa and the St. Lawrence, the silica forms a large proportion of the solid matters present. When these waters are evaporated, the lime and magnesia which they always contain are separated, in part in the form of carbonates, but in part also as silicates of lime and magnesia.

Silicious deposits. The large amounts of silica contained in solution in the waters of some thermal springs, and of many rivers, are separated when these waters are exposed to spontaneous evaporation, partly as silicates of lime and magnesia, and partly in the forms of crystalline quartz, hornstone, and opal. In many different formations, beds are met with, composed entirely of crystallized grains of quartz, which have apparently been deposited from solution. In other sediments, this element abounds in the form of grains of chalcedony, or as amorphous soluble silica. The beds and masses of chert, flint, hornstone, buhrstone, and many jaspers, have all apparently been deposited from aqueous solutions; and the menilite or opal, which is found imbedded in the sepiolites of the Paris basin, has had a similar origin. The large quantities of silica which occur in the form of infusorial earth, have also been held in solution in natural waters.

Carbonates of lime and magnesia. The carbonates of lime and magnesia, which enter into the composition of sedimentary rocks, are derived from the disintegration of limestones and dolomites, from their solution by carbonic acid, or from the action of the latter upon silicious minerals containing lime and magnesia, such as labradorite and pyroxene. The acid for these reactions may be derived directly from the atmosphere, or may come from that subterranean decomposition of carbonates which is connected with metamorphism. A third, and more abundant source of the two carbonates, is to be found in the decomposition, by the carbonate of soda in natural waters, of the soluble salts of lime and magnesia contained in sea-water.

It is evident that the reaction between the carbonate of soda and the chlorids of calcium and magnesium in the sea, must, while forming the carbonates of lime and magnesia, have greatly augmented the amount of chlorid of sodium, which has thus replaced the earthy chlorids of the primeval ocean. This conclusion is in accordance with the observed composition of the brines which issue from the Lower Silurian limestones, in which only about one half the chlorine is combined with soda, the remainder being nearly equally divided between the lime and magnesia (page 551). The frequent absence of sulphates from these brines leads to the conjecture that they may be derived from the bitterns of the ancient ocean; from which, by concentration, the whole of the sulphates had been separated in the form of gypsum. By this reaction, not less than by the formation of sulphur and metallic sulphurets, a large portion of sulphates has been gradually abstracted from the waters of the ocean.

Carbonate of magnesia. When alkaline waters containing bicarbonate of soda act upon sea-water, the lime salts which this contains are first decomposed, and carbonate of lime is precipitated; accompanied, as in ordinary limestones, by two or three hundredths of carbonate of magnesia. When all the soluble lime-salts have been thus decomposed, a further addition of bicarbonate of soda gives rise to a somewhat soluble bicarbonate of magnesia, which afterwards separates by evaporation as a hydrated carbonate. The carbonate of lime (Dolomite.) which the alkaline waters generally contain, being precipitated with the magnesian carbonate, the combination of these two subsequently gives rise to dolomite or to magnesian limestones.

Another source of carbonate of magnesia is the reaction between solutions of bicarbonate of lime and waters containing sulphate of magnesia, from which the soluble salts of lime, such as the chlorid of calcium, have previously been separated in the form of sulphate or of carbonate. In this way, sulphate of lime and bicarbonate of magnesia are formed by double decomposition; and by the subsequent evaporation of the mixed solution, the

Gypsum. former salt is first separated in the form of gypsum. At a later stage in the process, the more soluble bicarbonate of magnesia is deposited in the form of hydrated carbonate, and becoming mingled with a portion of carbonate of lime, gives rise to the dolomites and magnesian marls which generally accompany beds of gypsum. Both of these processes seem to have been active in every age; since dolomites, with and without gypsum, belong to all geological periods. These reactions, however, require inland seas, or basins cut off from communication with the ocean; while, on the other hand, the conditions for the production of carbonate of lime are everywhere found. Hence the amount of lime removed from the sea has been much greater than that of magnesia, and the salts of the latter base are now the more abundant in its waters. (Amer. Jour. of Science [2], xxviii, 170, 365.)

From the principles already discussed, it will be seen that the constituents of sedimentary rocks may be reduced to the following classes:

Silicious deposits. I. Silicious deposits, including those of mechanical origin, which are formed from the ruins of quartzites or quartziferous rocks, such as granite, and constitute most sandstones. Besides these, are the various forms of silica deposited from solution, and already enumerated above.

Aluminous sediments. II. Silico-aluminous sediments. These are for the most part mechanical in their origin; and their important relations to the chemistry of the sedimentary rocks, have already been pointed out. These sediments may be divided into four groups: — First, those in which the alumina is combined with the full amount of alkali (chiefly potash) necessary for the formation of orthoclase or of albite: these are often mingled with quartz. Second, finely divided sediments, related to the last, with a considerable excess of silica, and containing a portion of alkalies (the potash generally predominating), insufficient to form orthoclase or albite with the whole of the alumina present. Most argillites belong to this class, and contain, besides a little lime and magnesia, a considerable quantity of oxyd of iron, and a portion of water. Third, sediments which have been derived from soda feldspars more or less completely decomposed, and finely divided, so as to have been separated by the action of water from orthoclase and quartz, thus containing no excess of silica. The decomposition of the feldspars having been attended with a separation of silicate of soda, the amount of silica and alkali diminishes as that of the alumina increases, and the residue approaches to the composition of kaolin. Fourth, sediments resembling the last in the proportions of silica and alumina, but containing a quantity of potash, which equals five or six per cent., or even more. To this group belong the rocks mentioned under the title of agalmatolite. These sediments may perhaps owe their potash to the decomposition of vegetable matters, as has been explained on page 572. The soils which, on the contrary, have been deprived of their alkalies by vegetation, evidently belong to the second group.

III. Silicates of chemical origin. During the evaporation of many natural waters at ordinary temperatures, hydrous silicates of lime and magnesia are deposited, and, under favorable conditions, accumulations of these have given rise to large beds. Their production by the evaporation of the waters of the Ottawa, and of various alkaline mineral springs, has been already noticed (page 559). A hydrous ter-silicate of magnesia, which has been described by the name of sepiolite, occurs in various regions, associated with limestones and clays of tertiary age, and of fresh-water origin. It is the meerschaum of some authors, and the magnesite of others; but is not to be confounded with the carbonate of magnesia, which is sometimes called by the latter name. The quincite of Berthier, which occurs disseminated in a fresh-water limestone, is a similar compound; and beds of sepiolite often include carbonates of lime and magnesia. This substance, in its composition, approaches to talc, like which it often has a lamellar structure. Unlike talc, however, it is readily decomposed by acids, both before and after ignition. Although it has not been noticed among the unaltered sediments of Canada, sepiolite is important as probably being the source of the talc and the steatite of crystalline strata. A silicate of lime, similar in its origin to sepiolite, probably exists among unaltered sediments, although it has not yet been recognized. Third class. Sepiolite.

Glauconite, which is a hydrous silicate of protoxyd of iron and potash, with variable proportions of alumina, appears to be a chemical deposit from solution. The amounts of the latter base found in glauconite, indicate a solubility of alumina under certain conditions. The hot alkaline spring of Plombières, according to Daubrée, deposits along its channel an amorphous hydrated silicate of alumina, allied to halloysite, of which the elements had been dissolved in the water. Evidences of the solution of a silicate of alumina are also seen in the formation of the minerals allophane and collyrite; and in the crystalline hydrous silicate of alumina and magnesia, which occurs as a recent deposit from the water of certain mines, and has been described by Scheerer under the name of neolite. It is not improbable that similar aluminous silicates, of a like origin, may sometimes be formed in large quantities, and by their alteration give rise to chlorite, as sepiolite doubtless does to talc. Silicate of alumina.

IV. In the fourth class may be placed the various limestones, dolomites, and magnesites, the elements of which are formed by direct chemical processes, already pointed out. In the case of limestones of organic origin, the source of the carbonate of lime is still the same. The beds of phosphate of lime in ancient rocks perhaps owe their origin to deposits analogous to the modern accumulations of guano. Fourth class.

V. In the fifth class may be included the deposits of gypsum, anhydrite, rock-salt, and more rarely of sulphate of magnesia, and of sulphate and carbonate of soda, which have been formed by the evaporation of sea-water, Fifth class.

and of other natural waters. To these may be added the deposits of iron, either as carbonate of protoxyd, or as peroxyd, generally hydrated, and with or without organic acids; together with occasional similar deposits of oxyd of manganese, and of zinc, lead, and copper; the latter metals as carbonates, silicates, or sulphurets. Mixtures of a hydrate of alumina with hydrous peroxyd of iron, constituting the substance called bauxite, are abundant in the tertiary sediments of the Mediterranean basin; forming large beds, in which the alumina often greatly predominates. These deposits are probably derived from the decomposition of solutions of native alum by alkaline or earthy carbonates. Similar matters, composed chiefly of hydrate of alumina, are often found in the fissures of the chalk in England. Compounds of alumina with organic acids sometimes occur in nature, and indicate that these may occasionally have been the dissolvent; but the existence of the sub-sulphate of alumina, websterite, in layers and concretionary masses in tertiary clays, points to sulphuric acid as having been, in many cases, the solvent of the alumina. These aluminous compounds, although not known in the unaltered strata of Canada, are important as showing the source of the corundum and spinel which occur in the crystalline rocks.

Hydrate of alumina

Sixth class.

VI. In the sixth class may be included substances of organic origin, such as coal, lignite, peat, and vegetable mould. Matters of this kind, derived from plants, and in some cases apparently from animals, and analogous to lignite in their nature, are occasionally intermingled with calcareous and with argillaceous rocks, giving rise to what are called bituminous shales or pyroschists (page 528). By their alteration, these carbonaceous matters yield graphite.

Three divisions.

The great mass of sedimentary strata may, for general purposes, be considered as composed of sandstones, shales, and limestones. In the former are included the sediments of the first class. The shales or clays embrace the argillaceous matters of the second class, while the limestones include the compounds of the fourth class. The various matters of the other classes, although they are mineralogically of great importance, make up but a small part of the mass of sedimentary rocks. Of these three divisions, the shales, and a great part of the silicious rocks, consist of the comminuted and undissolved portions of pre-existing rocks. The elements of the limestones, and of the matters of the third, fifth, and sixth classes, have, on the contrary, been separated from aqueous solutions, or from the atmosphere, with or without the concurrence of organic life. It is scarcely necessary to remark, that mixtures, not only of different classes of sediments, but of various sediments of the same class, constantly occur, thus giving rise to great varieties in the composition of rocks.

The conditions and modes of combination of the principal chemical elements of the unaltered sedimentary rocks, may now be considered.

The silica exists in combination with alumina in the clays and feldspathic sediments, and in sepiolite with magnesia; but a great proportion is uncombined. The alumina is chiefly united with silica, but is in part, also, as a hydrate. The magnesia, although chiefly in the form of carbonate, occurs likewise as a hydrated silicate. A portion of lime may also exist in a similar condition; but with this exception, the lime in sedimentary rocks is present in the forms of carbonate and sulphate, or more rarely as phosphate. The alkalies, except such portions as exist in soluble forms, are almost wholly combined with aluminous silicates. Iron occurs chiefly as carbonate, or as a peroxyd, which is often hydrated. Small portions of lime, magnesia, and oxyd of iron, also exist in the condition of silicates, such as hornblende and labradorite, derived from the ruins of crystalline rocks, and mingled with the argillaceous sediments. Condition of elements

In altered or metamorphic strata, the same elements appear under different aspects, and often in different combinations. The alumina exists in part as simple silicates, such as andalusite, kyanite, and pyrophyllite, and in part as double silicates. These include the alkaliferous silicates, such as feldspars, micas, tourmaline, and agalmatolite, passing through scapolite and anorthite, to such double silicates as garnet, epidote, staurotide, chloritoid, chlorite, pyrosclerite, and loganite. To these are to be added the zeolites, which may be regarded as hydrous feldspars; and the argillites, which are common both to altered and unaltered strata. The aluminous minerals which do not contain silica, such as corundum, emery, diaspore, spinel, and chrysoberyl, may also be mentioned, and some rarer species, including fluorids, like cryolite, and some sulphates and phosphates, like alunite, lazulite, and wavellite. The bases, lime, magnesia, and oxyd of iron, besides entering into the composition of the double aluminous silicates, occur in the various forms of hornblende, pyroxene, and wollastonite, as well as in olivine, serpentine, talc, and lievrite. The oxyd of iron, which forms the base of the latter mineral, also appears in the forms of carbonate, and of hematite and magnetite. The limestones and dolomites of metamorphic series, as is well known, contain great numbers of silicious minerals, including both silicates of protoxyds, and double silicates of these with alumina. Similar silicious minerals occur in the gypsums of metamorphic regions. Minerals of altered rocks.

One of the conditions of the metamorphism of sediments appears to be an elevation of temperature. As a consequence of the heat of the deeper portions of the earth's crust, the strata, when buried to a certain depth, are subjected to an elevation of temperature; which, from the average rate of increase, as determined by numerous observations at depths up to more than 2000 feet, may be fixed at about one degree Fahrenheit for every sixty feet. This, taking the temperature near the surface at 46° F., would give 212°, or the temperature of boiling water, at the depth of 10,000 feet. Conditions of alteration.

It is by no means impossible that, beyond the small depth to which we have been able to penetrate, the increase may be more rapid. The hypothesis of a cooling globe necessarily leads to the conclusion, that, in earlier geological periods, this augmentation of temperature must have been far greater than at the present day; so that strata buried to the depth of 10,000 feet, during the secondary period, would have been exposed to a temperature much higher than that above supposed. Sedimentary rocks, thus exposed to heat, and permeated, as they always are, by water, will undergo certain chemical changes, the nature of which will vary, both with the composition of the sediments, and that of the waters penetrating them. The limestones, which in the older formations are exclusively of marine origin, will be impregnated with sea-water, holding in solution common salt, together with lime and magnesia in the form of chlorids and sulphates. Similar salts will at first impregnate the accompanying argillaceous sediments; but the feldspathic matters which these contain, by their slow decomposition give out a portion of soda in the form of a soluble silicate. This decomposes the soluble salts of lime and magnesia present, and then, reacting upon any carbonates of these bases, by a similar decomposition gives rise to carbonate of soda. Hence the mineral waters rising from argillaceous rocks are generally found to be alkaline from the presence of carbonate of soda, which in some cases prevails almost to the exclusion of the other salts of this alkali (page 550). These alkaline waters may eventually penetrate, to a certain extent, the adjacent calcareous strata, and displace the earthy salts, so that the marine limestones themselves will become impregnated with a solution of carbonate of soda.

Internal heat.

Alkaline waters.

Nature of metamorphism.

By the chemical metamorphism of sedimentary rocks, is meant a change of form, which results from new combinations, or from new arrangements of their elements. The first and most obvious mode of metamorphism of a rock, is the crystallization of the mechanically divided silicates which it contains. In a sediment composed of the ruins of a granite, the feldspar may be re-crystallized, and so arranged as to give to the rock the form of granite, granulite, or porphyry. Should the sediment be deficient in alkali, a portion of the silicate of alumina may crystallize in the form of mica, or even of a simple silicate of alumina, like andalusite or kyanite. In like manner, amorphous silicates of lime and of magnesia, whether of mechanical origin or chemically formed precipitates, may, under proper conditions, be crystallized.

Crystallization of feldspar and quartz.

The late researches of Daubrée have thrown much light on the theory of metamorphism. He found that when kaolin, a hydrated silicate of alumina, was heated in contact with a solution of an alkaline silicate, to a temperature of 400° Centigrade, crystallized feldspar was slowly formed; and that a foliated mineral, having the characters of a mica or of chlorite, was developed in a certain clay, when this was submitted to the same treatment. By the action of highly heated waters upon vitreous alkaline silicates, like glass and obsidian, feldspar, pyroxene, and quartz were all obtained in a crystalline form. From solutions of alkalies saturated with silica, a portion of the latter, through a change in the basic relations of the silica, separates, at an elevated temperature, in the form of crystallized quartz. The solvent power of alkaline solutions is farther shown by an experiment of De Senarmont, who found that a solution of bicarbonate of soda, at a temperature of 480° F., under pressure, dissolves sulphate of baryta, and deposits it again in crystals on cooling. Water alone, according to Schafhautl and Wöhler, effects, under similar conditions, the solution and crystallization of quartz and apophyllite.

The above experiments show that silicate of alumina may combine directly with an alkaline silicate to form feldspar, and that, not only this mineral, but the already-formed silicates of lime and magnesia, may crystallize in the presence of heated alkaline solutions, in accordance with the first mode of metamorphism mentioned above. The origin of those minerals which consist of silicates of lime, magnesia, and oxyd of iron, or of double silicates of these bases and alumina, remains to be considered. Two views of their formation are admissible: In the first place, these silicates may have been deposited at the earth's surface, and at the ordinary temperature. Such compounds have been mentioned as forming the third class of sediments, and their subsequent metamorphism may give rise to various silicious minerals. The chemical composition and the structure of sepiolite are such that it may, by crystallization, with the loss of a part of its water, be transformed into talc or steatite. Pyroxene, chlorite, and many other minerals, may have had their origin in the crystallization of natural silicates of aqueous origin.

Silicates of protoxyds.

First method

The other view is, that the silicates of lime, magnesia, and oxyd of iron, which enter into these minerals, have been generated during the process of metamorphism, by reactions between the silicious matters of the sediments, and the intermingled lime, magnesia, and iron, existing chiefly in the form of carbonates and oxyds. A solution of carbonate of soda, at a temperature of 212° F., possesses the power of dissolving silica, even in the form of quartz, disengaging carbonic acid, and forming a soluble silicate of soda. This, in its turn, is decomposed by carbonates of lime, magnesia, and iron, with the formation of a silicate of these bases; while the regenerated carbonate of soda is set free to dissolve a new portion of silica, and thus continue the process of converting the carbonates into silicates. In this way, a small portion of carbonate of soda, by its power of dissolving silica, may serve as the medium of converting a large amount of insoluble carbonates into silicates, which may crystallize in the forms of pyroxene, hornblende, wollastonite, and olivine. The presence of a silicate of alumina in the sediment would furnish the element necessary for the produc-

Second method

tion of labradorite, garnet, epidote, and chlorite. The agency of the liberated carbonic acid, in dissolving the carbonates and bringing them in contact with the alkaline silicate, is also not to be overlooked. (Amer. Jour. of Science [2], xxiii, 437.)

Altered limestone of Montreal.

The direct formation of silicates in sedimentary rocks by a reaction of this kind, is placed beyond question by the frequent development of silicated minerals, through local metamorphism. An instructive example of this kind is furnished at Montreal, where the bluish fossiliferous limestone of the Trenton group is traversed by dykes of dolerite, which are subordinate to the great intrusive mass of Mount Royal. The limestone, for a distance of a foot or two, is hardened, but retains its bluish tint. Within a few inches, it is changed to a greenish-white color, which is seen to be due to an amorphous mineral disseminated in the white carbonate of lime. The unaltered limestones from the vicinity contain variable amounts of insoluble argillaceous matters. A specimen treated with dilute hydrochloric acid, left a residue of about twelve per cent. of a fine clayey substance, colored by a small amount of carbonaceous matter, and mixed with a little pyrites, which was removed by dilute nitric acid, This residue, after ignition, gave to a solution of carbonate of soda, 9·5 per cent. of its weight of soluble silica; and the insoluble portion, being submitted to analysis, gave the result I. A portion of the limestone which was near to the intrusive rock, and was hardened and partially altered, was subjected to the action of dilute nitric acid, and gave an insoluble residue, with the composition II. The more thoroughly altered greenish limestone was also treated with dilute nitric acid, which dissolved the carbonate of lime, and left a residue, the analyses of which, from two different portions of the rock, are given under III and IV.

	I.	II.	III.	IV.
Silica,	73·02	54·00	42·60	40·20
Alumina,	18·31	14·00	13·70	9·30
Lime,	·93	16·24	31·69	36·40
Magnesia,	·87	5·27	4·17	3·70
Protoxyd of iron,	traces	3·60	4·68	5·22
Potash,	5·55	3·14	undet.	undet.
Soda,	·89	1·22	"	"
Volatile,	....	·90	1·20	·20
	99·57	98·77	98·04	95·02

The residue of the unaltered limestone, including the silica soluble in alkalies, contains nearly 75·5 parts of silica, and 16·5 of alumina. These, under the influence of the intrusive rock, have become saturated with protoxyd bases, including the small portions of magnesia and of oxyd of iron which the limestone contains. This process evidently involves a decomposition of the carbonate of lime, and the expulsion of the carbonic acid. It is worthy of remark, that, while the unaltered limestone contains a little carbonate of magnesia, the rock from which III was obtained yielded not a trace of magnesia to dilute nitric acid. II marks an intermediate stage in the process, and shows that the alkalies are still retained in combination with the aluminous silicate. These amorphous silicates, which have been formed by local metamorphism, might, under favorable circumstances, have crystallized in the forms of feldspar, scapolite, garnet, pyroxene, or some other of the silicious minerals which so often occur in metamorphic limestones. The agent in producing these silicates of protoxyds, at the expense of the carbonates of the limestone, was probably a portion of alkaline salt, either derived from the feldspathic matter of the limestone, or possibly infiltrated from the contiguous feldspathic rock, whose elevated temperature produced the reaction which has resulted in thus altering this limestone.

Examples of local metamorphism in sediments, which can be traced to the action of adjacent intrusive rocks, are peculiarly instructive, and have been studied with great detail by Delesse. They serve to throw much light on the wide-spread regional metamorphism, which has altered great areas of sedimentary rocks, far removed from any intrusive masses. The similarity of the phenomena in the two cases tends to show that heat has been a great agent in alteration, and that the intrusive rock has served only as a local source of heat, which in the case of regional metamorphism has been furnished by the central heat accumulated in deeply buried sediments. Local metamorphism.

Mixtures of silica and argillaceous sediments with variable proportions of carbonate of lime, of carbonate of magnesia, and of oxyd of iron, may then, by a reaction similar to that in the limestone just mentioned, give rise to silicates, which may take the forms of pyroxene, hornblende, or serpentine; or, by uniting with the aluminous silicate, may produce labradorite, garnet, epidote, chlorite, and such like species, which are among the most characteristic minerals of metamorphic strata. It will be seen that the two views here proposed to explain the origin of the silicates of protoxyd bases found among metamorphic rocks, are alike admissible. The silicate of magnesia formed in waters, at the earth's surface, and at ordinary temperatures, may, by its crystallization, give rise to the same mineral species as is generated, at an elevated temperature, by the reaction between silica and carbonate of magnesia, in the presence of an alkaline solution. Still another source of silicates of lime and magnesia in unaltered sediments, has been pointed out in a previous page. It is the reaction of the silicate of soda set free from the decomposing feldspars in the sediments, upon the carbonates of lime and magnesia, and also upon the soluble salts of these bases with which it may come into contact. Third method.

Experiments have already shown the effects of heated alkaline solutions, and even of pure water, upon many of the materials of sedimentary rocks. Water, in the presence of an alkaliferous silicious mineral, appears to take up a portion of alkali, and acquires new solvent powers. The presence of soluble lime and magnesia salts in excess, might however be supposed to prove an obstacle to metamorphism, although the presence of crystalline silicates imbedded in the gypsum of metamorphic regions, indicates that the sulphate of lime permits the crystallization of ready-formed silicates in its midst. The apparent anomaly, which has been noticed, of seemingly unaltered portions of limestone strata in the midst of the metamorphic rocks of the Alps, and that of similar cases elsewhere, may probably find their explanation in the presence of certain saline elements in the rock; which prevent change, while in other parts the soluble alkaline matters play the part of a ferment.

Hot alkaline springs.

The experiments of Daubrée upon the crystallization of feldspar in presence of water, were made at a temperature approaching to redness; but the solution of silica by carbonate of soda, and the conversion of carbonates of lime, magnesia, and iron into silicates, by its aid, may be effected at the heat of boiling water. The observations made by Daubrée upon the warm alkaline spring of Plombières in France, show that its waters, at a temperature not above 160° F., have, during the course of centuries, generated crystallized zeolitic minerals, such as harmotome, apophyllite, and chabazite. These species, together with hyalite, fluor-spar, calcite, and arragonite, are found lining cavities in the bricks, and in the concrete of lime and fragments of sandstone, forming the old Roman works surrounding this spring, thus throwing great light upon the formation of these and similar minerals in amygdaloids and other rocks.

The various silicious minerals of crystalline or metamorphic rocks may then be regarded as having been formed, either by the crystallization and rearrangement of silicates occurring in the sedimentary strata, or by the union of silica, uncombined, or, united with an insufficient amount of base, with oxyds existing in the sediments, generally in the state of carbonates. In these reactions are included the formation from the materials of sedimentary rocks, of feldspars, micas, scapolite, epidote, garnet, tourmaline, kyanite, andalusite, staurotide, chlorite, pyroxene, hornblende, olivine, serpentine, and talc. These minerals, with quartz, the oxyds of iron, and the carbonates of lime and magnesia, make up the great mass of crystalline rocks, both stratified and unstratified.

Metamorphism by hot waters.

From his observations on the local metamorphism at Plombières, by the action of the thermal waters circulating through the masonry, Daubrée has been led to suppose that hot springs, which may have arisen along lines of dislocation, and been thence diffused throughout great areas of stratified rocks, may have been the agent of wide-spread or regional metamorphism; and that this may thus have been produced near to the surface of the earth. It is however very difficult to admit the applicability of this theory of metamorphism by thermal springs, to a system of sedimentary rocks like the Laurentian, which, in Canada alone, occupy an area of about 200,000 square miles, and in every portion of this, so far as yet examined, are profoundly altered. The palæozoic rocks of eastern North America offer another example of wide-spread metamorphism, along a belt which extends from the Gulf of St. Lawrence nearly to the Gulf of Mexico, throughout the whole Appalachian chain, and having a breadth, in New England, of more than a hundred miles.

Thermal springs seem totally inadequate to produce effects of this kind and extent, and, like the intrusion of igneous rocks, should be looked upon only as a cause of local metamorphism. Heated waters have however doubtless been the agents of regional metamorphism, but in the way already pointed out; and the necessary heat has been communicated to the strata, not by the circulation of the waters, but by the upward conduction of the internal heat, at a time when great accumulations of sediment covered the strata, which, by subsequent denudation, have been exposed in an altered and crystalline condition. The sediments of the Laurentian system were metamorphosed and denuded before the deposition of the Huronian and Silurian series, so that it cannot now be determined beneath what strata they were buried at the time of their alteration. The case is however different with the palæozoic rocks of the Appalachian chain. The metamorphic portion of these in Eastern Canada, embraces not only the Quebec group, but higher strata, including the Lower Devonian; while, in Massachusetts, a portion of the carboniferous system has been subjected to alteration. Above the horizon of these altered Devonian strata, there is found, both in Gaspé on the east, and in Pennsylvania on the south-west, a thickness of about 10,000 feet of strata before reaching the coal measures (page 389). There is reason to believe that, at one time, this great volume of strata was continuous over the whole area now occupied by the metamorphic strata, and many thousand feet belonging to the carboniferous series may then have covered the now altered coal beds of Massachusetts. The accumulation of a great thickness of strata seems to have been a condition both of the corrugation and of the metamorphism of sedimentary rocks. Regions of altered strata appear to be in all cases folded and corrugated.

Metamorphic rocks of Canada.

A connection has generally been supposed to exist between the metamorphism of a region and the presence of masses of intrusive rock. This condition of things, if it anywhere exists, is however altogether accidental; since, throughout the altered regions of Canada, unstratified rocks are extremely rare. As will be seen in the succeeding chapter, the great igneous masses of Eastern Canada occur, for the most part, in the unaltered palæozoic strata. The serpentines, diorites, hyperites, euphotides, and granites, which abound in metamorphic regions, have, by most geologists, been regarded as rocks of igneous origin, whereas they appear

Rarity of intrusive rocks.

to be, for the greater part, undoubtedly altered sedimentary layers or masses. In the following pages it is proposed to describe, in their order, the stratified rocks of the Laurentian and Huronian systems, to be followed by those of the palæozoic series, both in their unaltered and their metamorphic condition. In this description, the various rocks of each series will be considered in the order already laid down in the preceding pages of the chapter: first, the silicious rocks; secondly, the aluminous rocks; and, thirdly, the silicates of protoxyds, with the limestones, dolomites, and various substances of the sixth and seventh classes. Much has already been done towards the description of these rocks, in the preceding chapters, to which frequent references will be made.

THE LAURENTIAN SYSTEM.

Laurentian series.

The general characters and the distribution of the rocks of the Laurentian system have already been described in the third chapter of this volume. They have been traced from the coast of Labrador to Lake Huron, and thence northward to the Arctic Ocean, and occupy moreover a considerable region in northern New York. Besides these, there are other areas of crystalline rocks in the west and south-west, which are noticed on page 65, and probably belong to this system. These Laurentian rocks, which underlie the Silurian and Huronian series, and are the oldest known strata of the earth's crust, are generally concealed in Europe. In the Western Islands, however, and on the adjacent coast of Scotland, they have been identified by Sir Roderick Murchison; and it is probable that the crystalline rocks of Greenland are of the same age. The Primitive Gneiss formation of Scandinavia seems also to be, both in position and lithological characters, the equivalent of the Laurentian system,* and is, so far as yet known, the only portion of it exposed on the European continent. The Laurentian series has never yet been seen in an unaltered condition, and is everywhere highly crystalline, but the sedimentary origin of all of its members is clearly evident. This great series of strata consists, in its lower part, chiefly of orthoclase gneiss, with quartzites and limestones, followed by a formation of anorthosite rocks. Future investigations may furnish evidence which will divide the Laurentian series into several distinct formations, distinguished by want of conformity and by mineralogical differences. The existence of what appear to be organic forms in the limestones of this series, has been noticed on page 49; and the indirect evidences of organic life which are furnished by beds of graphite, oxyd

* See on this subject, and on the parallelism of Norwegian and Canadian rocks generally, Mr. T. Macfarlane's valuable memoir on The Primitive Formations of Norway and Canada. Canadian Naturalist for 1862.

of iron, metallic sulphurets, and phosphate of lime, are abundant throughout this series.

Quartzites. The masses of quartz rock which accompany the limestones of the Laurentian series, are sometimes of considerable thickness, and are generally of a nearly white vitreous quartzite, occasionally holding grains of garnet, and more rarely of pyroxene. Sometimes the rock assumes the characters of a granular sandstone, which encloses conglomerate beds, as in the section in Bastard described on page 32. In this rock, which is interstratified with a crystalline limestone holding mica, graphite, and chondrodite, some of the pebbles are of vitreous quartz; while others are of greyish sandstone, in which the layers of sedimentation are perfectly distinct. This shows the fallacy of the notion which attributes to metamorphic action the vitreous texture of certain quartzites. This is probably due to the peculiar conditions of original deposition, since vitreous quartzites are often met with in unaltered regions, while, on the other hand, those of metamorphic formations are sometimes granular and friable.

Gneiss. The highly crystalline orthoclase gneiss of the Laurentian series has already been described, on pages 23 and 29. The coarse grained granitoid and porphyritic varieties, which often form mountain masses, sometimes have, at first sight, but little of the aspect of stratified rocks, and might be mistaken for intrusive granites. The color of the feldspar is generally white or pearl-grey, but sometimes reddish. The mica, which is never abundant in the coarse-grained gneiss, is generally black or dark brown, but in some cases white. Hornblende is occasionally present, giving rise to a hornblendic or syenitic gneiss.

Albite. Small portions of a white triclinic feldspar, which is apparently oligoclase or albite, are occasionally found with the reddish orthoclase of the coarser gneiss; especially in small lenticular masses of the latter, which sometimes occur in the finer grained beds. The albite in these rocks appears, for the most part, to be confined to coarse granitic veins, which are apparently the result of segregation, and have been described on page 36. The analysis of a fine grained reddish gneiss from Grenville, given on page 474, shows, however, an amount of soda nearly equal to that of the potash; while the white coarse grained gneiss described on the same page, consists in great part of a nearly pure potash feldspar. Beds of a rock made up of orthoclase and pyroxene, with quartz, have been described on page 475, and the epidotic gneiss is noticed on page 37.

The Laurentian gneiss is often fine grained, and sometimes passes into a sort of mica-schist, which is, however, rare and in small amount. Argillites are moreover as yet unknown in the rocks of the Laurentian system in Canada. The aluminous sediments which make up the great gneissic series of the Laurentian system, had lost but small portions of their alkalies at the time of their alteration, and contained sufficient potash and soda to form orthoclase and albite with by far the greater part of the alumina. The only species indicating a deficiency of alkali, which are found to any extent in this series, are epidote, garnet, muscovite, agalmatolite, scapolite, and tourmaline. Of these, the first three characterize portions of the gneiss; while agalmatolite, or gieseckite, which closely approaches in composition to a hydrous potash mica, forms beds in the Laurentian series in New York (page 484), and occurs crystallized in the limestones; in which scapolite and tourmaline are also of frequent occurrence. Garnet. Garnet not only forms a large proportion of some varieties of the gneiss, but is disseminated in the quartzites, and, in some cases, constitutes small beds of a nearly pure garnet-rock. From the comparative rarity of aluminous silicates, other than feldspars, it seems probable that the sediments of that early period were, for the most part, rapidly accumulated, and were speedily metamorphosed.

Anorthosites. The great anorthosite formation of the Laurentian system is described on page 33. In some parts of their distribution, the rocks of this formation are interstratified with orthoclase gneiss; but great masses, apparently many thousand feet in thickness, are made up of alternating bands of rocks, exhibiting great differences of texture, but composed chiefly of anorthic feldspars. Coarsely granitoid varieties abound, consisting of large cleavable masses of feldspar, aggregated, or imbedded in a granular base. Granular anorthosites of every grade are met with, passing into compact and impalpable varieties with a conchoidal fracture. The crystalline varieties of this rock often exhibit, in great perfection, the striæ resulting from the polysynthetic macles of the crystals, which are sometimes beautifully opalescent.

The foreign minerals of these rocks are few in number. Carbonate of lime is occasionally found disseminated in the granular varieties. Quartz occurs in small portions, but is rare. Grains of red garnet are sometimes found marking the lines of stratification, generally with pyroxene; and epidote is said to occur with the anorthosites of the Adirondacks. A brownish-black mica, probably biotite, is met with in small quantities in the granitoid varieties; but pyroxene is more abundant. It is sometimes dark green and granular, occasionally predominating in small beds, so as to form a pyroxenic rock, in which kernels or little lenticular masses of cleavable feldspar are imbedded. In other cases, where its quantity is smaller, it may be seen passing into a brownish lamellar variety, approaching in its characters to hypersthene. Hypersthene. This mineral, which characterizes certain varieties of these anorthosites, is, however, seldom abundant in these rocks. Its color is generally brownish-black, with bronze reflections; but a greenish variety, resembling diallage, is sometimes met with. The hypersthene whose analysis is given on page 468, occurs in a remarkable anorthosite in Château Richer, which is made up of a finely granular base, greenish or greyish-white in color, holding masses of a reddish cleavable feldspar, which are sometimes from one tenth to one half an inch in diameter; but they often take the form of large imperfect crystals, with cleavage surfaces which are frequently twelve inches long, and four or five inches wide. Analyses of this feldspar, which has the composition of andesine, have already been given, on page 478, I, II, III. The hypersthene is irregularly distributed through the rock in flattened masses, which exhibit in their arrangement a general parallelism. These are occasionally four or five inches in breadth, by an inch or more in thickness, and are separated from the granular feldspathic base by a thin film of brownish mica. Ilmenite is also found in this rock in grains and lenticular masses, occasionally an inch or two in thickness. These occur in the granular base, and generally near to the hypersthene; but grains of the ore are occasionally found in the crystalline feldspar. Quartz occurs in the small grains in the ilmenite, but nowhere else in the rock. The hypersthene equals, in different portions of the mass, from two to five hundredths of the whole, and the ilmenite is still less in amount. Ilmenite is a characteristic mineral of these anorthosites; and at Bay St. Paul it occurs in great masses, with rutile, imbedded in an anorthosite rock.

Château Richer.

Ilmenite.

Characteristic varieties of anorthosite occur in Rawdon and Chertsey. They are often fine-grained and homogeneous, and form an exceedingly tough rock, with an uneven sub-conchoidal fracture, and a feebly vitreous lustre. This variety is bluish or greyish-white in color, somewhat translucent, and exhibits, here and there, cleavable grains of feldspar. Great masses of this rock are almost free from foreign minerals; while other portions abound in a green granular pyroxene, arranged with ilmenite, in thin interrupted parallel layers. These layers of pyroxene are seldom more than four or five lines in thickness, and occur an inch or two apart; while the layers of ilmenite are still thinner, and are often enclosed in those of the pyroxene, along the limits of which, grains of red garnet are occasionally seen. These different minerals appear in relief upon the white weathered surfaces of the feldspathic rock. Small rounded masses of bluish cleavable feldspar are frequently disseminated in the same planes as the other minerals. In some instances, the pyroxene appears to graduate into, and to be replaced by, hypersthene. The analysis of a white granular homogeneous rock from this locality, is given on page 479, VII.

Rawdon.

The predominant colors of these anorthosites are various shades of blue, passing into greenish, yellowish, and rarely reddish hues: they are sometimes nearly pure white. The lustre of the cleavable feldspars is vitreous; of the granular varieties, waxy or dull. The weathered surfaces are always of an opaque white; but for which, some of the white granular anorthosites might be mistaken, at first sight, for quartzites.

Triclinic feldspars. The specific gravities of the feldspars of these rocks range from 2·67 to 2·73, and their composition varies from that of andesine nearly to that of anorthite. Farther descriptions of them will be found as above. From the complete analyses of ten specimens of these feldspars, from different localities, granular, crystallized, and compact, and containing from forty-seven to sixty per cent. of silica, the following mean composition is deduced, giving the oxygen ratios affixed :

Silica,	56·00 =	29·86	Oxygen.
Alumina,	27·30 =	12·85	"
Lime,	9·42 =	2·69	"
Soda,	4·84 =	1·25	"
Potash,	·84 =	·14	"
Magnesia } Protoxyd of iron, } Water, and loss, }	1·60		
	100·00		

Mean composition. The proportions between the oxygen of the silica, the alumina, and the protoxyds in the above, are very nearly as 7·0, 3·0, 0·96; the normal ratio between the alumina and protoxyd bases in the feldspars being as 3 : 1. This mean result may be regarded as a close approximation to the composition of the aluminous silicate of these anorthosite rocks. By comparison with analyses to be given farther on, it will be seen that the aluminous sediment which may be supposed to have given rise to these feldspars, was richer in alumina than more recent argillites, and was intermediate in its composition between these and kaolin. The large proportion of soda, as compared to the potash, is a remarkable character ; and the almost complete absence of oxyd of iron throughout great masses of the rock, is equally worthy of notice. But for the universal diffusion of lime throughout these sediments, their alteration might have given rise to feldspathic and micaceous rocks, with simple silicates of alumina. These anorthosite rocks seem, as it were, the complement to the vast masses of orthoclase gneiss, and quartzite, which have been noticed above. In no other series of metamorphic strata, so far as yet known, are these triclinic feldspars developed on such an immense scale as in the Laurentian series, and their investigation is as yet far from complete.

Pyroxene. The rocks composed chiefly of silicates of protoxyds, are now to be considered. The various forms of pyroxene associated with the limestones, have been noticed on page 467. Among the anorthosites, beds are met with in which a dark green granular pyroxene prevails, enclosing, however, small grains and crystals of triclinic feldspar. This pyroxene sometimes assumes the characters of hypersthene ; and by an increase in the amount of feldspar, these rocks pass into the anorthosites already described. Black or dark green hornblende, besides character-

ising parts of the gneiss in the Laurentian series, sometimes forms great beds of rock, generally associated with a little mica, and sometimes with a triclinic feldspar. A rock composed in great part of wollastonite has already been described. Talc is of rare occurrence, but a rock chiefly composed of it has been noticed; and pyrallolite, or rensselaerite, is more frequent. All of these will be found described under their respective titles in the seventeenth chapter; where also are given several analyses of the Laurentian serpentines, and the related mineral, aphrodite. The rocks com- Serpentine.
posed chiefly of serpentine, to which the name of ophiolites is given, although less abundant in this series than in the rocks of the Quebec group, present some varieties worthy of notice. They are generally mingled with more or less carbonate of lime, or dolomite, in which the grains of serpentine are sometimes arranged in bands, marking the stratification, and so far predominating in some layers as to form an almost pure serpentine rock. The serpentines of this series are generally pale Ophiolites.
yellowish or oil-green, and sometimes sulphur-yellow. Occasionally, however, the ophiolite rock is red and opaque in portions, from an admixture of peroxyd of iron; and small scales of mica are not unfrequently disseminated. A calcareous ophiolite of this kind, from Burgess, was made up of an olive-green serpentine, somewhat crystalline in texture, and mingled with a little magnesian carbonate of lime; which, as well as the serpentine, was reddish-colored in some parts, from diffused hematite. When pulverized and digested with boiling acetic acid, the rock gave 6·28 per cent. of carbonate of lime, and 3·27 per cent. of carbonate of magnesia. It was then ignited to decompose any remaining carbonates, and boiled with a solution of nitrate of ammonia; which dissolved a further portion of magnesia, equal to 0·67 per cent. of carbonate. Another portion of the ophiolite treated in like manner, after ignition, with a boiling solution of nitrate of ammonia, so long as ammonia was given off, gave 5·90 per cent. of carbonate of lime, and 3·84 of carbonate of magnesia. The residue from the acetic acid, gave to analysis, silica 42·10, magnesia 38·94, protoxyd of iron 3·69, volatile 14·50 = 99·23. An analysis of an argillaceous ophiolite will be found on page 472. Under the title of lievrite, will be found the reasons for supposing that this species also forms a rock in the Laurentian series.

The crystalline limestones of the Laurentian series are remarkable for their Limestones.
great extent, and for the variety of crystalline minerals which they contain. They are interstratified with beds of dolomite; which sometimes contain a portion of carbonate of iron, and enclose serpentine, tremolite, quartzite, and a little white mica, but are generally less abounding in foreign minerals than the pure limestones, in which the following species have been found: apatite, fluor-spar, heavy-spar, chondrodite, wollastonite, hornblende, pyroxene, pyrallolite, serpentine, scapolite, orthoclase, oligoclase, agalmatolite

or gieseckite, loganite, tourmaline, phlogopite, clintonite, garnet, idocrase, zircon, spinel, corundum, quartz, sphene, magnetite, iron pyrites, copper pyrites, and plumbago. In addition to these, a crystalline hydrate of alumina and magnesia, which has been named houghite by Shepard, and is related to völknerite, occurs in the limestones of the Laurentian series in New York. In veins cutting these limestones in Canada, calcite, heavy-spar, and sulphurets of lead and of copper occur; besides which, fluor-spar and carbonate of strontia are found in a vein in the same rocks in New York.

These minerals are confined to particular beds of the limestone, and present certain more or less constant associations, which have been noticed in the description of the several species. The crystals of many of these minerals exhibit a rounding of the angles, which has often been remarked elsewhere in crystalline limestones, and is particularly noticeable in the crystals of apatite, pyroxene, chondrodite, and quartz.

The foreign minerals of these rocks do not differ essentially from those of the crystalline limestones of other regions, and of other geological formations. Most of the characteristic species of the Laurentian limestones are found in those of southern New York, which are regarded by some American geologists as of Lower Silurian age; and in those of eastern Massachusetts, which are probably Devonian.

Beds of apatite.

Several mineral species, besides serpentine, may be mentioned as marking bands in the stratification: among these are apatite, chondrodite, pyroxene, magnesian mica, and graphite. The latter species, besides forming beds, is, like mica, disseminated in small scales through great masses of the limestone. The same thing may be said of apatite; which moreover often forms irregular beds, running with the stratification, and composed of nearly pure crystalline phosphate of lime.

The following analyses will give some notion of the composition of the dolomites and the magnesian limestones of the Laurentian series:

Analyses of dolomites.

I is a white and coarsely crystalline dolomite from the fourth lot of the tenth range of Loughborough. It leaves, when dissolved in acids, a residue of quartz and serpentine, and contains traces of oxyd of iron, and of phosphates. II is a white dolomite from the first lot of the sixth range of Sheffield. Its cleavage faces present diagonal striæ. The specific gravity of this rock is 2·684, and it contains a very little quartz and mica. III is a fine-grained white marble from Mazinaw Lake, and is a pure dolomite. IV is a white lamellar dolomite from Grenville, which contains a large proportion of grains of honey-yellow serpentine. The analysis here given is that of the portion soluble in dilute nitric acid. That of the contained serpentine will be found on page 472. V is a dolomite from the thirteenth lot of the eighth range of Madoc. It is greyish-white in color, almost compact, with a conchoidal fracture, and a specific gravity of 2·849. This rock contains veins and disseminated grains of quartz. VI is a reddish granular dolomite from the village of Madoc, having a specific gravity of 2·834. Like the previous ones, it contains quartz, and a little oxyd of iron, to which it owes its color. A portion of this however, as in the last, is probably in the state of carbonate of protoxyd. Analyses of dolomites.

	I.	II.	III.	IV.	V.	VI.
Carbonate of lime, ...	55·79	52·57	53·90	55·13	46·47	57·37
" magnesia, ...	37·11	45·97	45·90	44·87	40·17	34·66
Peroxyd of iron, ...	traces	·24	....	....	1·24	1·32
Insoluble, quartz, etc., ...	7·10	·60	....	....	12·16	7·10
	100·00	99·38	99·80	100·00	100·04	100·45

A fine grained greyish-white magnesian limestone from the fourth lot of the fifth range of Madoc, has a specific gravity of 2·757, is very silicious, and contains a portion of carbonate of iron. Its analysis gave carbonate of lime 51·90, carbonate of magnesia 11·39, carbonate of iron 4·71, quartz 32.00 = 100·00.

A magnesian limestone from the sixth lot of the tenth range of Loughborough is coarsely crystalline, but strongly coherent, snow-white in color, vitreous, and almost translucent. This rock contains small crystals of tremolite, grains of quartz, often rose-colored, bluish and greenish apatite, and scales of yellowish-brown mica. Its analysis gave 4·00 per cent. of insoluble matter, and 7·50 per cent. of carbonate of magnesia, with but a trace of oxyd of iron. Cold dilute acetic acid dissolved the carbonate of lime, with 3·65 per cent of carbonate of magnesia; and the residue, which consisted of a mixture of dolomite with the foreign minerals, gave to hydrochloric acid, 36·70 per cent. of magnesian carbonate.

The great beds of iron ore in the Laurentian system should be ranked among its rock-masses. These consist of the magnetic oxyd, and more rarely of compact or crystalline red hematite, and will be described in detail in the chapter on economic geology. Among the few mineral species found in the magnetic iron ore, may be noticed actinolite and graphite. The latter mineral is disseminated in crystalline scales through a portion of the Hull ore bed, and, by its presence in contact with the oxyd of iron, affords a strong argument against the igneous origin of magnetic iron ore. Apatite, in crystalline grains, is found abundantly disseminated through the magnetic iron ores of this series, in Essex County, New York. The great masses of titaniferous iron ore, or ilmenite, which occur in anorthosite rock at Bay St. Paul, and sometimes enclose grains of rutile, have already been described. Iron ore beds.

THE HURONIAN SERIES.

The rocks of the Huronian series, and their distribution, have been described in the fourth chapter. Quartzite may be said to be the predominant rock. It varies in its color from white to grey and brown, and is occasionally greenish or reddish. It is variable in texture, being sometimes vitreous, and at other times a granular sandstone. It is not unfrequently schistose, and sometimes slightly micaceous or feldspathic; but no well-characterized gneiss or mica schist have as yet been met with in this series. The quartzites are often conglomerate; and they contain pebbles of white vitreous quartz, hornstone, and jaspers, of various colors. Bands of chert, interstratified with limestone, are also abundant in this series. Great masses of a greenish slaty rock are met with, varying in hardness and texture, from a silicious slate, passing into hornstone, on the one hand, to a bluish glossy argillite, or a greenish chloritic slate, which is sometimes epidotic, on the other. These slates frequently include pebbles of crystalline rocks, which are chiefly feldspathic, and derived from the Laurentian strata. With them, however, are mingled others of quartz, and of various colored jaspers.

Quartzites.

Slates.

The proportion of the pebbles varies very much; and the rocks pass into what have been designated in the description of this series, as slate conglomerates. The matrix of these is sometimes an argillaceous or a chloritic slate, and occasionally becomes very quartzose, passing into a quartzite; so that it is sometimes difficult to draw a distinction between the conglomerate slates, and the jasper quartzite conglomerates.

Diorites.

The diorites or greenstones of the Huronian series are intercalated in beds, alike with the quartzose, and the argillaceous and chloritic members. They are sometimes coarse grained and crystalline, being made up of dark green hornblende and a greenish feldspar. In other parts, the rock becomes finer, and even compact in its texture, and it is frequently porphyritic from the presence of crystals of feldspar. Great masses of the diorite become schistose, and are then intermingled with a considerable amount of chlorite, passing into dioritic and chloritic slates, which are often associated with a considerable amount of epidote, generally granular or imperfectly crystallized. In one locality, amygdaloidal strata, holding in their cells, quartz and calcite, are found interstratified with the chloritic and the porphyritic beds (page 58). In some few instances, the feldspar in the coarse grained diorite becomes reddish, and the rock includes a little quartz, passing into a variety of syenite. The Huronian series is traversed, like the Laurentian, by dykes of greenstone trap; but the great beds of diorite just noticed, are considered to be altered sedimentary rocks. Well-defined lodes cutting these diorites, afford in abundance the ores of copper, sometimes with nickel and arsenic; and small portions of metallic sulphurets are occasionally disseminated in the strata themselves. Copper pyrites occurs in this way, in an argillite on Root River; and the diorites in many places are found to contain grains of the same ore. A diorite of this kind from Whitefish Lake, when crushed to powder and washed, left one two-hundredth of heavy metalliferous matters. Of this, about one half was attracted by the magnet, and consisted of magnetic iron ore, with a little titanium, and a portion of magnetic pyrites, containing a trace of nickel. The non-magnetic portion was chiefly iron pyrites, but contained one hundredth of nickel, and two or three hundredths of copper. These observations show the diffusion throughout the rock, of the metals which are accumulated in the veins. Metallic ores.

In the absence of any other analyses of these greenstones, the results obtained in their examination by Mr. J. D. Whitney are subjoined. A tough light-green colored rock, associated with the stratified iron ores of the Huronian series, in northern Michigan, was made up of a feldspar, seemingly labradorite, and a green lamellar mineral having the appearance of hornblende; the latter predominating, and having sometimes a bright green color, and a granular texture. The absence of magnesia shows, however, that this mineral must be distinct from hornblende. The analysis of the rock is given under I. A light colored homogeneous feldspathic rock from the Menomenee, was also examined. It was readily fusible before the blowpipe to a colorless glass, and was imperfectly decomposed by acids. Its analysis is given under II. This rock, in some parts of its distribution, is mingled with small portions of a greenish mineral, which is described as resembling serpentine or talc in appearance. At Presqu'isle a dark green, apparently homogeneous rock occurs, consisting essentially of a hydrous silicate of magnesia and iron, which is soluble in hydrochloric acid, and is mingled with minute crystals of magnetite, and with from two to six per cent. of an insoluble silicate, apparently hornblende. The composition of the soluble portion of a specimen is given under III, from which it would seem to be a serpentine, in which a large part of the magnesia is replaced by oxyd of iron. Portions of the same rock from other localities, gave from fifteen to thirty-three per cent. of magnesia. (Geology of Lake Superior, ii, 92.) Whitney's analyses. Serpentine.

	I.	II.	III.
Silica,	46·31	54·54	37·25
Alumina,	11·14	21·45	....
Peroxyd of iron,	....	5·53	6·75
Protoxyd "	21·69	....	14·14
Lime,	9·68	8·40	....
Magnesia,	traces	traces	28·67
Soda,	6·91	7·54	1·16
Water,	4·44	2·54	10·89
	100·17	100·00	98·86

Limestones. The limestones of this series are but small in amount. One band of three hundred feet in thickness has however been traced for considerable distances to the north of Lake Huron. Its colors are chiefly greyish, greenish, or buff, rarely white, and its fracture is conchoidal, and sometimes granular. It is often ferruginous and yellow-weathering, very silicious, and somewhat magnesian. Thin silicious layers give to its weathered surface a very uneven aspect; and it is strikingly contrasted with the Laurentian limestones, by the absence of pure crystalline varieties, and of imbedded crystalline minerals. Two smaller bands in the series consist of similar impure limestones, with regular layers of yellowish chert, the latter predominating. See a section on page 56.

The analyses of the limestones from the two extremities of Lake Panache, on the Whitefish River, will show their ordinary composition.

	I.	II.
Carbonate of lime,	55·10	41·97
" magnesia,	6·50	2·40
Insoluble, sand, and a trace of iron,	38·40	55·63
	100·00	100·00

Iron ores. A small bed of red iron ore occurs with the Huronian rocks at the Wallace mine, on Lake Huron; and in northern Michigan, the great beds of stratified red hematite, associated with slates, quartzites, and jaspers, appear to belong to the Huronian series. It is doubtful as yet how far the crystalline rocks to the north and the west of Lake Superior, as described by Drs. Bigsby and Owen, belong to the Laurentian, and how far to the Huronian series. The same question also arises with regard to the azoic strata of Arkansas and Missouri (see page 65). The rocks of these various localities exhibit crystallized mineral species which have not been found in the Huronian strata in Canada; and some of the species, such as staurotide and chlorite, are as yet unknown to the Laurentian series. The rocks of the Huronian system in Canada, seem, from Mr. Macfarlane's comparison above cited, to correspond with what he has called the Quartzose Division of the Primitive Slate formation of Norway, the Tellemarken Quartz formation of Naumann. The predominance of quartzites, of stratified diorites, of conglomerate quartzites holding jasper, of slate conglomerates, and of chert beds; the absence of the characteristic gneiss and mica-slate of the Laurentian series, and the rarity of limestones, are so many features which are common alike to the Norwegian formation, and to the Huronian series, which occupies the same stratigraphical horizon.

THE PALÆOZOIC SERIES.

Palæozoic series.

In describing the Quebec group, on page 234, it has been shown that a series of great dislocations, with upthrows to the east side, traverse eastern North America, one of which is traced from near Lake Champlain to Quebec, and, thence passing along the island of Orleans, appears again along the northern shore of Gaspé. An effect of this immense break, or series of breaks, has been to bring up a great mass of lower strata, causing them to overlie the Trenton, Utica, and Hudson River formations. For the present purpose, it will be convenient to consider this line of dislocation as one separating the palæozoic rocks of Canada into an eastern and a western district. In the latter, which also extends eastward as far as Anticosti, to the north of the line, there are found the various members of the palæozoic series, from the Potsdam formation to the Devonian system inclusive, presenting the characters by which they are generally known to American geologists, and unaltered and nearly horizontal in position.

Two divisions.

In the eastern district, on the contrary, is found a vast series of strata, consisting of what has been described as the Quebec group, with its underlying strata of the primordial zone, and regarded as the stratigraphical equivalents of the Potsdam and Calciferous formations, perhaps with the addition of the Chazy. The higher members of the Lower Silurian series are here wanting; but, to the eastward, rocks of Upper Silurian and Devonian age are found reposing on those of the Quebec group. It is proposed to describe separately the lithological characters of the rocks of the eastern and those of the western district.

PALÆOZOIC ROCKS OF THE EASTERN DISTRICT.

Quebec group.

The rocks of this district have been described in the chapter on the Quebec group, and in that on the Gaspé formations. The first, and the most important to be considered, are those of the Quebec group, of which a section, showing a large portion of the series, has been given on page 227. These rocks are there seen in an unaltered condition, and consist of alternations of limestones, dolomites, sandstones, and shales: from which issue, in various localities, saline and alkaline springs. The whole of these rocks are however much contorted, and, with the exception of a narrow belt along the north and west limits of the district, are in a metamorphosed condition, and are included in that great belt of altered rocks which forms the Appalachian chain, and stretches from Gaspé to Alabama. As already remarked on page 585, the metamorphism has comprehended not only the strata of the Quebec group, but those of the Upper Silurian and Lower Devonian series to the east of them; and in Massachusetts, it has included the rocks of the Carboniferous system; of which the shales have become crystalline, and the coal is changed into graphite. It is moreover probable that the rocks of New Hampshire, including the White Mountains, are altered strata of Devonian age. It is however chiefly to the rocks of the Quebec group that the present descriptions will be confined, as the higher strata in the eastern district, so far as yet studied, have not presented many marked mineralogical characteristics.

Notre Dame Mountains. The rocks of the Quebec group, in their altered state, compose the Notre Dame and the Shickshock Mountains, which are a continuation of the Green Mountains of Vermont. In describing successively the lithological groups of the altered region, their unaltered equivalents will be noticed at the same time. It will be observed, that, although the mineral species of these palæozoic rocks are in great part identical with those of the Laurentian system, they nevertheless present such variations in composition, arrangement, and structure, that the several classes of rocks are, for the most part, very distinct from their equivalents in the older series. This is due, in part, to original differences in the composition of the sediments, and in part, probably, to a less energetic metamorphism.

Quartzites. The silicious rocks of the eastern district offer but few peculiarities. The sandstones of the unaltered portions are sometimes nearly pure quartzites, and at other times contain an admixture of calcareous, dolomitic, or argillaceous matter. This latter characterizes the sandstones of the Sillery formation, which vary from a fine grained rock to a conglomerate holding small pebbles, and sometimes contain scales of graphite and of mica. The argillaceous admixture is generally greenish; but in some cases, it is red from diffused peroxyd of iron, which is occasionally accumulated in the form of small layers and masses of red hematite. These greenish sandstones are sometimes slightly calcareous; and they not unfrequently contain a little carbonate of manganese, which causes them to become blackish-brown on the weathered surfaces. In some cases, the coloring matter of these sandstones is allied to glauconite in composition: see the analyses of the soluble elements of such a rock, on page 487.

Sillery sandstone. A green sandstone from Sillery was attacked by boiling sulphuric acid, which left 71·45 parts of quartz sand: the decomposed portion yielded silica 9·00, alumina and oxyd of iron 13·00, magnesia ·69. These sandstones have not yet been farther analyzed; but the red sandstone of Charlotte, in Vermont, which belongs to some part of this series, was examined by Prof. G. F. Barker. A specimen, which was said to be more than ordinarily silicious, had a specific gravity of 2·65, and gave by analysis, silica 83·30, alumina, with some oxyd of iron, 8·70, lime 1·12, magnesia ·10, potash 4·59, soda ·45, volatile ·80 = 99·06. (Geology of Vermont, page 707.) From this analysis, it would seem that the argillaceous matter of this sandstone contains as much potash as is required to convert it into orthoclase.

The metamorphic portions of this region often contain white vitreous quartzites, which are interstratified with, and pass into quartzose mica-schists and gneiss. These quartzites are not unfrequently conglomerate; and in Vermont, they are said to contain, in some parts, crystals of magnetite, and small quantities of plumbago. It will, however, be evident from the descriptions given in the chapter on the Quebec group, that quartzites are found at several horizons in this series.

Beds of jasper occur at various places in this series. At Rivière Ouelle, there is a band of red and green jasper, interstratified with unaltered shales of the Quebec group. It contains veins of chalcedony; and it appears to owe its red color to disseminated hematite. Near to Sherbrooke, in the metamorphic region, there is also a bed of red jasper, which contains hematite, and passes into jaspery red iron ore. Jasper

Beds of a peculiar fine grained quartzo-feldspathic rock occur in various localities in this series. Near to the falls of the Etchemin at St. Henry, is a mass of this kind, fifty feet in thickness, and divided into layers of from two to twelve inches, by films of interposed shale, which are sometimes bright green in color. This is succeeded by a smaller mass of fifteen feet; the whole interstratified with greenish and greyish shales, in an unaltered region. Thin beds of a similar rock occur, under like conditions, at St. Anselm. This substance is finely granular, sub-conchoidal in its fracture, tough, with the hardness of feldspar, and translucent on the edges. Its color varies from pale greenish-white to olive-green, with clouds of a darker green. A similar rock occurs in the metamorphic region, associated with serpentines, on the sixth lot of the sixteenth range of Orford. It is homogenous, somewhat translucent, and does not become opaque on the weathered surfaces. It is compact, very tough, has a scaly, conchoidal fracture, a greenish or greyish-white color, and a dull, waxy lustre. The hardness of this rock is equal to that of feldspar, and its specific gravity is 2·64. Its analysis is given under I, and that of a specimen from St. Henry under II. Feldspathic rocks Petrosilex

	I.	II.
Silica,	78·40	71·40
Alumina,	11·81	13·60
Soda,	4·42	3·31
Potash,	1·93	2·37
Lime,	·84	·84
Magnesia,	·77	2·40
Protoxyd of iron,	·72	3·24
Volatile,	·90	2·50
	99·79	99·66

A second portion of the Orford rock gave silica 77·70. When that from St. Henry was treated with a boiling dilute solution of soda, 6·1 per cent. of silica, and only traces of alumina, were dissolved. Acids have but little action on these rocks. The oxygen ratios for the alumina and the alkalies in I are as 5·52 : 1·47, and in II as 6·35 : 1·25.

These rocks have the composition of intimate mixtures of feldspar and quartz; but it is worthy of note, that even in the metamorphic region they do not seem to have become crystalline. They approach in composition to what has been called petrosilex, and to the krablite of Iceland, which, according to Genth and Von Walterhausen, is a distinct species of feldspar.

Gneiss. Many of the quartzo-feldspathic rocks of the eastern district, however, assume the form of true gneiss; which is sometimes highly quartzose and micaceous, passing into mica-schist. At other times, great masses of granitoid orthoclase gneiss are met with; but these are generally finer grained and more quartzose than the gneiss of the Laurentian system, with which the practised observer can scarcely confound them. The coarse grained and porphyritic white and reddish varieties common to the latter, are never met with in the rocks of the eastern district, where the gneiss is generally of pale greyish and greenish hues. In some cases, great portions of it are so destitute of marks of stratification, that, but for their relations to the adjacent beds, they might be taken for intrusive rocks. The mica is generally white, and in small quantity. Examples of this granitic gneiss occur in St. Joseph, in Shipton, and in Sutton Mountain.

Argillites. In the next place may be considered the argillites, and some related aluminous schistose rocks, which occur in the altered region. A great proportion of the argillites have however undergone no apparent change, but are found in the immediate vicinity of the serpentines and steatites, earthy in texture, and with no appearance of alteration. I is a roofing slate from the Kingsey quarries, purplish-blue in color, and having a specific gravity of 2·88. II is a similar roofing slate, from Walton's quarries in Melbourne. III is a red shale from the Etchemin River, two miles above St. Anselm. IV is a tender greyish-green shale, from the island of Orleans; and V is a black shale, yielding a white powder, and forming a layer one fourth of an inch thick in IV.

	I.	II.	III.	IV.	V.
Silica,	54·80	64·20	66·00	60·85	58·20
Alumina,	23·15	16·80	24·60	15·80	21·20
Protoxyd of iron,	9·58	4·23		5·94	4·23
Lime,	1·06	·73	traces	1·92	1·23
Magnesia,	2·16	3·94	"	4·10	2·48
Potash,	3·37	3·26	3·67	4·34	3·86
Soda,	2·22	3·07	2·22	1·22	1·43
Volatile,	3·90	3·40	3·00	4·90	5·30
	100·24	99·63	99·49	99·07	97·93

III holds traces of manganese; and it doubtless contains a portion of iron as peroxyd, to which it owes its red color.

It is worthy of notice, that some of these argillaceous rocks contain small portions of magnesia. Thus the argillite IV, from the island of Orleans, contained no carbonates, but gave to the action of sulphuric acid 2·00 per cent. of magnesia, with but a trace of lime. A green band imbedded in the red shale of St. Henry, and in immediate contact with the native copper of this locality, did not effervesce with acids; and when boiled with a solution of nitrate of ammonia, after ignition, it gave only traces of magnesia and lime. When decomposed by heating with sulphuric acid, however, it yielded of alumina, with a little peroxyd of iron, 16·1 per cent., and of magnesia 5·5 per cent., besides traces of lime and copper. A similar green shale from Sillery, which contained small flakes of green carbonate of copper, gave in like manner 14·8 per cent. of alumina and oxyd of iron, with 2·5 per cent. of magnesia, and a trace of lime. The magnesia in these unaltered shales evidently exists in the form of a readily decomposible silicate, which may probably be sepiolite or an analogous compound. Not unfrequently, however, the argillites contain admixtures of both lime and magnesia, in the form of carbonates. A yellow-weathering green shale from the island of Orleans, was attacked with effervescence by dilute nitric acid, which removed, besides a little oxyd of iron and alumina, carbonate of lime 11·05, and carbonate of magnesia 9·75, equal to 20·80 per cent. of dolomite. Magnesia in shales.

In some parts of the metamorphic region the argillites are found to assume a talcose aspect. This is especially true of the red and green shales of the Sillery formation. These at Ste. Marie, Beauce, are much intersected by veins of quartz, and are very soft and fissile, exfoliating by the action of the weather, and becoming converted, when moistened, into a pasty mass, which is very unctuous to the touch, and has a silvery glimmering lustre. The green beds retain their color, and the red ones have a pale purplish or lilac color, being occasionally spotted on their cleavage surfaces with scales of a greenish mineral resembling chlorite in appearance. A characteristic specimen of this red slate, from a locality in Ste. Marie, where explorations have been made for copper pyrites, which is found there in small quantities, was selected for analysis, and the unctuous material having been separated by elutriation from grains of quartz, and dried at 212° F., yielded on analysis the result I. Similar rocks from Vermont, belonging apparently to the same series, have lately been analysed by Prof. G. F. Barker (Geology of Vermont, page 707), whose results are here cited for comparison. II is from Irasburgh, and is designated as novaculite slate. It is described as very unctuous, apparently homogeneous, translucent, of a dirty grey color, infusible before the blowpipe, and with a specific gravity of 2.65. III is a greenish-grey friable talcose schist from Roxbury, with a specific gravity of 2.73. IV is an olive-green talcose schist from Middlesex. V is a soft unctuous rock from North Talcose or nacreous shales.

Carolina, which is ground to powder and employed in the arts instead of steatite. Its analysis is by Dr. Charles T. Jackson :

	I.	II.	III.	IV.	V.
Silica,...........	66·70	78·70	69·90	64·10	75·00
Alumina,........	16·20	12·80 }	20·00	23·50	{ 18·75
Protoxyd of iron,.	6·90	traces }			{ traces
Lime,...........	·67	1·23	1·51	·84	.....
Magnesia,........	2·65	traces	1·80	1·98	.....
Potash, ...	undet.	·89	1·45	3·70	2·00
Soda, ...	"	5·57	2·33	2·20	.....
Volatile,.........	3·10	·60	2·40	3·60	3·50
		99·79	99·39	99·92	99·25

The analysis II gives for the oxygen ratio between the silica, alumina, and protoxyd bases, very nearly 21 : 3 : 1. It is evident from the analyses, that these rocks, which are generally called talcose slates, do not owe their softness and unctuosity to talc, or to any other magnesian mineral, but to an admixture of some soft foliated aluminous silicate, which may be either pyrophyllite, pholerite, or a hydrous mica. They have therefore for distinction sometimes been called nacreous slates. A somewhat unctuous schistose rock from Shipton, made up of minute scales, and resembling chlorite slate in aspect, has been described on page 494: it differs from a hydrous mica chiefly in the smaller proportion of alkalies. Some of the black slates of this series contain a small amount of carbon in the form of plumbago, and have been noticed on page 528.

Agalmatolite. Under the title of agalmatolite, on page 484, has been described a class of rocks found among the shales of St. Nicholas, with similar schistose rocks in Vermont, and the agalmatolites of St. Francis and Stanstead. These substances are remarkable for the small amount of silica, and the large proportion of potash, which they contain. In their softness and unctuosity, they approach to some of the more silicious rocks just described, but resemble still more serpentine and steatite.

Rocks composed in great part of triclinic feldpars are common in this series, and represent the anorthosites of the Laurentian system. They are seldom, however, coarsely crystalline, and are often compact. The feldspar in some cases approaches to albite, or to oligoclase in composition. Diorite. Through an admixture of hornblende, these feldspar rocks pass into diorite; in different varieties of which, the one or the other mineral predominates. These compound rocks are often so finely granular as, at first sight, to appear homogeneous; at other times they are rather coarse grained, and are sometimes porphyritic from the presence of large crystals of feldspar in a fine grained greenish base. Varieties of these diorites at Drummondville and in Potton are described on pages 243 and 250. At the latter locality, portions of the rock are a nearly pure anorthosite ; while other parts assume a conglomerate character, holding grains of quartz, and fragments of indurated shale. The imbedded hornblende crystals are occasionally of considerable size, and dark green in color. In some parts, the hornblende is replaced by pyroxene, or by diallage. At Drummondville, parts of the rock are porphyritic; while others are amygdaloidal, holding portions of calcite and nodules of agate. Amygdaloid.

A variety of this diorite, from Brompton Lake, in the second lot of the sixteenth range of Orford, was examined. Its color is white, with a greenish or yellowish-grey tinge, evidently due to some disseminated mineral, which turns yellowish-brown by ignition, while the base becomes whiter and more opaque, and is then seen to consist of grains of crystalline feldspar, sometimes with striated cleavage planes. The rock has a waxy lustre, is sub-translucent, and has a somewhat conchoidal fracture. Its hardness is about that of feldspar, and its specific gravity from 2·75 – 2·76. Its powder is not acted upon by nitric acid. The analysis of this rock is given under I. A second determination gave silica 63·60 and lime 7·28. A similar rock from St. Francis, Beauce, was more coarsely crystalline than the last, and had a pale bluish-green color, from the admixture of an imperfectly crystallized hornblende with a somewhat translucent cleavable feldspar. The hornblende turns dark olive-brown by ignition, and the structure of the rock is then very evident. Its lustre is feeble and waxy, and its specific gravity from 2·71 – 2·72. The pulverized rock yields to dilute nitric acid, a trace of alumina, and a little lime. Its analysis is given under II.

	I.		Oxygen.	II.		Oxygen.
Silica,	63·40	=	33·81	63·60	=	33·92
Alumina,	12·70	=	5·93	14·20	=	6·63
Soda,	7·95	} =	2·07	5·09	} =	2·01
Potash,	·13			4·13		
Lime,	7·50	=	2·14	4·37	=	1·22
Magnesia,	3·37	=	1·35	6·84	=	2·73
Protoxyd of iron,	4 23	=	·94	1·92	=	·43
Volatile,	·40			·70		
	99·68			100·85		

In the analysis I, the oxygen ratio of the alumina and alkalies is very nearly as 3 : 1; and if to these be added the silica necessary to form a soda feldspar, we have the elements of 64·0 parts of albite. The remaining silica, and the other bases, afford the oxygen ratio 9·81 : 4·43, showing a little excess of silica over that required to form hornblende. In analysis II, there is a slight deficiency of alkalies; and 0·71 parts of lime may be supposed to enter into the composition of 73·81 parts of albite. The oxygen of the silica and of the remaining bases, gives the ratio 7·43 : 4·18, or a slight deficiency of silica; rendering it not improbable that the rock may contain oligoclase, or a mixture of some more basic feldspar with orthoclase, which is indicated by the large amount of potash.

Greenstone. Other varieties of these diorites are much darker in color, and heavier, from a larger admixture of hornblende. These closely resemble in their aspect many intrusive greenstones. A portion of such a rock from near the copper mine in Acton, has a specific gravity of 3·04 – 3·07, and is Acton. seen to consist of fine grains of greenish-white feldspar, sometimes showing cleavage planes, mingled with a blackish-green amorphous mineral. Its powder did not effervesce with strong acetic acid; but nitric acid attacked a small portion of pyrites, which is disseminated in the rock, and dissolved moreover a considerable portion of alumina. A few scales of a brown mica were visible in the residue after the action of the acid. The results of two analyses of the rock are given under III and IV. A specimen of a similar fine grained diorite from near the copper mine in Upton is Upton. greenish-grey in color, but weathers to a reddish-yellow. Its powder was attacked with slight effervescence by acetic acid, which removed portions of carbonates of lime, magnesia, and oxyd of iron, equal to about three per cent. The pale green residue became reddish-brown by ignition, and gave by analysis the result V. The fissures of this rock contained thin layers of a soft greenish, amorphous, translucent substance, resembling serpentine in appearance. This was partially decomposed by sulphuric acid, leaving an insoluble residue. It contained no lime nor carbonates, and gave by the analysis of ·581 grams: silica ·141, alumina ·065, magnesia ·047, protoxyd of iron ·148, volatile ·055, insoluble ·125 = 581. The composition of the soluble portion, calculated for 100 parts, is given under VI.

	III.	IV.	V.	VI.
Silica, ...	49·45	49·95	51·80	30·90
Alumina, ...	14·80	undet.	11·30	14·20
Potash, ...	1·15	"	undet.	....
Soda, ...	2·96	"	"	....
Lime, ...	11·10	11·20	3·25	....
Magnesia, ...	8·85	8·70	7·80	10·30
Protoxyd of iron,.	9·90	....	13·14	32·40
Water, ...	2·60	3·10	4·40	12·20
	100·81			100·00

Lake Superior. It is interesting to compare with these analyses, the similar results obtained by Mr. J. D. Whitney with the greenstones from the Upper Copper-bearing rocks of Lake Superior. These, as has already been pointed out in preceding chapters, are the stratigraphical equivalents of the Quebec group, which they resemble, both in their metallic contents and their lithological characters. A specimen of the fine grained and apparently homogeneous greenstone from Rock Harbor on Isle Royale, gave, on analysis, the result I. Another variety from the Cliff Mine was dark greenish in color, and compactly crystalline, and showed, under the microscope, three distinct minerals,—a feldspar, which was colorless or slightly greenish, a dark green substance resembling chlorite, and a third element, which was apparently pyroxene or hornblende. Small crystals of magnetic iron are also occasionally disseminated. The pulverized rock was partly decomposed by long digestion with hydrochloric acid, nearly at the boiling point. This dissolved 21·17 per cent., leaving a residue of silica and undecomposed mineral. The analysis of the rock as a whole is given under II, that of the soluble portion under III, and that of the residue under IV. Whitney's analyses.

	I.	Oxygen.	II.	Oxygen.	III.	IV.
Silica, ...	47·97	=24·93	50·20	=26·08	....	64·58 (by loss.)
Alumina, ...	15·56	= 7·28	15·43	= 7·22	30·95	11·67
Soda, ...	6·24	= 1·61	4·75	= 1·22	11·26	3·14
Lime, ...	7·07	= 2·02	5·47	= 1·56	9·36	4·57
Magnesia, ...	8·28	= 3·21	8·62	= 3·34	15·96	6.86
Protoxyd of iron,...	12·41	= 2·75	13·79	= 3·06	32·47	9·18
Water, ...	2·46	= 2·18	1·74	= 1·55	....	....
	99·99		100·00		100·00	100·00

Mr. Whitney supposes that the alumina in these rocks exists in the form of labradorite. On deducting from the above two analyses the alumina and soda, together with the lime and silica necessary to form labradorite with these, there remains, in both cases, a large excess of bases over the amount required for hornblende or pyroxene. This excess, and the presence of water, are explained by the admixture of magnetic iron and of the chlorite-like mineral noticed in the rock from the Cliff Mine, which may, probably, be similar in composition to the silicate separated from the diorite of Upton. (Whitney, Geol. of Lake Superior, ii, 87.)

It is not easy to determine the mineralogical composition of these hydrated greenstones of the Quebec group, from Lake Superior and from the eastern district. In the latter region, while they graduate on the one hand into pure feldspar rocks, they appear in other cases to contain a variety of diallage; and this, from the analyses given in page 469, is often a hydrated mineral very distinct from pyroxene; so that it is not improbable that in the hydrated rocks in question, either this diallage, or chlorite, or something like the mineral from Upton, just described, may, wholly or in part, replace the hornblende.

On Isle Royale, and elsewhere on Lake Superior, according to Mr. Whitney, epidote enters very largely into the composition of these diorites, and even forms beds of considerable extent. This epidotic rock sometimes becomes amygdaloidal, and then often contains quartz. Epidote characterizes great masses of the altered rocks in the eastern district. In some cases, it is found as a fine-grained and apparently homogeneous mix- Epidotic rocks.

ture of pale yellowish-green epidote with a portion of quartz. The description and analysis of a variety of this epidosite are given on page 497. In some portions of the rock the two minerals occur in distinct grains. More frequently the epidote occurs in rounded masses, sometimes an inch, or even several inches in diameter, composed of radiating crystals, and imbedded in a fine-grained micaceous quartzite or mica-schist, which is either greyish in color, or greenish from disseminated scales of chlorite. The laminæ of the schist are often seen conforming to the masses of epidote, which are elongated in the direction of the layers. They sometimes make up the greater portion of the rock, and give to its surface a curiously knotted aspect. Not unfrequently the nodules of epidote are accompanied by vitreous quartz, which sometimes surrounds the epidote, and occasionally forms little masses by itself. A feldspar, having the characters of orthoclase, is sometimes found in these nodules, with the quartz; and small radiating masses of actinolite are occasionally met with, sometimes with scales of graphite. Chlorite is very often associated with epidote, and some bands consist of a fine grained mixture of epidote and chlorite, often with quartz, and with small crystals of specular or magnetic iron ore. Very great variations exist in the proportions and the arrangement of these minerals, from the homogeneous epidote rock above described, to pure slaty chlorite, and to schists in which specular iron predominates, with a mixture of quartz and chlorite. Most of these varieties are well seen in Sutton and St. Armand, as noticed on page 246. Epidote is found crystallized with chlorite, quartz, calcite, and talc, in the red concretionary argillite rock of St. Joseph, described on page 255.

Feldspar.

Chlorite.

Orthoclase in argillite.

Orthoclase, besides occurring crystallized in the quartzose epidotic strata above noticed, is found under remarkable conditions among argillaceous rocks at the St. Francis copper-mine in Cleveland. Here are beds of a soft fine-grained somewhat schistose dark bluish-grey argillite, enclosing small ovoidal or elongated masses of crystalline feldspar, which have a general parallelism, and are oblique to the divisional planes of the rock. The laminæ of this conform to the feldspathic masses, which give a knotted surface to the exterior of the rock. These are in some portions from one eighth to one tenth of an inch in diameter, and are nearly spherical, or elongated two or three diameters. In other portions of the rock, they are an inch or more in length, and more irregular, though always rounded in outline. The exterior of the nodules is a white or pink feldspar; but in the centre of some, especially of the larger nodules, white translucent and vitreous quartz occasionally occurs; and these not unfrequently are composed of this mineral, with only a thin envelope of feldspar. In some parts, the feldspar is seen to extend from the nodules, in thin layers among the laminæ of the slate, giving to such portions a gneissoid aspect. In most cases however the rock has completely the aspect of an amygdaloid; especially in sections, which exhibit the feldspar surrounding the quartz, in the ovoidal masses. In the immediate vicinity of this rock, is another in which a brick-red orthoclase has filled and penetrated in an irregular manner a bluish-black argillite. Much of the rock in this vicinity is however chloritic, and assumes the character of a chloritic slate. In one portion in which the slaty structure is scarcely apparent, and which resembles rather a soft chloritic greenstone, small nodules of crystalline quartz are disseminated, as in the argillite, but without feldspar, and give to this rock also the aspect of an amygdaloid. A somewhat similar chloritic and schistose rock from Orford contains great numbers of spheroidal masses, sometimes half an inch in diameter, and arranged like those just described. They are fine grained, compact, nearly as hard as quartz, and are yellowish-green in color, often purple at the centre. They become soft and decomposed on the weathered surfaces, and, from their hardness and specific gravity, appear to be feldspathic. A similar amygdaloidal character is also well marked in portions of the reddish and greenish epidotic argillite of St. Joseph above mentioned, which contains numerous almond-shaped cavities filled with calcite; and in the diorites of Acton, St. Flavien, and Drummondville, which at the latter place hold agate as well as calcite. Amygdaloids.

The occurrence of orthoclase in veins with quartz, chlorite, and specular iron, in these rocks, has already been noticed on page 476. These minerals occur both in the epidotic quartz-slates of Sutton, and in the argillites; and, like the quartz, feldspar, and epidote met with in nodules in both of these rocks, indicate that during metamorphism these minerals were in solution, and were deposited, either in fissures, or in concretions in the midst of the sediments. Quartz is still more abundant than feldspar in the veins cutting these slates, and is sometimes associated with white mica, and not unfrequently with bitter spar, talc, and chlorite; besides which, these veins hold, not only metallic sulphurets, but rutile, specular iron, and native gold. Feldspar in veins.

The chloritic slates of Cleveland are traversed by small veins, from one tenth to one fourth of an inch in diameter, which are perfectly well defined, and are filled with pure scaly chlorite, sometimes intersected by seams of quartz, and evidently analogous to the larger veins just mentioned. In some cases, the slates themselves are a pure chlorite or potstone. A rock of this kind, from the twenty-sixth lot of the sixth range of Potton, was of a pale greenish-grey color, unctuous to the touch, and was composed of lamellæ of chlorite, so arranged as to give a schistose structure to the mass. Its analysis gave silica 29·60, magnesia 25·95, protoxyd of iron 14·49, alumina 19·70, water 11·30 = 101·04. A partial analysis of another specimen of the same rock yielded to Delesse, silica 29·88, water 11·50, lime 0·77, besides traces of oxyd of chrome. Chlorite slates.

Garnet-rock. After the epidotic rocks, may be mentioned those consisting chiefly of garnet. A compact white garnet has been described on page 496, as forming a rock, with a little intermingled serpentine; or as intimately mixed with a silicate approaching to pyroxene in composition, and forming a hard heavy white rock, which in some portions is penetrated by feldspar, and by a coarsely crystalline hornblende. Red garnet occurs but sparingly in the crystalline rocks of the eastern district in Canada, but is found massive in Chester in Vermont. It also abounds, with kyanite and staurotide, in a very quartzose mica-slate in Cavendish; and with grey actinolite, and a little chlorite, it forms a bed in Plymouth in the same state. In similar associations in Canada, epidote and chloritoid seem to replace garnet. Chloritoid. Chloritoid, as has already been described on page 498, occurs abundantly in grey quartzose micaceous schists.

The minerals consisting chiefly of silicates of protoxyd, occupy an important place among the metamorphic rocks now under consideration. Black crystalline hornblende schists, holding small red garnets, occur in beds Hornblende. with the serpentines of Mount Albert; and actinolite, either alone or mingled with talc, forms large beds, as described on page 466. Analyses and descriptions of the diallage rocks which are associated with the serpentines, are given on page 469; and the large proportion in which hornblende enters into the composition of the diorites of this region, has Steatite. been noticed above. The chemical composition of the beds of talc or steatite which abound in this series, has been given on page 470; and it now remains to speak of the serpentines.

Serpentine. Those rocks which have serpentine for their basis are conveniently designated by the title of ophiolites. Many facts with regard to their structure Ophiolites. and distribution will be found on pages 248 and 266. The simple or normal ophiolites are nearly pure massive serpentine; while others are mixtures of this mineral with variable proportions of carbonate of lime, carbonate of magnesia, or dolomite. All of these varieties are met with in Canada, or in the adjacent state of Vermont. These compound ophiolites are sometimes porphyritic from an admixture of diallage. At other times, they have the aspect of conglomerates, and exhibit rounded or angular masses of pure serpentine of various sizes, imbedded in a dolomitic paste, which is itself more or less colored by intermingled serpentine. A magnesitic ophiolite from Vermont has a gneissoid structure, due to an admixture of crystalline magnesite spar, with scales of talc, apparently showing planes of stratification. The ophiolite of Mount Albert is marked with red and with green bands, having the aspect of sedimentary layers, page 266. The relations of the serpentine throughout this series, where its out-crop has been traced for hundreds of miles, are always those of an interstratified deposit, and not of an erupted rock. It occurs with argillite, dolomite, magnesite, diorite, and steatite, with each of which it has been found in contact, and it seems occasionally to replace other magnesian rocks. The colors of these ophiolites are of various shades of green, generally much darker than those of the Laurentian series. The pure serpentines are sometimes curiously chequered by veins or seams, as described on page 248; and a dark red color occasionally occurs in spots or bands, or pervades the whole mass, which in some cases, at least, is due to diffused hematite. Foliated and fibrous varieties of serpentine often occur in these ophiolites, constituting the varieties called baltimorite, picrolite, and chrysotile, as described on pages 248 and 473. Chromic iron is also a characteristic mineral, both in grains and in interstratified beds and lenticular masses. Magnetic iron ore occurs in these rocks under similar conditions, sometimes with ilmenite: see under these titles for further details. The facts with regard to the general distribution of chrome and nickel among the serpentines and other magnesian rocks of this series, will be found under the head of these metals, in the seventeenth chapter.

Besides the analyses of the serpentines from these ophiolites, which have been given on page 472, a description of some of the principal varieties of the rock, and the results of their chemical examination, are subjoined. A calcareous ophiolite, which occurs on the tenth lot of the sixteenth range of Orford, is fine grained and sub-crystalline, with a somewhat conchoidal fracture. It is translucent on the edges; and except in its color, which is a mottled greenish-grey, with occasional purple stains, it resembles some common varieties of limestone. When in powder, the rock effervesced even in the cold, with acetic acid, which by the aid of heat removed 57·0 per cent., consisting of carbonate of lime 91·33, carbonate of magnesia, with traces of iron, 8.67 = 100.00. The remainder was attacked with effervescence by dilute nitric acid; which, by the aid of a gentle heat, dissolved 10·76 per cent. of a ferruginous dolomite, consisting of carbonate of lime 49·45, carbonate of magnesia 43·68, carbonate of iron 6·87 = 100·00. The residue from nitric acid, when dried at 212° F., equalled 32·00 per cent., indicating a loss of ·24 per cent. It was decomposed by heated sulphuric acid, without any effervescence, and was a nearly pure serpentine, giving silica 41·20, magnesia 32·16, protoxyd of iron 11·16, lime ·65, alumina 2·67, water 12·70 = 100·54. The action of acetic acid removes all the free carbonate of lime; attacking at the same time a portion of the dolomite, the remainder of which is afterwards dissolved by the nitric acid. This ophiolite is thus shown to consist of a mixture of serpentine and some aluminous silicate, mingled with carbonate of lime and a little dolomite. Calcareous ophiolite.

A dolomitic ophiolite from the shore of Brompton Lake, on the seventh lot of the thirteenth range of Orford, is fine grained and greenish-grey, like the last; but it is somewhat darker in color, and weathers to a yellowish-brown; while the pure ophiolites are white on their weathered surfaces. Its fracture is uneven, presenting grains of a crystalline spar; and it has a Dolomitic ophiolite.

fibrous coating in the joints of the rock. Its hardness is a little greater than that of limestone. When reduced to powder, it did not, like the calcareous ophiolite, effervesce with acetic acid; but it was readily attacked by dilute nitric acid, which removed carbonates of lime, magnesia, and oxyd of iron, with traces of nickel and manganese, and left a residue of 51·9 per cent. of serpentine. The analysis of this gave silica 43·20, magnesia, by difference, 36·11, protoxyd of iron, with nickel, 8·29, water 12·40 = 100·00. The soluble portion consisted of carbonate of lime 49·58, carbonate of magnesia 46·32, carbonate of iron, with manganese, 4·10 = 100·00. The rock is thus a mixture of serpentine and dolomite.

Conglomerate ophiolite.

Another dolomitic ophiolite, also from Brompton Lake, on the twelfth lot of the eighteenth range of Orford, is a breccia, or a conglomerate, holding masses of serpentine from a line to an inch or two in diameter, and more or less rounded, although angular in form. These are imbedded in a greenish-white base, and are of various shades of dark green, sometimes appearing nearly black when polished. The analysis of one of these has been given on page 472, II. The rock contains nickel and grains of chromic iron ore. The nature of the cement varies in different parts. A portion having been pulverized, it was attacked with effervesence in the cold, by acetic acid; which, with the aid of heat, took up twenty per cent. of carbonates, consisting of carbonate of lime 88·30, carbonate of magnesia, with a trace of oxyd of iron, 11·70 = 100·00. The residue was digested with nitric acid, which dissolved no lime, but a portion of magnesia, and some oxyd of iron and alumina, due to a partial decomposition of the serpentine. This then gave silica 45·10, magnesia, by difference, 34·68, protoxyd of iron 6·12, alumina ·80, water 13·30 = 100·00. A portion from another part of the conglomerate ophiolite, was finely pulverized, and digested for some time with boiling acetic acid, which dissolved carbonate of lime 7·35, carbonate of magnesia 7·72, carbonate of iron 1·78 = 16·85. The residue from this treatment still retained carbonate of magnesia; for on igniting a portion, and boiling it for some time with a solution of nitrate of ammonia, which is without action on calcined serpentine, there were dissolved, lime equal to ·3 per cent., and magnesia equal to 3·26 per cent. of carbonate. The residue, still retaining this admixture of carbonates, gave silica 43·93, magnesia, by difference, 35·64, protoxyd of iron 7·83, lime, traces, water, and carbonic acid, 12·60 = 100·00. A further trial was made by igniting a portion of this last specimen of the conglomerate, and boiling it with a solution of nitrate of ammonia so long as an odor of ammonia was perceptible, when there were dissolved carbonate of lime 6·50, carbonate of magnesia 7·65. From these experiments, it is evident that while portions of this conglomerate approach to a calcareous ophiolite in containing a somewhat magnesian carbonate of lime, other portions hold a mixture of dolomite and carbonate of magnesia. Veins of from four to six lines in breadth are common in this conglomerate. Their walls are covered with a layer of a pale green serpentine, having a fibrous structure perpendicular to the walls of the vein. Upon this is deposited a bluish-white fine grained dolomite; while in the middle, a nearly pure cleavable calcite occurs. A portion of this dolomite gave carbonate of lime 59·32, carbonate of magnesia 34·15, carbonate of iron 4·83 = 98·30. The stratified origin of these ophiolites is very evident in some of the conglomerate varieties, where bands of different texture and color are seen to alternate. This is very well shown in a calcareous conglomerate ophiolite from Melbourne, which, like that from Orford, has been wrought for ornamental purposes.

Veins in serpentine.

The predominence of the carbonate of magnesia over the lime, is seen in the example just described; and in some of the ophiolites of Vermont, carbonate of lime is altogether wanting, being replaced by magnesite. This, according to Drs. Jackson and A. A. Hayes, is the case with the ophiolites of Lynnfield, Cavendish, and Roxbury. In this, according to the latter observer, fragments of talcose schist and argillite are sometimes imbedded with serpentine in the magnesite, which equals, on an average, 38·0 per cent. The results of an examination of the magnesitic ophiolite from Roxbury, undertaken for comparison with the preceding, may here be given. Some specimens of the rock are granular, with an uneven fracture, and are mottled with light and dark green. Other portions are white and crystalline, with greenish-grey parallel layers of talc and serpentine, giving the rock a gneissoid aspect. The white portions are carbonate of magnesia, containing about three per cent. of carbonate of iron, and having a hardness of 4·0, and a specific gravity of about 3·0. The green granular portion of the rock effervesces when boiled with dilute nitric acid; which removes magnesia, oxyd of iron, manganese, and a trace of nickel, but no lime. The residue was then boiled with a solution of carbonate of soda, which dissolved a portion of silica from the decomposed serpentine, and left a green granular residue, mixed with scales of talc. A portion of this residue, when ignited and boiled with nitrate of ammonia, was found still to contain 1·21 per cent. of carbonate of magnesia. It was however decomposed by sulphuric acid; and the silica was separated by carbonate of soda from the insoluble talc, which equalled 6·8 per cent. Deducting this, and the small portion of carbonate of magnesia, the composition of the serpentine, dried at 250° F., was silica 43·34, magnesia 39·55, protoxyd of iron 5·32, oxyd of nickel, traces, water 11·79 = 100·00. The insoluble talc, separated as above, gave by analysis, silicia 62·60, magnesia 31·30, alumina and oxyd of iron 4·06, water and loss 2·04 = 100·00. This ophiolite is thus shown to be an admixture of serpentine, talc, and ferriferous carbonate of magnesia.

Magnesitic ophiolite.

In the preceding analyses, it will be seen that only traces of alumina occur in these ophiolites. A nearly opaque greyish-green rock from the twentieth lot of the first range of Ireland, which resembled serpentine in appearance, and had a specific gravity of 2·65, gave on analysis, silica 43·70, magnesia 23·46, alumina with peroxyd of iron 23·00, water 11·57 $=101·73$. In this rock, the iron exists as protoxyd, and the mineral is like that from the Laurentian series, at the Calumet, described on page 474, an ophiolite mixed with some aluminous mineral. In many cases, the ophiolites of the eastern district include diallage, and pass into the hydrous diallage-rock described on page 469, which contains 6·80 per cent. of alumina. Through this, there is an apparent passage to feldspathic rocks containing diallage, and to others holding hornblende, or, as in the diorites of Acton and Upton, more basic silicates, approaching to chlorite in composition. Both the serpentines and the diorites sometimes become schistose: and the latter seem to graduate into chloritic slates and epidosites, on the one hand, and into hornblendic slates on the other; so that it is difficult to resist the conclusion that the whole series of rocks just named, from diorites, diallages, and serpentines, to talcs, chlorites, and epidosites, have been formed under similar conditions.

Limestones. The limestones, dolomites, and magnesites of this series are next to be described. Great masses of pure compact limestone occur in the Quebec group; but they seem, like the associated dolomites, to be irregular, and interrupted in their distribution, in some parts attaining a considerable thickness, and in others appearing to thin out, or to be replaced by sandstones. These limestones frequently form masses of many feet in thickness, which are without visible marks of stratification, and are destitute of organic remains. The rock is in these cases compact, conchoidal in fracture, and sub-translucent; and it exhibits a banded agatized structure, which leads to the conclusion that it is a travertine, or a chemical deposit from water. Masses several inches in diameter, of a crystalline fibrous carbonate of lime, arranged in concentric layers, and closely resembling the modern deposits from calcareous springs, are often imbedded in this limestone, and have been described on page 445. These travertines are pearl-grey, dove-grey, or occasionally of a pale greenish color, and weather smooth and white. Their analysis shows them to be pure carbonate of lime. Sometimes however this material includes grains of sand, or is the cement of a conglomerate. Such a specimen gave 9·30 per cent. of sand, and ·75 per cent. of carbonate of magnesia. The microscopic examination of thin sections of this rock shows it to be finely and uniformly crystalline, often without any traces of organic remains.

Travertines.

Dolomites. Interstratified with these travertines, however, are beds of finely granular, opaque limestones, weathering bluish-grey, and holding in abundance the remains of trilobites, and other fossils of the Quebec group. These fossils are often replaced by a yellow-weathering dolomite. In some other portions of the Quebec group, pure grey limestones are met with, as near Missisquoi Bay. Here, as at Quebec, they are interstratified with yellow-weathering dolomites, which, throughout the eastern district, are more abundant than the pure limestones. They are generally mixed with a considerable portion of silicious matter, and more rarely with clay; and they commonly contain a portion of carbonate of iron in their composition, which causes them to weather yellowish or reddish-brown, and to become friable to a considerable distance from the surface. They are, besides, very generally traversed by narrow veins of white quartz, or of calcareous spar, which intersect each other, giving to the surface of the rock a chequered appearance. These veins are found alike in the metamorphosed region; and in the vicinity of Quebec, where the dolomites are unaltered, and slightly bituminous. They often contain small masses of crystalline calcite filling cavities, which, at other times are lined with crystals of calcite or of quartz, forming small geodes, as near Missisquoi Bay, where the dolomite also encloses masses of black and grey chert or hornstone.

These dolomites in many parts,—especially in the vicinity of Quebec, as described in the section on page 227,—include conglomerate beds, which hold, in a red-weathering sandy dolomitic base, grains and rounded masses of pure limestone, often resembling the travertines of the series; besides, more rarely, fragments of quartz, of shale, and also small masses of a nearly pure crystalline dolomite. These last are perhaps concretionary in their origin, and not imbedded fragments. Conglomerates.

The following are some analyses of the dolomites of this series: I is a fine grained variety from the island of Orleans, of which the insoluble residue contains a little clay. II is associated with the travertine at the lime-quarry at Point Levis. It is highly crystalline, and shows in its fracture broad surfaces of cleavage, like the Fontainebleau sandstone: the insoluble portion is pure quartz. III is a white-weathering dolomite from Philipsburg, enclosing a large quantity of quartz sand. IV is a greyish, granular dolomite from the ninth lot of the ninth range of Sutton, which contains, in some parts of the bed, thickly disseminated octahedral crystals of magnetic iron, with chlorite, and weathers brownish-black, from the presence of a large proportion of manganese. The insoluble residue was nearly pure quartz. Analyses of dolomites.

	I.	II.	III.	IV.
Carbonate of lime,	45·06	53·04	25·60	40·10
" magnesia,	31·81	31·96	19·40	20·20
" iron,	10·31	5·80	....	10·65
" manganese	....	traces	....	7·65
Insoluble,	13·80	8·80	55·00	21·40

The presence of about twenty per cent. of dolomite in some of the yellow-weathering green shales of the island of Orleans has been noticed above. A bed of compact earthy rock, interstratified with the shales at Point Levis, and decomposing to a yellow earth, gave to acids about fifty per cent. of ferriferous dolomite. The insoluble residue was chiefly a clay, holding about four per cent. of alkalies, of which two thirds were potash. One of the small masses of dolomite from the magnesian conglomerate of Point Levis gave of carbonate of lime and a little iron, by difference, 61·6, carbonate of magnesia 33·8, silicious sand 4·6 = 100·00.

A black, thin-bedded compact dolomite, which weathers reddish-yellow, occurs among the black shales of this series on the Magdalen River, and is noticed on page 268. The surfaces of the beds are marked by thin crystalline crusts of calcite. The analysis of this limestone gave carbonate of lime 43·17, carbonate of magnesia 32·12, alumina with oxyd of iron, the latter in part as carbonate, 4·10, insoluble 20·30 = 99·69. The insoluble residue is a fine clay; and the rock, which by calcination assumes a pale buff color, makes a superior cement, which hardens in a few minutes under water.

Chrome and nickel.

The above dolomites were all examined for chrome and nickel without success; but both of these metals are frequent in the dolomites of the metamorphic region, and in one case were met with in an impure, somewhat magnesian limestone from the unaltered strata of the Quebec group at Granby, noticed on page 245. This rock, which is interstratified with red and greenish shales, and green sandstones holding scales of mica and graphite, was digested with acetic acid, which attacked it with strong effervescence. A little hydrochloric acid was added towards the close of the operation, and there were dissolved carbonate of lime 30·08, magnesia, calculated as carbonate, 3·68, oxyd of iron and alumina 5·45, oxyd of manganese ·58 = 39·79. The residue gave on analysis, silica 53·20, titanic acid 6·20, alumina 7·90, peroxyd of iron 15·75, magnesia 8·79, oxyd of chrome ·10, oxyd of nickel ·15, volatile 4·80, with alkalies, oxyd of manganese and loss 3·11 = 100·00. In another trial, 5·3 per cent. of titanic acid were obtained from this rock.

Titanium.

In the analyses of the various magnesian limestones hitherto given, the amount of carbonate of magnesia does not exceed that required to form a dolomite with the carbonate of lime, the proportions being 54·35 of carbonate of lime to 46·65 of the carbonate of magnesia, or one equivalent of each. Any excess of carbonate of lime is present in an uncombined state, and may be separated by dilute acetic acid, in which the dolomite is much less soluble than the simple carbonate. The carbonates of iron and manganese, which these dolomites so often contain, generally replace a portion of the magnesian carbonate, so that the lime still amounts to an equivalent. In some cases however the carbonate of magnesia predominates: and an example of a dolomite with an excess of magnesian carbonate, has been lately described by Prof. G. F. Barker from rocks supposed to belong to this series in Brandon, Vermont. It gave to analysis carbonate of lime 40·38, carbonate of magnesia, 51·40, carbonate of iron 3·67, insoluble, quartz, etc. 3·44 = 99·89. (Geology of Vermont, 769.)

In this rock, after excluding the carbonate of iron, there are about three equivalents of carbonate of magnesia to two equivalents of carbonate of lime; and this composition shows a passage towards the magnesites which are found in this series, and which occasionally contain a little carbonate of lime, probably as dolomite. These rocks have already been described on page 457; where it has been shown that they occur in Sutton in mica-schist, and in Bolton interstratified between steatite and an impure serpentine, which passes into diorite; in both cases, weathering yellow from the presence of a large proportion of carbonate of iron, colored green by a chromiferous mica, and containing a portion of oxyd of nickel. In the latter township, it also occurs in argillite, as a compact uncrystalline rock resembling the magnesian limestones of the region, for which it may perhaps have been mistaken in many different localities. A bed of steatite, stained green with oxyd of nickel, which occurs at the falls of the river Bras, in St. Francis, Beauce, is filled with crystalline grains of carbonate of magnesia. In many other localities however, the steatites of this series contain a ferruginous bitter-spar or dolomite. Magnesites.

The mineral species found in the altered limestones, dolomites, and magnesites of the Quebec group in Canada, are few in number. Among them may be mentioned serpentine, since some of the ophiolites pass into limestones and dolomites. To these may be added small portions of talc, chlorite, and chromiferous mica. Crystals of garnet have been observed in a few localities in the dolomites: and the remarkable locality of chrome-green garnets and crystallized pyroxene, found near the serpentine of Oxford, should probably be regarded as pertaining to the calcareous portion of the series. Iron ores.

The beds of iron ore found in this series consist chiefly of iron slates, composed of fine grains of specular iron, more or less mingled with quartz, and often with chlorite; so that they offer various grades, from a nearly pure compact or micaceous red oxyd, to chloritic and quartzose schists, very poor in iron. They have been noticed on page 245, by the name of specular schists, and are identical with the itabirite of Brazil. Some analyses of these specular schists from Sutton, and from Brome, gave from fifty to seventy per cent. of peroxyd of iron; the insoluble matter being in some parts chiefly quartz, and in others containing an admixture of chlorite. In many cases, the ore takes the form of magnetite, and is imbedded in chloritic slate, or in a chloritic dolomite like that described Itabirite.

on page 613. Both of these ores are known in Vermont, and also in South Carolina, where they occur in the same associations as in Canada, and have been carefully studied by Lieber. These ores sometimes contain small portions of titanium; and the same is true of the massive magnetite which is found in St. Francis, in serpentine. The chromic iron ore also forms beds, which may be looked upon as belonging to the rock-masses of these series. The variable and often considerable portions of alumina and magnesia which occur in combination with the oxyds of chrome and iron in this ore, suggest that the elements of it have been deposited from solution, under conditions somewhat similar to those which have given rise to the oxyds of iron, manganese, and aluminum found elsewhere in stratified rocks. The part which the sulphurets of copper play in the beds of the Quebec group, as described on page 515, is such, that they may be also regarded as forming part of the stratified rocks of this series.

Chrome ore.

The group of rocks just described, is recognized by its mineralogical characters throughout the Appalachian chain. Among its most constant marks are the frequency of serpentines, steatites, and other magnesian rocks, containing chrome and nickel, often with titanium. To this may be added the frequent occurrence of gold with the so-called talcose schists of the series, sometimes in veins, but occasionally disseminated, like the copper, in beds. Similar mineralogical associations occur in California, where serpentines and magnesites, with both chrome and nickel, occur, resembling those of Canada. Serpentines and steatites of like characters occur in Newfoundland; and beyond the sea, in the Highlands of Scotland, in a series of rocks resembling those of the Notre Dame Mountains. In Norway, what is called the schistose division of the Primitive Slate formation, as developed about Drontheim and in the Dovrefield Mountains, exhibits a marked correspondence with the crystalline strata of the Quebec group, as shown by Mr. Macfarlane in his memoir already referred to on page 586. These rocks are, by the Swedish geologists, placed at the base of the Silurian series; into the fossiliferous strata of which, according to Keilhau, they appear to graduate, through a series of slates and sandstones. The similar strata in Scotland are by Murchison and Ramsay regarded as Silurian, and as newer than the oldest fossiliferous strata. Mineralogical associations like those of the Quebec group, are met with in strata in Cornwall, in the Vosges, the Alps, and the Urals, and many other regions; but it remains to be seen how far all these strata are of the age of the similar rocks of Norway and of eastern North America.

Higher rocks.

As regards the Upper Silurian and Devonian rocks of the eastern district, little can at present be added to the facts already detailed in the sixteenth chapter. On the Chaudière and St. Francis Rivers, and their tributaries, and on Lake Memphramagog, these rocks are seen in an altered condition; and, as described on page 428 and the succeeding pages, they consist of quartzites and feldspathic sandstones, interstratified with argillites, and with micaceous schists. In one place, strata abounding in black hornblende, and containing small garnets, are met with. Occasionally, as on Lake Memphramagog, black calcareous schists are found, containing disseminated finely divided plumbago.

Argillites. The argillites of these upper strata have, in some parts, the character of roofing slates. One of these, from the township of Westbury was greenish-blue in color, with a silky lustre on the cleavage surfaces. It was translucent on the edges, and had a specific gravity of 2·77. Its analysis gave silica 65·85, alumina 16·65, protoxyd of iron 5·31, lime ·59, magnesia 2·95, potash 3·74, soda 1·31, manganese, traces, volatile 3·10 = 99·50. A variety of argillaceous rock on Lake St. Francis is dark bluish-grey, earthy in texture, and has an imperfect slaty cleavage. It contains crystals of andalusite, which vary from one twentieth to one fourth of an inch in diameter; besides small scales of a black micaceous mineral, irregularly disseminated, and in no particular plane. In this locality, the andalusite is only seen near to a mass of intrusive granite; but elsewhere in the vicinity, it appears to be a result of regional metamorphism. Andalusite.

The altered limestones of this series are often micaceous, and sometimes fissile from the presence of thin films of brownish or yellowish mica between the layers. In some parts of their distribution, they become interstratified with micaceous schists, which are themselves calcareous: and in their southward extension, these rocks constitute the calcareo-micaceous slate formation of the Vermont geologists. The limestone strata at Dudswell are characterized by the fossils enumerated on page 433. These, which are sometimes nearly black in polished sections of the stone, are imbedded in a yellow crystalline magnesian limestone. In other beds, the structure seems to show that thin layers of a grey fossiliferous limestone have been broken, and cemented with the yellow magnesian paste, which itself sometimes forms layers half an inch in thickness. Analysis shows that the fossils, and the grey limestone which frequently envelops them, are nearly pure carbonate of lime. The yellow magnesian portion, on the contrary, gave on analysis, carbonate of lime 56·60, carbonate of magnesia 11·76, carbonate of iron 3·23, insoluble 26·72 = 98·31. This, however, contained a mixture of dolomite and of carbonate of lime; and on treating the rock with cold dilute acetic acid, the latter was removed, together with 4·0 per cent. of carbonate of magnesia. The residue, treated with dilute hydrochloric acid, left undissolved 52·0 per cent. of sand and pyrites; and the soluble portion consisted of carbonate of lime 51·75, carbonate of magnesia 35·73, carbonate of iron 12·52; being a very ferruginous dolomite. These limestones have been polished as marbles. In the arrangement of their colors, they resemble the Portor marble from Italy, which is like Magnesian limestones.

them in composition; the black parts in this also being a nearly pure limestone, while the yellow veins are a ferruginous dolomite.

Mineral veins.

The veins of infiltration and segregation which are found in the eastern district have already been noticed in the previous portion of this volume. Those which contain feldspar, with quartz and mica, are described on page 476; and others, in which quartz and bitter-spar are the gangue of sulphurets of copper, on pages 257 and 515. Small veins of calcite, purple fluor-spar, and galena, occur in the black slates at Quebec; and a vein of heavy-spar is found in serpentine, on the river Bras, in St. Francis, Beauce. All the above, so far as known, are confined to the strata of the Quebec group; but veins of quartz, sometimes holding ores of arsenic, zinc, lead, silver, and gold, are found, both among the rocks of the Quebec group and the argillites of the Upper Silurian and Devonian series. The quartzites and micaceous schists of the same series hold other quartz veins, containing ores of copper, with mica and crystallized apatite (see pages 437 and 517). The veins of calcite holding galena, which have been described at page 400, as occurring in the Gaspé limestones, may also be mentioned in this connection.

ROCKS OF THE WESTERN PALÆOZOIC DISTRICT.

It has already been explained that in the western district of palæozoic rocks, are included those to the west and the north of the great line of break, which brings up the lower rocks that form the western portion of the eastern district. The Upper Copper-bearing rocks of Lake Superior, which are regarded as the equivalents of these last, are however excluded from the present description of the western district, which comprehends all the formations from the Potsdam to the Portage and Chemung group, both inclusive, as they have been described in preceding chapters of this volume.

The strata of this great district have nowhere been exposed to violent undulations, and are for the most part nearly horizontal. They are everywhere unaltered, except in the immediate vicinity of some of the intrusive masses, which abound in the eastern part of the district. The strata are moreover generally impregnated with soluble saline and alkaline salts, and give rise to great numbers of mineral springs, whose history and relations to the different groups of strata have been discussed in a preceding chapter. It is proposed in the following pages to notice the most important chemical and mineralogical facts in the history of these various formations, taken in ascending order. The observations of the New York geologists, and the more recent and important chemical researches of Mr. J. D. Whitney and others, on the palæozoic rocks of Michigan, Iowa, and Wisconsin, will also be referred to in this connection.

The Potsdam formation, which appears at the base of the series, is in this western division, for the most part, a pure quartzose sandstone, or hard vitreous quartzite, made up of sharp, angular grains. Occasionally it is feebly coherent, and crumbles to sand at the outcrop; and not unfrequently it is a conglomerate, holding pebbles of quartz, grains of feldspar, or, more rarely, fragments of green and black shale. In many localities, it is so pure as to be fitted for the manufacture of glass; while in some parts, it is colored red by oxyd of iron, which occasionally appears in the form of little masses and layers of red hematite, as described on page 93. Some beds of the sandstone contain small portions of carbonate of lime, or are magnesian, indicating a transition to the mineralogical characters of the overlying division, to which the name of the Calciferous formation is given; although, as has already been described, its lower part is chiefly a bluish-grey crystalline dolomite, often slightly ferruginous, and weathering yellowish-brown. It generally exhibits small geodes, filled, for the most part, with calcite; but in some parts lined with quartz crystals, or holding crystallized sulphates of baryta and strontia, or more frequently gypsum, as described on page 459. The upper portion of this series is a calcareous argillite, sometimes curiously concretionary in its structure, as noticed on page 113. The dolomite of this formation at Mingan is nearly pure. A variety from Beauharnois, which holds masses of gypsum, and is shaly, contains a considerable amount of insoluble matter. A specimen of the compact bluish-black dolomite from Rigaud, holding masses of calcite, gave carbonate of lime 33·70, carbonate of magnesia 27·00, oxyd of iron and alumina, by loss, 2·40, sand and clay 36·90 = 100·00.

Potsdam formation.

Sandstone.

Calciferous formation.

Dolomite.

Gypsum.

The Chazy formation includes in its lower portion a considerable amount of shales and sandstones, together with impure magnesian limestones; but towards the summit pure limestones prevail. This formation is thus, lithologically, a passage from the silicious and magnesian rocks beneath, to the pure limestones of the Trenton group. Geodes of calcite and of sulphate of strontia, which characterize the rocks of the Calciferous formation, are met with in strata supposed to belong to the Chazy at Kingston, and in its vicinity (page 459); and the argillaceous magnesian beds at Nepean, used for the fabrication of the Hull hydraulic cement, are also geodiferous. A specimen from this locality gave to the analysis of Delesse, carbonate of lime 45·30, carbonate of magnesia 12·77, alumina and oxyd of iron 12·52, insoluble argillaceous residue 19·77, water and loss 9·64 = 100·00.

Chazy formation.

The dark colored compact fossiliferous limestone of the Chazy formation near the St. Lawrence toll-gate, Montreal, contains between its beds, thin interrupted layers, occasionally an inch or more in thickness, of a yellow crumbling material, which holds great numbers of fragments of encrinal stems. The analysis of a portion of this matter, from which the fossils had been separated, gave carbonate of lime 40·95, carbonate of magnesia 24·19, carbonate of iron 27·03, silicious sand 9·01 = 101·18. This is evidently a very ferruginous dolomite in a state of partial decomposition. A portion of the grey limestone, about an inch from the magnesian layer, yielded 18·4 per cent. of insoluble argillaceous matter, and only 1·09 of carbonate of magnesia. Other reddish, pulverulent layers, among the strata of this locality, contain carbonate of lime with a large amount of hydrous peroxyd of iron, but no magnesia. Such a material in one instance forms the cement of a breccia of fragments of dark blue limestone. It was perhaps originally a double carbonate of lime and protoxyd of iron, now partially decomposed. In some of the black fine grained beds in the vicinity, the organic remains are replaced by a coarsely crystalline yellow-weathering dolomite, which forms a solid mass having the external form of the fossil. This rock, which is nearly free from magnesia, dissolves in hydrochloric acid with evolution of a little sulphuretted hydrogen, and leaves an argillaceous residue, mixed with pyrites, and colored with a carbonaceous matter.

Dolomitic fossils.

Trenton group.

These dolomitic casts of fossils are also found in the same formation at Mingan, and in the limestones of the Trenton group at Ottawa. Here the limestone is compact and dark bluish-grey. It gave by solution in acids, 3·9 per cent. of clay and sand, and 0·6 per cent. of oxyd of iron with alumina, without any magnesia. The fossil casts are those of the interior of species of *Orthoceras*, *Pleurotomaria*, *Murchisonia*, and perhaps other genera. They are very abundant, coarsely crystalline, and bluish-white within; but on the weathered surface of the rock they appear in high relief, and are weathered to a reddish-brown. Dilute acids remove the limestone matrix, and the fossil is then seen to be in many cases but partially replaced by the dolomite. That portion which was uppermost in the stratum is often filled by the limestone, in some instances to the extent of one third or one fourth of the whole, while in other specimens the entire mould is filled with dolomite. Both here and at Montreal small veins of dolomite, no thicker than paper, are found cutting the rock, and running from the fossils. In the interior of some of the larger casts, are found drusy cavities lined with crystals of dolomite and of quartz. An analysis of a specimen from this locality has been given on page 457. The limestones of the Trenton group moreover contain, in other localities, small concretions or grains of a yellow-weathering dolomite, which perhaps replace organic remains, and may be seen at Montmorenci Falls, and on the Jacques Cartier River. Apart from these, however, the limestones of this group, so far as examined, are nowhere magnesian. That from Ottawa, as just stated, gave no trace of magnesia on analysis. I is a fine grained, almost black limestone, from Ste. Rosalie, near St. Hyacinthe, yielding a very pure lime; and II is a coarser grained limestone from the same vicinity, which is penetrated by seams of shale and grains of pyrites,

Limestones.

and gives an inferior lime. It is not certain whether these specimens belong to the Chazy or to the Trenton group.

	I.	II.
Carbonate of lime	97·65	75·60
" magnesia,	1·05	1·00
Oxyd of iron and alumina,	·20	1·50
Insoluble,	1·30	22·00
	100·20	100·10

The first of these limestones, when gently ignited, became nearly white, and lost only ·3 per cent. of its weight. When dissolved in hydrochloric acid, it gave off a trace of sulphuretted hydrogen.

The insoluble portion of these limestones is generally a very fine argillaceous matter, with a large proportion of silica and potash, and approaches to orthoclase feldspar in composition. The analysis of the residue from a specimen of the Chazy limestone from Montreal is given on page 582. The compact brown limestone from Paquette's Rapids, which holds silicified fossils, left on solution 7·0 per cent. of impalpably fine feldspathic matter, with a few grains of pyrites, which were separated by nitric acid. The residue gave to dilute soda ley, traces only of silica ; and after ignition, it yielded by an incomplete analysis, silica 77·2, alumina 15·2, and potash 3·5 = 95·9. In an examination of the buff-colored magnesian limestone which lies at the base of the Trenton formation in Wisconsin, Mr. Whitney obtained twenty-two per cent. of insoluble matter, whose analysis gave silica 63·7, alumina 14·7, peroxyd of iron 3·5 ; the remainder being alkalies, chiefly potash, with a little magnesia. A dove-colored limestone of the Black River formation, from Lake Couchiching, is fine grained, homogenous, compact, with a conchoidal fracture, is translucent ont he edges, and resembles in aspect some hornstones. It is a nearly pure carbonate of lime, containing however 1·27 per cent. of carbonate of magnesia, and 1·17 per cent. of insoluble matter, of which ·8 per cent. is soluble silica. Insoluble matter.

The limestones of the Chazy and the Trenton groups almost always give off a characteristic odor of bitumen, when struck or dissolved in acids ; but the bituminous matter in these is generally very minute in quantity. In some cases, however, mentioned on page 521, its amount is more considerable. Small grains of pyrites, of yellow blende, and of galena, are found in many localities disseminated in these limestones.

The upper portion of the Trenton limestone becomes interstratified with thin layers of black shales, which form a transition to the black pyroschists of the Utica formation. Similar black bituminous shales are interstratified a little higher up in the series, among the grey and green shales and sandstones which constitute the Hudson River formation. These black shales, in Canada, are highly calcareous, and often pass into impure limestones. Utica formation.

Of two specimens of this kind from Collingwood, one gave to dilute acids fifty-three, and another fifty-eight per cent. of carbonate of lime, with a little magnesia and oxyd of iron. The insoluble snuff-brown argillaceous residue from the former, when ignited in a close vessel, gave off 12·6 per cent. of volatile combustible matter, leaving a coal-black carbonaceous residue, which, when calcined in the open air, lost 8·4 per cent. additional, and became ash-grey. The insoluble residue from the second specimen was digested for some time with heated benzole, which took up from it about one per cent. of a solid brown bituminous matter. It then no longer gave the odor of bitumen when heated, but a smell like that of burning lignite. The matter, which had thus been treated with benzole, still gave by ignition, 11·8 per cent. of volatile and inflammable matters. It was not attacked by a boiling solution of caustic soda. Portions of this shale, when distilled in close vessels, give from four to five per cent. of oily and tarry matter, besides combustible gases and water.

Pyroschists. A series of careful analyses of various specimens of these pyroschists from the Utica formation in Canada, were made by Messrs. Chandler and Kimball, for Prof. J. D. Whitney, and are published by him in the Report on the Geology of Wisconsin, vol. i, p. 184. I is a blackish-brown, very fine-grained rock, from Cape Smith, Lake Huron. It has a somewhat conchoidal fracture, is not schistose in its structure, and contains no traces of fossils. II is from an island to the north of Maple Cape, and is blackish-brown, fine grained, and earthy in texture, with a laminated structure, and contains no fossils. III is from Ste. Anne, Montmorenci, and is dark brown, shaly, and contains graptolites. IV is from Gloucester, and is a black shale filled with fragments of trilobites and crinoids. In these analyses the carbonates of lime and magnesia, with the alumina and oxyd of iron, were removed by solution in acids, and the elements of the organic matter determined in the insoluble portion.

	I.	II.	III.	IV.	V.
Clay and sand,...........	38·45	34·60	37·26	48·27	73·57
Carbon,.................	6·83	6·63	·61	6·99	15·03
Hydrogen,...............	·74	·77	·83	1·13	1·65
Oxygen,.................	3·20	2·96	1·71	3·39	5·39
Carbonate of lime,........	45·02	49·31	52·60	20·30	1·29
" magnesia,...	2·09	2·53	3·42	11·48	·76
Alumina and oxyd of iron,.	2·16	2·09	3·29	7·99	2·79
	98·49	98·89	99·72	99·55	100·48

The analysis V in the above table is that of a pyroschist from this formation, in the lead region of Wisconsin. It was dark chocolate-colored, weathering greyish-white, and showed no trace of fossils. It is chiefly silicious, containing only small amounts of carbonates, but is very rich in carbonaceous substances, and gave by ignition in a close vessel, 14·12 per cent. of volatile and combustible matters, leaving 6·84 per cent. of carbon, which was removed by calcination in the air. The amount of carbon in these shales is in no way proportionate to the darkness of their hue, and the organic matter in them is very light colored. This is evident in a yellowish-brown silicious shale examined by Whitney, which contained eleven per cent. of combustible substances; and in another similar rock, yielding over sixteen per cent. which was light yellowish-brown, becoming of a bluish-ash color on exposure to the air. Both of these rocks contained minute fossils, chiefly Lingulæ; and they blackened when exposed to heat, burning with a bright flame. The experiments of Dr. C. F. Chandler, show, on the contrary, that the black, glazed, and apparently highly carbonaceous shales from the valley of the Hudson River, which probably belong to the lower rocks of the eastern district, contain from one half to one per cent. of fixed carbon, but yield no volatile combustible matters. (Geology of Iowa, vol. i, 359.) The source of the hydrocarbonaceous substance which exists in these pyroschists, in a form entirely distinct from bitumen, and in a rock of a marine formation, is not easily determined. It may arise from the decomposition and complete disintegration of either animal or vegetable remains, and seems to be not unlike in its nature to vegetable mould. Organic matters.

The Silurian rocks of the West examined by Hall and Whitney, present some interesting points of comparison with those of Canada. The Potsdam and Calciferous formations are there, as here, represented by great alternations of quartzose sandstones and dolomites, occasionally holding green-sand (page 488), and terminated by a buff-colored magnesian limestone, which is regarded as the representative of the Chazy, Birdseye, and Black River formations. A specimen of dolomite from this part of the series on the Escanaba River contains an excess of magnesian carbonate. Its analysis gave to Whitney, carbonate of lime 25·28, carbonate of magnesia 32·77, the remainder being chiefly silicious sand (Geology of Lake Superior, ii, 193). The blue limestone, which there represents the Trenton formation is, however, like the same rock in Canada, a pure limestone, but is overlaid by the Galena formation, which is the great lead-bearing rock of Iowa and Wisconsin. This is a pure dolomite, which in some localities seems to pass into the Trenton limestone, and which has no representative in Canada. It is there overlaid by the Utica and Hudson River formations, with their pyroschists just noticed, which are much less calcareous than the same strata in Canada. Galena formation.

The strata of the Hudson River formation in Anticosti are made up almost entirely of limestones; and they are there followed by a series of pure limestones, interstratified with small quantities of shaly and argillaceous rocks, which make up the Anticosti group. The lower portions of this are represented in Western Canada and New York by sandstones and red Anticosti group.

and green shales, which constitute the Medina and Clinton formations. These red shales include in one part a band of fossiliferous red hematite; and at the base of the latter formation on Lake Huron is a considerable mass of dolomite, holding silicified fossils.

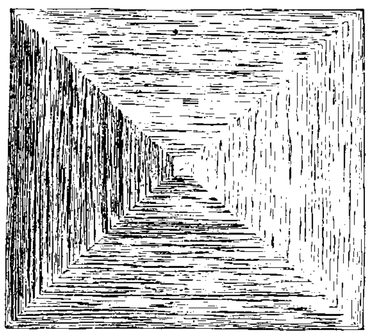
Niagara formation. The beds at the base of the Niagara formation, which at Thorold yield a hydraulic cement, contain but little magnesia; but the great part of the formation is dolomitic. It holds nodules and masses of chert in abundance, and, as already described, contains small quantities of the sulphurets of lead and zinc, together with geodes holding bitter-spar, calcite, fluor-spar, and sulphates of baryta and strontia, with anhydrite and gypsum. Dolomites. Small portions of the latter mineral are occasionally met with in the Medina formation, and even among the shales of the Hudson River formation on Lake Huron. They seem to be the precursors of the great development of gypsum which occurs in the Onondaga formation. A portion of the pearl-spar from Niagara Falls was found on analysis to contain carbonate of lime 55·3, carbonate of magnesia 40·9, carbonate of iron 3·4 = 99·6.

Guelph formation. Succeeding to the Niagara formation is that of Guelph, which seems to be in all cases a pure dolomite, and is frequently made up of brilliant crystalline grains, which under a lens are seen to have a characteristic pearly lustre. The rock is generally porous, cellular, and exhibits small cavities lined with crystals. The organic remains, which were common in this formation, have in most cases been removed by solution. In many cases, as described on page 338, the shell has been simply enveloped in the rock, and has left only a cavity corresponding to its exterior. At other times, the interior of the shell was also filled with the dolomite; so that the cavity corresponds only to the thickness of the shell, of which the markings of both the interior and exterior surfaces are preserved.

More rarely, the cavities thus formed have been filled up with calcareous matter, apparently replacing the substance of the shell; and in one place, great numbers of encrinal fragments have become replaced by a white sparry dolomite, whose color contrasts with the yellowish hue of the base. This last rock, which came from Strange's quarry, Rockwood, was however, like the others, cellular, and a pure dolomite. It was submitted to analysis, with another specimen without fossils, from the same locality, a third from Howitt's quarry, Puslinch, and a fourth from McDonald's quarry, Guelph. The first and second gave respectively ·90 and ·65 per cent. of insoluble sand, while the others dissolved without remainder. All of these were pure dolomites, yielding from fifty-three to fifty-four per cent. of carbonate of lime, with traces of oxyd of iron.

To the Guelph dolomite succeeds the Onondaga formation, which has been minutely described in the thirteenth chapter, both with regard to its distribution, and to its mineralogical and lithological characters. The absence of organic remains, the interstratified beds of gypsum, the beds of dolomite marked by prismatic and hopper-shaped forms; with others filled with thin, lenticular crystals of calcite, whose loss gives to the weathered surface a curiously fissured appearance, have all been noticed; as have also the vesicular cavities in certain beds of dolomite, forming the vermicular lime-rock of Vanuxem. These cavities, in the recently fractured rock are found to contain pulverulent carbonate of lime, whose removal gives to the weathered surface its carious appearance. The hopper-shaped impressions, which are supposed to have been formed by crystals of common salt, have since been found between two beds of this series, near York. In a specimen from this place, from which the accompanying figure is drawn, are other similar depressions, not more than half an inch in diameter. Onondaga formation

453.—HOPPER-SHAPED MOULD IN DOLOMITE.



From the lower bed. Natural size.

After referring to the descriptions already given, it will be sufficient to give the analyses of some argillaceous dolomites of this series, which are sometimes employed for the fabrication of hydraulic cement. The first two are by Delesse: I is a dark grey earthy rock, from Martindale's gypsum quarry at Oneida; II is a specimen of the vesicular dolomite, brownish-yellow in color, from the gypsum quarries at Paris, on the Grand River; and III is a greenish crumbling shaly rock from the same locality.

	I.	II.	III.
Carbonate of lime,..............	39·91	51·33	25·20
" magnesia,..........	34·15	40·91	19·70
Argillaceous residue,...........	22·10	5·50	52·20
Water,........................	3·84	2·26	2·90
	100·00	100.00	100·00

The argillaceous matter in the first of these dolomites was attacked by hydrochloric acid; which dissolved 6·25 per cent. of alumina, with a little peroxyd of iron.

Soda in limestones.

The great mass of strata, from the Clinton to the Onondaga formation inclusive, in Western Canada, is thus magnesian, and, for the most part, approaches to a pure dolomite: the same fact has been observed by Mr. Whitney throughout these formations, as far to the westward as the Mississippi River. In his numerous analyses of the various limestones and dolomites from this region, he generally obtained a small proportion of soda; which apparently exists in the rocks in a form insoluble in water, but readily soluble in acids. Thus in a very pure limestone of the Trenton group from Wisconsin, containing only ·75 of silica and alumina; he obtained ·27 of carbonate of soda; and in a crystalline dolomite from the Galena formation, holding 4·43 of silica, with but small traces of alumina and oxyd of iron, there were found ·38 of carbonates of soda and potash; besides traces of chlorid of sodium, and of sulphate of lime. The alkalies were in part set free by calcination; after which, water removed ·090 per cent. of carbonate of potash, and ·054 of carbonate of soda. Still another of these dolomites, which contained 2·46 per cent. of insoluble matter, but gave to acids not a trace of alumina, yielded ·26 of carbonate of soda, besides traces of chlorids. A limestone from the Niagara formation, which contained 4·16 of insoluble matter, and 1·01 of soluble alumina and oxyd of iron, gave ·25 of carbonate of soda, and traces of chlorine and sulphuric acid, without any potash; while another pure dolomite of the same series gave ·35 of carbonate of soda, with a trace of potash. Many other similar observations by Mr. Whitney show the presence of portions of combined alkali in these limestones and dolomites, and may serve to throw light on some facts in the history of mineral waters.

Dolomitic conglomerate.

Resting upon the Lower Silurian and Laurentian rocks, in the vicinity of Montreal, there occur several small areas of dolomitic conglomerate; which appear to overlie, and to include, masses of pure limestone belonging to the Lower Helderberg group. These conglomerates have been noticed on page 355, and it only remains to describe some of their chemical and mineralogical peculiarities. That of St. Helen's Island contains pebbles of shale, chert, and sandstone, besides the included masses of limestone; the whole mingled with silicious sand, and cemented by a ferriferous dolomite into a very tough greyish, yellow-weathering rock. By the action of acids, there were taken up from a portion of the matrix, forty-six per cent. of soluble matter, leaving a residue of sand. The soluble part consisted of carbonate of lime 57·8, carbonate of magnesia 16·4, carbonate of iron 25·8. A conglomerate with a similar cement occurs at Ste. Anne, and another at Mont Calvaire, which holds, besides pebbles of chert and sandstone, fragments of orthoclase, and of a violet-colored triclinic feldspar from the Laurentian rocks, besides portions of black cleavable augite and brownish-black mica. In rolled masses of a similar conglomerate, along the shores of Montreal

Island, large fragments of augite and mica are also seen imbedded, and, more rarely, portions of olivine half an inch in diameter. At the White Horse Rapids, is a similar conglomerate, but with a somewhat greenish base; holding, besides fragments of quartz, argillite, and mica, others of a mineral like obsidian. The cement in all these is ferruginous and magnesian; but some beds of the conglomerate at Mont Calvaire, weather white, and their cement is found to be a pure carbonate of lime.

Corniferc formatioı

Succeeding to the magnesian strata of the summit of the Onondaga formation, is found in Western Canada, the Oriskany sandstone; which, as described on page 360, consists in many parts of chert or hornstone, and forms the base of the Corniferous formation of the Devonian series. This formation is a pure or non-magnesian limestone, which abounds in fossils, and is remarkable for the abundant beds and masses of hornstone, to which it owes its name, and for the liquid and the solid forms of bitumen which it contains. These have been described in detail in the seventeenth chapter, commencing at page 522.

Hamilton formation

Pyroschis

To these limestones succeed, in Western Canada and New York, the shales, marls, and impure limestones of the Hamilton formation, terminated by the black pyroschists or shales of Bosanquet, described on page 387; which are supposed to be the highest palæozoic strata in Western Canada. A specimen of the schist, by ignition in a covered crucile, lost 12·4 per cent. of volatile and inflammable matter, and left a black residue, which was not calcareous. Another portion, in fine powder, was digested for several hours with heated benzole, which dissolved ·8 per cent. of bituminous matter. The residue, carefully dried at 200° F., then gave off by ignition in a close vessel, 11·3 of volatile matter, and by calcination lost 11·6 more; equal to a total of 23·7 per cent. of combustible and volatile substances. The calcined residue was grey in color. By distillation in an iron retort, there were obtained from the shale, in two experiments, 3·7 and 4·2 per cent. of volatile liquid hydrocarbons; besides a large quantity of inflammable gas, and a portion of ammoniacal water.

Lithologicı resemblances.

These pyroschists, which closely resemble those of the Utica and Hudson River formations, are supposed to correspond to the Genesee slate of New York. At the base of the Hamilton formation in that state, is still another band of pyroschists, resting upon the limestones of the Corniferous formation. It is worthy of notice, that the Upper Silurian and Devonian rocks of this region present a lithological succession which resembles that of the Lower and Middle Silurian. In the two series, the Potsdam formation may be compared with the sandstones at the base of the Medina, while the dolomites of the Calciferous, and the lower part of the Chazy, with their accompanying minerals, are paralleled by those of the Clinton, Niagara, Guelph, and Onondaga formations. The pure limestones of the Trenton group, holding chert, silicified fossils, and petroleum, are repeated in the Corniferous formation; while the shales and pyroschists which follow the latter, resemble lithologically those of the Utica and Hudson River formations. The sandstones and conglomerates which succeed to the latter, represent, on a smaller scale, those of the Upper Devonian.

Hornstone. The chert or hornstone which is found in the various formations of the palæozoic series, has been repeatedly referred to. It occurs in rounded or lenticular masses, or in interstratified beds, generally in the limestones, and seems to correspond to the flints of the chalk, or to the beds of buhrstone in other formations; being evidently chemically deposited silica (page 574). Chert abounds in the limestones of the Birdseye and Black River division of the Trenton group, both near to Ottawa and in the vicinity of Montreal, where it is sometimes found in interrupted beds, and in masses of two or three inches in thickness. It is often nearly black in color, very brittle, conchoidal in fracture, and with a somewhat resinous lustre.

Deposits of the nature of chert are not however confined to the limestones. A jasper-like rock, two beds of which, respectively of six and eight feet, occur interstratified with the arenaceous shales of the Hudson River formation, near Cape Rouge, is probably nothing more than a chert, enclosing portions of argillaceous and ferruginous matter. This rock has the hardness of quartz, and a density of 2·64–2·66. It is perfectly homogeneous in texture, sharply conchoidal in fracture, translucent on the edges, and varies in color from dark grass-green to blackish-green. It is traversed by veins of calcareous spar. Analyses of specimens from the different beds at Cape Rouge gave as follows:

Jasper

	I.	II.
Silica,	77·50	73·30
Alumina,	8·50	16·30
Protoxyd of iron,	2·70	
Lime,	·73	traces.
Magnesia,	2·35	3·90
Potash,	1·66	undet.
Soda,	1·38	"
Volatile,	4·40	3·80
	99·22	

This rock is but slightly attacked by acids; but on boiling a finely pulverized portion of I, for an hour, with a dilute solution of caustic soda, there were dissolved 20·8 per cent. of silica, and only 1·2 per cent. of alumina; indicating thereby the existence of a large proportion of silica in its soluble modification.

Chert abounds in nodules and layers in the dolomites of the Niagara formation; but it characterizes in an especial manner, the limestones of the Corniferous formation. In these, the chert occurs both in nodular masses, and in interstratified layers of from one to four inches, which in some sections make up a large proportion of the rock. This chert is generally nearly white, or greyish and yellowish in color; opaque, dull, and somewhat earthy in its aspect. The layers sometimes exhibit bands of different shades of color, and the stratification of the limestone is seen to conform to the nodules of chert. Specimens of this substance from the Corniferous formation of central and western New York, have lately been examined by Dr. M. C. White of New Haven, and found to be, like the flints of the chalk formation, rich in microscopic organisms. These are principally Desmidieæ, embracing numerous forms of Xanthidia, besides a few Diatomaceæ, and the spiculæ of sponges. Similar forms have also since been detected in the chert from the Birdseye and Black River limestones. (Amer. Jour. of Science [2], xxxiii, 385.) Closely connected with the subject of these deposits of silica is that of the silicification of organic remains, so often referred to in preceding pages. Silicified fossils are met with in some of the limestones of the Quebec group at Point Lévis; but they are still more abundant in certain limestone beds of the Trenton group at Lake St. John, Montreal, Pakenham, Paquette's Rapids, and elsewhere. Fossils similarly replaced occur also in the dolomites of the Medina and Niagara formations in Western Canada; but they are most abundant in the limestones of the Corniferous formation; some beds of which, as already described in page 366, are little more than a coherent mass of silicified fossils, with a little intermingled carbonate of lime. This silicification is confined to certain layers of the rock; the fossils being often found unchanged in the same bed, half an inch above or below a layer of silicified specimens; and even in these, the replacement is often partial, being confined to a portion of the shell. This is still more remarkable in some of the fossil corals from the Trenton group; where certain portions of species of Receptaculites and of Columnaria are replaced by silica, while other portions of the same specimens are still calcareous. Silicified fossils.

The silica replacing the fossils is most frequently in the form of chalcedony, which often presents a mammillary surface, arranged in the form of several concentric circles around a bead-like and raised portion, which may be a tenth of an inch or even more in diameter. In other cases, the surface is nearly smooth, but still exhibits the peculiar structure of chalcedony. The interior of such shells is sometimes partially filled with crystalline quartz, as may be seen by dissolving the limestone by an acid. In two instances where whorled shells had been fractured, the fissure has been filled up by a tissue of chalcedonic quartz. In the case of a silicified specimen of Stromatopora, it is found, on cutting it in two, and subjecting it to the action of an acid, that the silica is confined to an external crust, and to occasional grains or portions scattered through the calcareous body of the fossil. This observation, together with the fact above mentioned, that the silicification is confined to certain planes, above and Chalc[...]

below which the fossils are unaltered, points to the conclusion that the replacement preceded their envelopment in the rock, and was connected with the presence of dissolved silica in the waters of the time. Mr. A. H. Church has lately shown that when a solution of silica in about one hundred parts of water, containing at the same time carbonic acid, is filtered through fragments of coral, the whole of the silica is taken up by the coral, while a large portion of carbonate of lime is dissolved. Similar results were obtained with shells, but to a less extent, and in this way Mr. Church endeavors to explain the silicification of calcareous fossils, by the solution of the carbonate of lime, and its replacement by silica.*

Quartz. In some of the fossil shells of the Trenton group, the substance of the shell alone is replaced; in other specimens, the internal cavity, instead of being filled with the sedimentary limestone, is wholly, or in part, occupied by crystallized quartz. The silicified fossils are often found in the immediate vicinity of masses of chert; and, in some instances, partially imbedded in it. In those of the Corniferous limestone, of which the corals are remarkable for their beauty and perfection, the chalcedony often constitutes only the exterior of the fossil; the inner part of which is filled with crystalline quartz.

Two classes of limestones. The limestones of the fossiliferous formations of Canada may be divided into two great classes,—those which are made up of calcareous fossils, and those which are apparently chemical precipitates, and have been formed

Organic. without the intervention of life. In describing the Chazy formation, and the Trenton group, attention has been called to the fact that great portions of these limestones are made up of comminuted organic remains; and that certain beds owe their peculiar granular texture to the crystalline structure of the fragments of crinoids and cystideans (pages 125 and 138). Dr. Dawson, in the Canadian Naturalist for 1859, vol. iv, p. 161, has described and figured the results of a microscopical examination of a series of sections of these fossiliferous limestones, from the island of Montreal. According to him, these, when examined with a magnifying power of from ten to twenty diameters, are seen to consist of minute fragments of corals, crinoids, and cystideans, with very small shells, cemented by a transparent crystalline calcareous spar. This, in other cases, is mingled with grains of sand, or portions of clay, and colored by a carbonaceous matter. One variety of the grey limestone from the Trenton group, is chiefly made up of fragments of brachiopodous shells; and, in another bed, according to Dr. Dawson, the fragments of the shells and crinoids are rounded, as if by attrition. He also examined two compact limestones from this series, in which fragments of fossils are imbedded in a fine grained homogeneous and earthy calcareous base.

* Proc. Chemical Society of London, Feb. 6, 1862; Chem. News, vol. v, p. 95; also, L. E. and D. Phil. Mag. (4), xxiii, 95.

The microscopic examination of a more extended series of specimens of the palæozoic limestones of Canada,* while confirming these results, has shown that there are many beds, which, even under powers of from forty to eighty diameters, appear to be made up of a fine grained, confusedly crystalline paste of carbonate of lime, often without any traces of organic structure. Examples of this are seen from the Quebec group, in the limestones of Acton, of Trois Pistoles, and of Point Lévis; the latter being the travertine already described on page 612, and containing, in one part, a few minute organisms. These rocks closely resemble, under the microscope, a fine grained and pure dolomite, without fossils, from the Calciferous formation. The compact brown limestone which holds the silicified fossils at Paquette's Rapids, has a similar structure to these, but is rendered opaque, in parts, by an admixture of clayey matter; while the lithographic stone of Marmora, which, like the last, is from the Trenton group, is still more finely crystalline, and homogeneous. The limestones from the Corniferous formation in Western Canada, exhibit differences similar to those of the Trenton group. A specimen from Walpole is, like some of the Montreal limestones, an aggregation of minute organic remains; others, from Port Colborne and the Saugeen, contain numerous fossils in a fine grained base; while others still, from Dumfries and St. Mary's, are finely crystalline, and can hardly be distinguished from that of Point Lévis. That from St. Mary's contained a few minute spiculæ, apparently organic. Specimens from the Upper Helderberg on the Métis River, and from the Lower Helderberg of St. Helen's Island, were, like those of Montreal, eminently fossiliferous. The limestone from near the Chatte River (page 264), which has an oolitic structure apparent to the naked eye, is seen, under the microscope, to consist of small globes, concentric in structure, imbedded in a base of broadly crystalline spar. A similar matrix, in other cases, encloses grains of sand. It is probable that the pure crystalline marbles of Vermont, and of many other regions, are, like those just described, chemical precipitates from solution; which, in some cases, have been, like modern travertines and tufas, deposits from calcareous springs, but have, in most cases, been formed from sea-water by the reaction pointed out on page 575.

Inorgai limesto

Oolite.

The columnar markings which occur in the limestone of the Trenton group at Marmora have been noticed on page 182, and those in the Niagara formation on page 323. They are also found in the dolomites of the Onondaga and Guelph formations; and in the pure limestones and cherts of the Corniferous, as described on page 346. These peculiar forms were, by Mr. Vanuxem, called epsomites, being ascribed by him to the crystallization of sulphate of magnesia, or Epsom salt, in the soft sediments

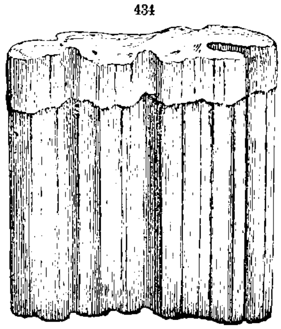
Columi markin

* These specimens were prepared by Edward Murphy, Esq., of Montreal, who has kindly presented a series of them to the Museum of the Geological Survey.

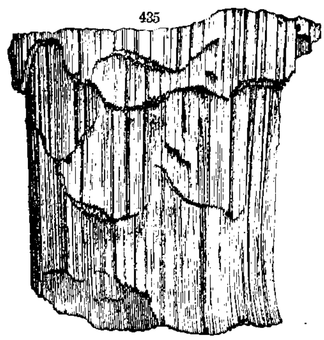
Crystallites. at the time the rocks were deposited; the salt having been subsequently removed by solution, leaving its mould in the sediment to be filled by the succeeding layer. The crystals may however have been of the sulphate of soda, rather than of the magnesian salt.

434, 435.—CRYSTALLITES.

434



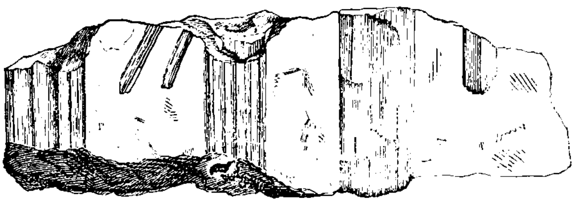
435



434.—Column from the limestone of Kingston.
435.—Column from the dolomite of the Guelph formation. Both of natural size.

Kingston. These curious forms appear to have been first described and figured by Capt. R. H. Bonnycastle, R. E., in an essay on the rocks of the vicinity of Kingston, published in 1831, in the American Journal of Science [1], xx, p. 74. They there occur in the limestone of the Trenton group, penetrating sometimes five or six inches, but, more commonly, only from half an inch to an inch in depth; and are described as consisting of a series of delicate columns or flutings, the minute striæ of which are always parallel to one other, although the columns are sometimes curved, or inclined at various angles to the bed of limestone. The columns are sometimes deeply channelled, and at other times have the form of irregular prisms. Their lower extremities are always rounded, as if by a folding of the ends into a cup, and the layer of shale which covers their surface is there thickened; while elsewhere it is but a thin brown shining film, which adheres either to the column or to its matrix. Around the upper part of the columns shorter ones are often grouped in a way which may readily be seen in the accompanying figure, 434, copied from one given in the paper above cited; the artist having, at the same time, before him other specimens from the same locality. Capt. Bonnycastle, who also figured at the same time a similar specimen from Niagara Falls, does not attempt to decide as to the nature of these columns; but he showed them to consist of limestone, with a thin coating of shale, which he supposed to be the result of infiltration. The explanation of Mr. Vanuxem, that they are the moulds of crystals, seems, in the present state of our knowledge, the most probable one, and supposes a great degree of concentration in the sea-water during the deposition of these limestone and dolomite beds.

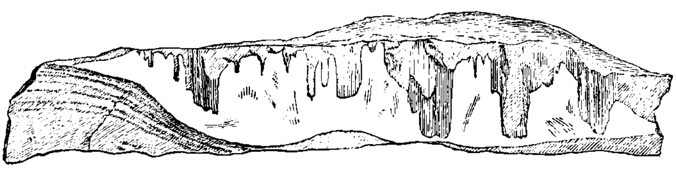
436.—CRYSTALLITES.



436.—Specimen from limestone of the Corniferous formation near Port Dover.

A specimen from the dolomite of the Guelph formation at Rockwood is represented in figure 435. It shows the short columns around the top, and also the slight curvature. The specimens from the Corniferous

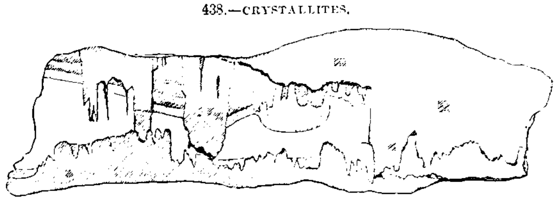
437.—CRYSTALLITES.



437.—Specimen from the same locality, in which the crystallites penetrate a mass of chert imbedded in the limestone.

formation near Port Dover are smaller. The limestone here encloses small beds and lenticular masses of hornstone, in which latter the columns are sometimes impressed. Figure 436 represents a mass of limestone

438.—CRYSTALLITES.



438.—Vertical section of a similar specimen from the above locality, the dotted portion showing the upper and broken layer of the chert.

from this locality, enclosing prisms of various lengths, two of them descending obliquely. Figure 437 represents the columns in a mass of chert imbedded in limestone, the layers of which are seen to conform to the chert. Figure 438 is from a vertical section of another specimen, showing the displacement of a thin layer of chert, which is indicated by a dotted surface, and, lying above the principal mass of this substance, appears as if it had been broken by a downward pressure.

Local metamorphism. The local alteration in the limestone in proximity to the igneous rocks of Mount Royal has already been described on page 582. On Montarville, which consists of a mass of intrusive dolerite breaking up through the shales of the Hudson River group, are seen some interesting results of local metamorphism. Not far from the manor-house is a quarry, where a considerable exposure of altered strata is met with. The rock is here, for the most part, fine grained, compact, and sonorous, somewhat schistose, and holds a few fossil shells. A bed of impure earthy limestone, containing grains of pyrites, is also interstratified. Not far from this, similar strata are again exposed. Some portions are very fine grained, reddish-brown, and having an earthy sub-conchoidal fracture, with occasional cleavage joints. The hardness of this rock is not great, and it is apparently a kind of argillite. Between two beds of this, is one of a coarse grained rock, greenish-grey in color, and mottled with a lighter hue. It appears to be feldspathic in composition, and is penetrated in various directions by numerous slender prisms of black cleavable pyroxene, sometimes half an inch in length. The layers of sedimentation are distinctly marked in this bed, as well as in the finer grained strata which enclosed it; and the whole affords an interesting example of the different effects of the same agency upon beds of unlike composition. Still larger prisms of pyroxene were seen in a loose fragment of a similar rock found near by. Large detached blocks of a highly crystalline rock are also met with on this mountain; composed of blackish-green cleavable hornblende, mingled with small rounded masses of a compact bluish-grey mineral, weathering reddish-brown. This was found by analysis to consist of carbonates of magnesia, lime, and iron; the first, apparently predominating. It gave besides, abundant traces of nickel; and the qualitative examination of the hornblende showed the presence of oxyd of chrome. Two varieties of a rock very similar to this in composition and aspect, are said to occur on Rougemont, which is an intrusive mountain of dolerite, like Montarville, and rises through the same formation. One of these is either concretionary or conglomerate in its structure. The paste is a dark greenish crystalline hornblende, which retains its color on the weathered surfaces, while the nodules of buff-colored dolomite become reddish-yellow. Another variety is made up of thin layers of a white crystalline reddish-weathering dolomite, with others of a compact greenish-grey mineral; and others still of blackish-green crystalline hornblende, which, like the other bands, vary from one tenth to one fourth of an inch in thickness, and are sometimes interrupted. Occasionally, the cleavages of the hornblende, which are nearly perpendicular to the beds, are seen cutting through thin layers of the dolomite. A portion of the rock, free from hornblende, was reduced to powder, and effervesced with warm dilute nitric acid; which removed carbonates of lime, magnesia, and iron. The analysis of the soluble portion yielded carbonate of lime 38·9, carbonate of magnesia 31·2, carbonate of iron 29·9 = 100·0. The insoluble residue gave silica 65·40, alumina 10·10, lime ·56, magnesia 2·05, protoxyd of iron 4·80, titanic acid 7·30, volatile 2·20, loss, probably alkalies, 7·59 = 100·00. Minute grains of pyrites in the rock gave traces both of copper and nickel.

In the admixture of ferruginous dolomite, and in the presence of nickel, chrome, and titanium, the stratified crystalline hornblendic rocks of Montarville and Rougemont resemble the sedimentary deposits of the eastern district; but as the rocks just described are not yet known to occur in place on these mountains, farther examination will be required to arrive at a satisfactory conclusion as to their origin.

The shales of the Utica formation in the vicinity of a trap dyke at Point St. Charles (page 208), and near to a mass of intrusive trachyte on a little island above St. Helens, occasionally exhibit small crystals of pyroxene, similar to those of Montarville. In other specimens, crystals having the characters of hornblende have been seen penetrating the altered shales.

In this connection, may be mentioned a remarkable example of local **Syracuse.** metamorphism, which occurs in the Onondaga formation, at Syracuse in New York, and is described by Vanuxem (Geology of New York, vol. iii, p. 109). The strata between two layers of the vesicular dolomite here consist for the greater part of serpentine, which is dark or blackish-green in color, sometimes blood-red, weathering yellowish, and often in a friable and apparently decomposed state. Some portions of the rock are described as containing well-characterized black and white mica, and hornblende; in small accretions of granite and syenite, having all the ordinary characters of these rocks. The adjacent slaty portions of the formation are also hardened and crystalline. A portion of the ophiolite from this **Serpentine.** locality was found to be an aggregate of grains and rounded masses of serpentine, with others of a fine grained pure limestone, imbedded in a greenish-grey calcareous base. The colors of the serpentine vary from blackish-green to greenish-white. It is often translucent, and takes a high polish. Small portions of bronze-colored diallage are occasionally disseminated in the mass. Acetic acid readily attacks this ophiolite, when in powder; and a proximate analysis thus made, gave carbonate of lime 34·43, carbonate of magnesia 2·73, oxyd of iron and alumina ·34, insoluble 62·50. The analysis of the residue of serpentine gave silica 40·67, magnesia 32·61, protoxyd of iron 8·12, alumina 5·13, water 12·77 = 99·30. No traces of nickel or of chrome were detected. The metamorphism is here in an undisturbed region, removed from any known intrusive rocks, and entirely local. This association of serpentine, diallage, and hornblende, wit gypsum and dolomite, in a saliferous formation, recalls the localitie in the Pyrenees where hornblendic rocks are accompanied by gypsum rock-salt, dolomite, and hot springs, in the Tertiary formation. At Syra cuse, as remarked by Vanuxem, there is no evidence of igneous action and hot springs might readily produce the local metamorphism her observed, in a manner similar to that described by Daubrée (page 584).

Metalliferous veins. The veins of segregation, or of infiltration, known to exist among the rock of the western palæozoic district, are few in number. Among them mus be included those which hold galena, sometimes with blende and coppe pyrites, in a gangue of calcite, or heavy-spar, and are generally found tra versing the Laurentian limestones. A vein of this kind in the townshi of Ramsay, however, intersects the Calciferous formation; and, with th others which resemble it, it may therefore belong to a more recent period Small veins of calcite, holding fluor-spar and galena, and traversing th limestones of the Trenton group at Bay St. Paul, have been described i page 161. The numerous veins of trappean rocks which intersect th strata of this region will be noticed in the succeeding chapter.

SOILS AND CLAYS.

A series of analyses of the soils of Canada was made a few years since in accordance with the notion then generally received, that there was suc a direct relation between the chemical composition of a soil and its fertility that its agricultural capabilities could be determined from the results o a minute chemical analysis. The more recent and profound investigation of the first chemists and agriculturists of our time, have however show that this idea is, to a great extent, fallacious. The extreme difficulty o obtaining a specimen of soil which shall represent the mean composition o a field, has been demonstrated by varied and careful trials, in German and elsewhere; and it has besides been repeatedly observed that man sterile and apparently exhausted soils contain in greater abundance th elements supposed to be necessary to vegetation, than other soils possessin a high degree of fertility. The complete chemical and mechanica analysis of a soil can, at best, indicate but a few of the many condition necessary to the healthy growth of plants; so that its use in guiding th farmer is very subordinate; and when its uncertainty and its inadequatenes to the estimation of the minute quantities which affect vegetable growth are considered, its value, as has been well said by an eminent authority, i insignificant.* Boussingault, in his late work on agricultural chemistry, give the following, as the summing up of his protracted experience and study

Soil analyses.

Boussingault's opinion.

* Prof. S. W. Johnson on Soil Analyses. Amer. Jour. of Science (2). xxxii. page 249

"At an epoch not now remote, it was believed that a strict connection existed between the composition and the quality of arable soil. Numerous analyses, however, soon modified this opinion, as too positive; and the sagacious Schübler even sought to prove, in an investigation which has become classic, that the fertility of a soil depends more upon its physical properties, its state of aggregation, its power of absorption, etc., than upon its chemical constitution.

"The physical properties, in my opinion, do not enable us, any more than the chemical composition, to pronounce upon the degree of fertility of the soil. To decide this point with some measure of certainty, it is indispensable to have recourse to direct observation. It is necessary to cultivate a plant in the soil, and ascertain with what vigor it is there developed. The analysis of the plant afterwards intervenes usefully, to indicate the kind and the quantity of the elements that have been assimilated."*

Inasmuch, however, as some of the results of the investigations into the composition of the soils of Canada are not without a certain interest in a chemical and geological point of view, whatever may be their value to the agriculturist, they are here subjoined in a table, on page 640.

The mechanical analysis of the soils was effected by washing a portion, to separate the clay from the sand. From the latter, the coarser material, when present, was removed by sifting. The soils being previously dried at the ordinary temperature, the amount of water was determined by exposing them to a temperature above 300° F., till they no longer lost weight. In the case of clays, which tenaciously retain moisture, the heat was raised as high as was possible without carbonizing the organic substances which might be present. The amount of organic and other volatile matters was then determined by heating to redness in an open vessel, and burning off the carbon, if necessary. The substances removed by a prolonged digestion with distilled water, at the ordinary temperature, were in some instances determined; but in most cases the analysis was confined to the soluble matters removed from the soil by digesting twenty grams of it, for an hour, at a boiling heat, with hydrochloric acid diluted with three or four parts of water. The solution thus obtained, was divided into three parts, in which the soluble silica, the phosphoric and sulphuric acids, and the bases, were determined by the usual methods. The phosphoric acid was separated by precipitating it from the solution, in combination with the alumina and peroxyd of iron, and fusing the dried precipitate with a mixture of carbonate of soda and silica; the phosphate from the solution of the fused mass being subsequently determined in the form of an ammonio-magnesian salt.

Modes of analysis.

* Boussingault, Agronomie, Chimie Agricole et Physiologie, vol. i, p. 283.

I and II are soils from the domain of Mr. Kierzkowski, in the seignior of St. Charles. I is a black mould taken at a depth of eight inches fro the surface, and consisting of sand 49·2, clay 23·4, organic matter 20·8 water 6·6 = 100·00. One hundred parts of this soil gave to distille water ·786 parts of soluble matters, chiefly organic; which by ignition le ·104 of an alkaline residue, containing lime, magnesia, and alkalies. Th watery solution gave ·008 of chlorine, with a small portion of nitrates, an a trace of sulphates. II contained but a trace of vegetable matter, an consisted of sand 56·0, pebbles of gneiss and quartz 8·0, clay 27·8, wate 8·2 = 100·0. One hundred parts of this soil yielded to water ·050 parts of solid matter, which by ignition were reduced to ·0347, and whic contained, chlorine ·0134, sulphuric acid ·00046, lime ·0085, besides mag nesia and alkalies, but no nitrates.

St. Hilaire. III and IV are soils from the farm of Major Campbell at St. Hilaire III is from a tilled field, taken at the depth of six inches, and containe but very little organic matter. It gave sand 3·0, clay, 89·7, water, etc. 7·3 = 100·0. IV was a portion of the underlying clay from a depth o thirty inches. It contained only traces of sand and organic matter, an lost by ignition 15·5 per cent.

St. Dominique. V and VI are from St. Dominique. V is the blue clay from beneath a large peat bog, and consisted of silicious sand, with a little feldspar an mica, 38.0, clay, with traces of organic matter, 59·0, water 3·0 = 100·00 VI is from near the surface of a long-tilled field near the bog, and wa regarded as an exhausted soil. It consisted of sand 46·00, clay 42·2 organic matter 9·5, water 2·3 = 100·0.

St. Hyacinth. VII and VIII are from about two miles south of St. Hyacinth. VII was said to be from a field which had been tilled sixty or seventy year without manure, and consisted of sand 34·0, clay 62·2, organic matte 1·5, water 2·3 = 100·0. VIII was said to be the sub-soil of the same field, from a depth of about two feet, and differs widely in its mechanica constitution from the surface soil. It contained neither sand nor organic matter, and lost only four per cent. by gentle ignition. It held portion of lime and magnesia as carbonates.

Chambly. IX, X, and XI are from Chambly. IX is a reddish clay, taken at a depth of sixteen inches, from a well-tilled field near the village. It contained but a small amount of sand, and traces of organic matter, and gave by ignition 5·5 per cent. of volatile matter. X is an apparently simila soil, from an adjoining field; which had been cultivated with wheat for many years, and was supposed to be exhausted. It consisted of silicious sand, with a little feldspar, 9·0, clay 79·2, vegetable matter 6·8, water 5·00 = 100·0. XII is from an untilled field, on a ridge of light, gravelly soil near to the church. An average portion of it contained twenty per cent. of pebbles and twelve of coarse gravel derived from Laurentian rocks

The portion which passed through a sieve consisted of gravel 75·0, clay 13·7, organic matter 6·1, water 5·2 = 100·0.

XII is from Montreal, and is the soil from a long-tilled field on the farm of James Logan, Esq. It is a clay, containing 13·5 per cent. of silicious sand, mixed with a little magnetic oxyd of iron. Its ultimate analysis gave silica, by difference, 65·53, alumina 13·15, peroxyd of iron 8·50, lime 1·73, magnesia 1·14, potash 1·76, soda 2·35, phosphoric acid ·54, water and organic matter 5·30 = 100·00. Montreal.

XIII is from Ste. Anne de la Pocatière, and is a clay almost entirely free from sand, taken from a meadow at the foot of the hill below the college. The preceding soils, with the exception of XI, from Chambly, belong to the quaternary clays of the St. Lawrence valley. Ste. Anne.

XIV and XV are soils derived from the disintegration of the red shales of the Sillery formation. The first is from St. Jean, Port Joli, and was collected at a depth of four inches, in a field covered with short turf, where the upturned edges of unbroken slates were within a few inches of the surface. The soil was scarcely coherent, and was separated by sifting from the fragments of shale. It was of a deep red-brown color, and contained scarcely any organic matter, except a few fibrous roots. XV is from St. Thomas, and was taken at a depth of six inches, in a pasture where the shales were about a foot from the surface. The disintegration was here more complete than in the last, and the soil was dark red, and strongly coherent. Both of these contained a little oxyd of manganese. St. Jean. St. Thomas.

XVI is from the twenty-eighth lot of the third range of Bastard, and is from an untilled field, where about a foot of very fertile soil rests upon the horizontal strata of the Calciferous formation. It was taken from a depth of six inches, and was a sandy loam, with very little organic matter. Bastard.

XVII and XVIII are soils from Strathmore, near Brantford. The first is from the plains known as the oak openings; and was taken from a depth of eight inches, beneath the sod of an untilled and recently cleared field. A large portion of this soil is finely divided, but cannot be called a clay. It consisted of sand 47·4, finer material 49·2, organic matter 2·4, water 1·0 = 100·0. XVIII is the rich black loam from the alluvial flats of the Grand River, and was taken under similar circumstances to the last. It contained considerable portions of lime and magnesia as carbonates, and consisted of sand 72·0, finer material 20·0, organic matter 6·5, water 1·5 = 100·0. Brantford.

XIX and XX are from the township of Raleigh. The first is from the rich alluvial flats of the Thames, which are covered with from six to ten inches of black loam, resting upon a yellowish clay. This, near to the village of Chatham, was observed to have a thickness of about four feet, and to be underlaid by a regularly stratified sandy loam; while beneath, at a depth of ten feet from the surface, was a tenacious blue clay. The Raleigh.

ANALYSES OF SOILS.

100 parts gave to hydrochloric acid	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Alumina,	4·280	1·440	12·420	4·380	4·520	3·675	2·200	5·200	3·300	undet.
Peroxyd of iron,	3·240	3·780	7·320	6·245	6·440	4·560	5·860	6·840	8·680	4·560
Lime,	1·033	·650	·697	·980	·717	1·008	·756	2·625	·711	·347
Magnesia,	·749	1·036	1·490	1·080	1·122	·687	1·024	2·647	2·310	·888
Potash,	·435	·276	·591	·753	·158	·189	·450	·723	·536	·380
Soda,	·795	·340	·231	·355	·340	·255	·630	·380	·340	
Phosphoric acid,	·557	·215	·390	·474	·152	·342	·189	·252	·418	·126
Sulphuric "	·144	·034	·022	·024	·017	·102	·018	·006	·020	·031
Silicic "	·075	·150	·105	·210	undet.	·270	·135	·210	·180	·080

100 parts gave to hydrochloric acid	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Alumina,	2·935	8·100	10·455	4·755	5·940	6·285	2·090	·915	2·620	4·340
Peroxyd of iron,	5·505						2·520	2·415	5.660	7·090
Lime,	·156	·806	·369	·151	·235	·353	·310	5·200	1·500	1·580
Magnesia,	·409	·632	·503	·183	·504	·330	·456	3·460	1.060	1·030
Potash,	·109	·185	·469	·249	·250	·130	·105	·162	·825	·855
Soda,	·144	·274	·385	·254	·148	·129	·060	·190		·240
Phosphoric acid,	·220	·285	·285	traces	traces	·209	·380	·303	·400	·320
Sulphuric "	·018	·011	·103	·020	·015	traces	·008	·093	·108	·155
Silicic "	·080	·225	·335	·255	·270	·480	·060	·225	·290	·380

2, St. Charles; 3, 4, St. Hilaire; 5, 6, St. Dominique; 7, 8, St. Hyacinth; 9, 10, 11, Chambly; 12, Montreal; 13, Ste. Anne de la Pocatière; 14, St. Jean, Port Joli; 15, St. Thomas; 16, Bastard; 17, 18, Brantford; 19, 20, Raleigh.

soil is one of great richness, and supports a growth of oak, maple, black walnut, and whitewood. The specimen was taken from the seventh lot of the first range, at a depth of six inches, from a recently cleared field, and contained but a trace of white silicious sand. It consisted of clay 83·4, organic matter 12·0, water 4·6 = 100·0. XX is from the seventeenth lot of the first range of the same township, and is the mould from a recently drained portion of the prairie land, which extends from near Chatham to Lake St. Clair. The mould is here a foot deep, and the specimen was taken at a depth of six inches. It contains no sand, but a small amount of carbonates; and consists of clay 80·9, organic matter 13·6, water 5·5 = 100·0.

Some of the quaternary clays of the St. Lawrence valley are calcareous, and effervesce freely with acids. A reddish-fawn colored impalpable clay, from the banks of the Rivière à la Graisse, in Rigaud, was attacked with dilute hydrochloric acid; which dissolved alumina and peroxyd of iron 12·95, lime 3·97, and magnesia 1·92. The ultimate analysis of this clay gave silica, by difference, 52·95, alumina and peroxyd of iron 27·30, lime 5·32, magnesia 2·62, potash 1·26, soda 2·06, phosphoric acid ·74, carbonic acid 3·25, water 4·50 = 100·00. The carbonic acid, which is the mean of two closely agreeing determinations, is very little more than is required to form a carbonate with the lime which is soluble in dilute acids; so that the remaining portions of lime, and the magnesia, probably exist as silicates. A fine blue clay, which is interstratified with the above, gave to hydrochloric acid, lime 2·74, magnesia 2·86 per cent.; while the ultimate analysis gave lime 8·12 per cent., of which a large portion therefore exists as a silicate. A portion of clay was taken, from a depth of eight inches, in an untilled field in the township of Niagara; resting upon the escarpment here formed by the dolomites of the Niagara formation. It contained three or four per cent. of silicious sand, besides some calcareous pebbles. After the separation of these, an analysis by hydrochloric acid gave as follows: insoluble 58·00, carbonate of lime 15·30, carbonate of magnesia 7·68, alumina and peroxyd of iron, with traces of manganese, 13·50, alkaies ·51, phosphoric acid ·09, water 4·70 = 99·78; besides traces of sulphate of lime. Clays. Rigaud Niagara.

A fine marly clay, which occurs at a depth of from five to ten feet from the surface, in and about London, and is seen in the banks of the Thames, near the town, was found to be mixed with limestone pebbles, and to give out a bituminous odor when treated with hydrochloric acid; by which process it yielded, insoluble 57·00, carbonate of lime 29·40, carbonate of magnesia 6.91, phosphate of lime ·39, alumina and oxyd of iron 4·40, water and loss 1·90 = 100·00. It contained no trace of sulphate of lime. Similar calcareous clays have been examined from Delaware, Mosa, and Port Stanley. The above analyses, although imperfect, are not without London.

interest, as indicating the composition of some of the more recent sedimentary deposits of this region. These are probably derived in part from the ruins of calcareous palæozoic rocks.

Peats. The great deposits of peat which abound in the province, will be considered in another chapter, with reference to their economical applications. The composition of some specimens, and the analysis of the ash of one of them, may, however, be given in this connection. Of two specimens from a peat bog in Sherrington, one was fine grained, compact, and so heavy as to sink in water. It gave by incineration only 3·53 per cent. of a light greyish ash, of which the greater part was soluble in hydrochloric acid, and consisted of carbonate of lime, with traces of magnesia and iron, a considerable portion of sulphates, and a little phosphate. A specimen of the lighter peat, from the upper part of the bog, gave 4·66 per cent. of ash.

Sherrington.

St. Dominique. The peat from the bog of St. Dominique was examined by igniting it in close vessels, and determining the loss of vegetable matter. A solid coke was in this way obtained, which left by ignition a light reddish ash. Of two well-dried specimens, a compact one gave fixed carbon 29·30, volatile 63·43, ash 7·27 = 100·00 : and a more porous one, fixed carbon 29·57, volatile 63·68, ash 6·75 = 100·00. The ash from this peat yielded to water a large amount of sulphate of lime, besides portions of alkalies as chlorids and sulphates. The lime and magnesia in the ash were in great part as carbonates, but partly, also, in a free state. One hundred parts gave by analysis, lime 47·040, magnesia 3·150, potash ·330, soda ·254, alumina 2·440, peroxyd of iron 4·680, oxyd of manganese ·040, sulphuric acid 9·175, carbonic acid 23·060, phosphoric acid ·932, chlorine ·247, combined silica 4·920, sand 4·040. These elements being combined in the usual manner, give for 100 parts of the ash, carbonate of lime 52·410, sulphate of lime 15·085, phosphate of lime 2·019, chlorid of sodium ·412, sulphate of soda ·076, sulphate of potash ·605, besides 10·431 of uncombined lime, and 3·750 of magnesia, from the decomposition of the carbonates; these, with the silica, alumina, and metallic oxyds, making up 100·308. The various shell marls which are often associated with the peat deposits in Canada, have, in all cases where they have been examined, proved to be nearly pure carbonate of lime. The chemical history of the ochres and bog iron ores of the superficial deposits of the country, has already been given in the seventeenth chapter.

Peat ashes.

CHAPTER XX.

ERUPTIVE ROCKS.

GENERAL CONSIDERATIONS; ORIGIN; STRUCTURE; COMPOSITION; CLASSIFICATION; DEFINITIONS; GRANITE, ORTHOPHYRE, TRACHYTE, DIORITE, DIABASE, DOLERITE.—INTRUSIVE ROCKS OF THE LAURENTIAN SERIES; DOLERITE; SYENITE; ORTHOPHYRE.—OF THE PALÆOZOIC SERIES.—TRACHYTE; BROME; SHEFFORD; CHAMBLY; MONTREAL; LACHINE; YAMASKA.—PHONOLITE.—DIORITE; YAMASKA; MOUNT JOHNSON; BELŒIL; RIGAUD.—DOLERITE AND PYROXENITE; MONTARVILLE; ROUGEMONT; MOUNT ROYAL.—GRANITES.

Before commencing an account of such of the intrusive rocks of Canada as have been examined, it is proposed to give a few definitions, and to explain the nomenclature which will be followed in their description. This is the more necessary, as much of the obscurity to be found among writers on lithology arises from the great number of names, often nearly synonymous, and from the vague manner in which these are applied. Many of those rocks which have been hitherto described as eruptive, are sediments, which, although altered, and retaining but little evidence of their former condition, are still in the beds in which they were originally deposited. At the time of their chemical metamorphism, they were impregnated with water, and, by the joint action of this and of an elevated temperature, were evidently reduced to a more or less plastic mass. This in some cases is found to have been displaced, and, having forced its way among disrupted strata, to have assumed the form of an intrusive rock; which becoming consolidated under a sufficient pressure, retains the same mineral characters as in its parent bed. This view may probably be extended to explain the origin of every eruptive rock; whose equivalent is thus to be looked for among crystalline strata. It is only those rocks which, like lavas, have become solid near to the surface and under a feeble pressure, that will present characters different from those of the undisplaced crystalline sediments. With these exceptions, then, the only distinction that can be drawn between stratified and unstratified masses must, in most cases, be founded upon their attitude, and their relations to the adjacent rocks. Theoretical views.

In the description of the Laurentian rocks, on page 28, facts are detailed which show that the stratified crystalline limestone of that series was at one time plastic, and, when in that condition, was forced into the fissures of broken silicious strata in the vicinity; thus taking the form of an

Limestones. eruptive rock. In another instance, two beds of crystalline limestone were connected by a dyke of the same rock traversing an intervening bed of gneiss. Other evidences of the softened state of these limestones, and of their accompanying rocks, have also been given above, in the thin interstratified bands both of gneiss and quartzite ; which have been broken, contorted, and even twisted spirally.

The observations of Dr. Edward Hitchcock among the altered strata of the Green Mountains, seem to show, in like manner, that the pebbles of quartz and of gneiss, in certain conglomerate beds, have been at one time so softened, as to have become flattened, laminated, and bent around each other. (Amer. Journal of Science [2], xxxi, 372.)

Similar facts to those mentioned above have induced some geologists to regard even crystalline limestone as eruptive. Serpentine has, in like manner, generally been described by European geologists as an intrusive

Serpentines. rock ; but it has been shown in the preceding chapters, that the serpentines, both of the Laurentian and palæozoic series, in Canada, are stratified rocks of sedimentary origin: although it is not improbable that serpentine may in certain cases, like limestone, assume the form of an eruptive rock. The sedimentary origin of many granites, syenites, diorites, and dolerites, cannot be denied; and hypersthenite, which has hitherto been described as eruptive, occurs in the Laurentian series as a stratified sedimentary rock.

Mineral species. It will, therefore, be proper first to indicate briefly the nature and composition of the various crystalline silicated rocks, and then to describe such of them as occur in Canada in an intrusive form. The mineral species which are essential to the composition of these rocks, are few in number; and consist of quartz, orthoclase, a triclinic feldspar, which may be albite, oligoclase, andesine, labradorite, or anorthite ; leucite, nepheline, natrolite, or some allied zeolite ; garnet, epidote, hornblende, pyroxene, olivine, serpentine, diallage, potash mica, magnesian mica, chlorite and talc. To these may be added the carbonates of lime, magnesia, and protoxyd of iron, together with magnetite. Tourmaline, beryl, zircon, spodumene, and various other minerals are found, with quartz, feldspar, and mica, in certain granitic veins. These, however, for reasons given on page 477, are to be regarded, like metalliferous veins, as the results of segregation, or of infiltration ; and are thus excluded from the present category of rocks.

Structure. The mechanical structure of crystalline rocks is very varied ; and differences based upon this fact have led to a great multiplication of names. First may be noted the granitoid structure, in which the mineral elements are crystalline and distinct, as in ordinary granite. As these become smaller, the rock is granular, and, from this, passes into a compact form, in which the constituent elements cannot be distinguished by the eye : such rocks are sometimes denominated cryptocrystalline. In certain cases, a foliated mineral, like mica or talc, may be so arranged as to give a gneissoid form to a rock; and this arrangement, although generally regarded as an evidence of stratification, has sometimes been observed in eruptive masses. Occasionally the crystallization of a rock takes place around certain centres, giving rise to small rounded masses, which have a radiated or a concentric structure, and form the so-called globular or orbicular rocks. Distinct crystals of feldspar or of augite are often found imbedded in a compact base. To such rocks the name of porphyry is given; and, by analogy, a rock with a granular base, enclosing larger crystals, is designated as porphyritic, or porphyroid. The name of porphyry, at first applied to designate a peculiar type of feldspathic rocks, has now become so much extended, that it must be regarded only as designating an accident of structure. The title of amygdaloid is given to various rocks having rounded cavities, which are wholly or partially filled with various crystalline minerals. Many of these amygdaloids are undoubtedly altered strata, like those described on page 607; while others are as evidently intrusive rocks, the cavities of which have been filled after their eruption.

Classification.

The masses into which some feldspathic mineral enters as a prominent element, constitute by far the greater part of the rocks now under consideration, and are naturally divided into two classes. The first of these is characterized by an excess of silica, with alumina, much potash, and small portions only of lime, magnesia, and oxyd of iron; and the second, by a smaller amount of silica, and larger proportions of alumina, lime, magnesia, and oxyd of iron, with soda, and but little potash. These chemical differences are apparent, in the crystalline rocks, in the nature of the constituent minerals, and in the compact varieties, by differences in color, specific gravity, and hardness. Thus, in the first class, the predominant mineral is orthoclase feldspar, generally associated with quartz: and the compact rocks of this class seldom have a specific gravity much above that of these species, or from 2·6 to 2·7. In the second class, the characteristic minerals are a triclinic feldspar, and pyroxene, or hornblende, the feldspar sometimes being predominant; while in other cases, the pyroxene, or hornblende, makes up the principal part of the rock. The presence of these latter minerals generally gives to the fine grained rocks of this class, a dark color, a hardness somewhat inferior to that of the more silicious rocks, and a specific gravity which may vary from 2·7 to above 3·0. It will however be found that the line between the two classes cannot always be distinctly drawn, inasmuch as rocks containing orthoclase and quartz often include triclinic feldspars, such as albite and oligoclase; and by an admixture of hornblende, offer a transition to the rocks of the second class. On the other hand, quartz is sometimes found with triclinic feldspars and hornblende, in the rocks of this class.

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The rocks in which epidote and garnet replace the feldspars, are related by their chemical composition to the second feldspathic class; and these two classes, by a diminution of the amount of the aluminous element, afford a natural transition to those rocks which consist essentially of silicates of protoxyd bases.

Three groups.

The silico-aluminous rocks may thus be conveniently grouped in three families: first, those in which the aluminous mineral is a potash orthoclase; secondly, those in which it is a triclinic feldspar, to which may also be added those rocks containing nepheline, leucite, and natrolite; and thirdly, those which contain epidote or garnet, in place of a feldspar. It is worthy of note that some feldspars, having the crystallization and the general characters of orthoclase, nevertheless contain a large proportion of soda. This is shown in the analyses of several feldspars from the Laurentian rocks, and from the trachytes of Canada. Feldspars from the trachytes of Germany, similar in composition to these, have been described by the name of potash-albite; but the low specific gravity of the feldspars from the Canadian trachytes, as well as their apparent crystalline form, shows them to belong to orthoclase rather than to albite. The relations in composition between the various triclinic feldspars, including albite, oligoclase, andesine, labradorite, and anorthite, have been defined on page 480. It is to be recollected that in the less dense of the triclinic feldspars, silica and soda predominate; while those of higher specific gravity are richer in alumina and lime, and are more readily attacked by acids, than the former. Thus anorthite, and even labradorite are, when in powder, decomposed by heated hydrochloric acid, with the separation of silica in a pulverulent form.

Various feldspars.

Pyroxene.

Pyroxene or augite, and hornblende, which are essentially silicates of lime, magnesia, and protoxyd of iron, occasionally contain portions of alkali, chiefly soda. Certain varieties of both of these species, especially the black ferruginous pyroxene, to which the name of augite is more particularly given, include large portions of alumina, apparently replacing silica. The composition of these two species is such that they may be represented by the same general formula: and their crystalline forms, as is well known, belong to the same system, and are very simply related to one another. The specific gravity of the different varieties of augite is however apparently greater than that of the corresponding ones of hornblende; from which it is probable that the two species are isomeric, and that the equivalent of pyroxene is more elevated than that of hornblende. These two minerals are not unfrequently found associated in the same rock (page 467). The varieties of pyroxene known as diallage and hypersthene, are sometimes surrounded or penetrated by hornblende; the crystals of the species having, in such cases, their axes parallel. This association of the two minerals in nature has frequently been observed, and should be kept in mind; inasmuch as the substitution of hornblende for pyroxene in feldspathic rocks is

Hornblende.

made the basis of a sub-division in their classification. (American Journal of Science [2], xxvii. 339, xxviii. 185.)

The principal varieties of crystalline rocks may now be mentioned; and for the reasons already given, the eruptive and the stratified masses will be noticed together. Inasmuch, however, as a stratified structure, arising from the arrangement of the constituent minerals may occur in eruptive masses, the sedimentary origin of crystalline stratified rocks in general, is denied by some geologists. On the other hand, certain undisturbed sedimentary masses, from the conditions of their deposition, or from the changes undergone during metamorphism, retain but few traces of their origin. In order to assert that any given mineral masses are sediments crystallized in place, it is proposed to designate them as indigenous rocks; in contradistinction to which, intrusive masses may be called exotic rocks. **Indigenous and exotic rocks.**

The admixture of crystalline orthoclase and quartz, generally with the addition of mica, gives rise to granite. Oligoclase or albite is often associated with the orthoclase, and may be distinguished by its striated crystals, or by its greyish or greenish color. The mica of granitic rocks is sometimes muscovite, and at other times a magnesian mica. These two species are sometimes associated in the same rock, or even in the same crystal, the one surrounding the other, with a common cleavage. Chlorite and talc frequently occur in granite; and the latter, by entirely replacing the mica, gives rise to protogine. Black hornblende often occurs with the mica, giving rise to syenitic granite; or, by a complete replacement of the mica, to syenite. Elæolite, epidote, and magnetite are sometimes met with in granitic and syenitic rocks; and the name of miascite is given to a granitoid mixture of orthoclase and black mica, with elæolite, sometimes with hornblende, albite, and quartz. To this may perhaps belong the elæolite rock from Pic Island on Lake Superior, noticed on page 480. On the main shore of the lake, nearly due north of the western extremity of this island, is a mass of syenitic rock, composed of red feldspar and hornblende, with zircons; which resembles the zircon-syenite of Norway. **Granitic rocks.**

The coarsely lamellar varieties of granite are sometimes distinguished by the name of pegmatite, or graphic granite; while fine grained mixtures of orthoclase and quartz have received the names of granulite, leptinite, and eurite; or where apparently homogeneous, are called petrosilex. This form often becomes porphyritic from the presence of crystals of orthoclase, giving rise to orthoclase-porphyry or orthophyre. In some of these porphyries, as in those of Grenville, about to be described, the quartz is also present in distinct grains; while in some of the red antique porphyries, the base contains no excess of silica, and occasionally holds crystals of oligoclase, or of hornblende. Many of the granites, syenites, and orthophyres, are intrusive; while others, scarcely distinguishable from these, are indigenous, and, becoming schistose, pass into gneiss and mica-schist.

Trachytes. The trachytes, which consist chiefly of orthoclase feldspar, are closely connected with the granites. The typical trachytes are white or of pale colors, granular or finely crystalline, and frequently porous or cellular. They appear to consist of aggregated grains, crystals, or lamellæ of orthoclase, without a cementing medium; and to this appears to be due that roughness to which they owe their name. Occasionally the feldspar becomes coarsely crystalline, forming a granitoid trachyte, and including crystals of hornblende or of magnesian mica. Grains of quartz are also sometimes met with, presenting a transition to granite.

The analyses of some trachytes show the presence of an excess of silica; while in others the proportion of this element is less than in pure orthoclase. It is also to be remarked, that the feldspathic substance of the trachytes generally contains, besides potash, a considerable portion of soda, which has led some to conclude that the feldspar of the trachytes is closely related to albite; while certain varieties are said to contain crystals of oligoclase. The granitoid trachytes of Canada consist, however, of an orthoclase containing a considerable proportion of soda. In many of the so-called trachytic rocks of Hungary and of Guadaloupe, the predominant mineral is a basic feldspar like labradorite; containing large amounts of lime and soda, with but little potash.

Among the trachytes found in Canada, besides the granitoid, compact, and earthy varieties, are trachytic porphyries; of which the base is sometimes compact, and at others crystalline. These trachytes often contain, intimately mingled, a considerable amount of carbonates, chiefly carbonate of lime, and occasionally portions of a zeolite, apparently natrolite, are also diffused throughout the mass. Through this admixture the trachytes pass into phonolite. Trachytes appear to be, in all cases, exotic rocks, and the lavas of many volcanoes of the historic period are trachytic. Obsidian and pumice-stone, which are often associated with trachytes, are related to them in composition; and pitchstone and perlite are similar rocks, differing,

Pitchstone. however, in containing a portion of combined water. Varieties of rocks, having the characters of pitchstone, and sometimes enclosing distinct crystals of feldspar, constituting a pitchstone porphyry, are found on the south side of Michipicoten Island, but have not yet been studied.

From the orthoclase rocks, there is a transition, through admixture of albite and oligoclase, and through trachytes containing labradorite, to those rocks which are characterized by the presence of triclinic or anorthic feldspars, to the exclusion of orthoclase; and which will be described under the names of diorite, diabase, and dolerite. Some of the older lavas of Etna contain, besides oligoclase, augite, and mica, crystals of orthoclase; and the compound rock, as it forms a link between two groups, has been designated trachydolerite. Those rocks which are made up almost entirely of triclinic feldspars, have been described in the preceding chapter, by the name of anorthosites. Most frequently, however, these feldspars are accompanied by amphibole or pyroxene; and through the predominance of these, a passage is afforded to amphibolite and pyroxenite, which are rocks entirely made up of these minerals.

Diorite. The name of diorite is, by good authorities, restricted to rocks whose dominant elements are a triclinic feldspar, with amphibole or hornblende; while the names of diabase and dolerite distinguish those rocks in which pyroxene takes the place of hornblende. As already remarked, however, on page 646, the association of these two minerals in the same rock affords a connecting link between diorite and diabase.

The feldspar of the diorites varies in composition from albite to anorthite, and is occasionally associated with quartz. This, although most frequent with the more silicious feldspars, is sometimes met with in diorites which contain species approaching to anorthite in constitution. The varieties in diorites depend not only upon differences in composition, but in structure. Sometimes the two elements are distinct, and well crystallized, constituting a granitoid rock; fine examples of which are seen in the intrusive masses of Yamaska and Mount Johnson. At other times, the rock becomes finely **Greenstone** granular or compact; when its color is generally of a green, more or less dark, from the disseminated hornblende, and it takes the name of greenstone. The greenstones of the Huronian series are, in part at least, diorites; but a great number of the so-called greenstone traps are pyroxenic, and belong to the class of diabase or of dolerite. Diorite not unfrequently contains mica, which is generally brown or black in color. Chlorite, magnetite, ilmenite, and sphene often occur as disseminated minerals, as also carbonate of lime. The finer grained diorites are very frequently porphyritic from the presence of crystals of feldspar or of hornblende. Occasionally the rock is concretionary in its structure, as in the orbicular diorite, or napoleonite, of Corsica; which contains a feldspar allied to anorthite, with hornblende, and some quartz. The norite from Sweden is a granular mixture of a similar kind, containing also mica; and the ophite of some authors, is a diorite in which hornblende greatly predominates, passing into amphibolite. The altered rocks of the Eastern Townships afford abundance of diorites, occasionally albitic; which pass into anorthosites on the one hand, and into amphibolites on the other. These rocks are there associated with pyroxenites and ophiolites, and are, in great part at least, indigenous.

Diabase. The rocks which are essentially composed of anorthic feldspar and pyroxene, present still greater diversities than the diorites, and have received various names, based upon differences in texture, and in the form of the pyroxenic element. It is here proposed to restrict the name of dolerite to such of these rocks as contain the black augitic variety of pyroxene, and to include the mixtures of triclinic feldspars with all other varieties of this species, under the head of diabase. These two subdivisions agree in the general absence of quartz; and in containing, as occasional disseminated minerals, olivine, epidote, garnet, chlorite, talc, magnesian mica, magnetite, ilmenite, sphene, and carbonates of lime, magnesia, and iron.

The finer grained and impalpable varieties of diabase have received the name of aphanite, which is often indistinguishable from the corresponding forms of diorite; and like these, it may become porphyritic, giving rise to the augite-porphyry of some authors. Different varieties of this have received the names of labradophyre, oligophyre, and albitophyre, according to the nature of the imbedded feldspar crystals. These are sometimes accompanied by crystals of pyroxene, or altogether replaced by them; in which case the pyroxene often takes the form of augite.

Hyperite. The name of hyperite or hypersthenite has been applied to those varieties of diabase which contain hypersthene, or a pyroxene with the form of diallage. These rocks occur abundantly in the Laurentian series, and have already been described in the preceding chapter. The hypersthene in these sometimes takes the form of a green diallage, or of a granular pyroxene, and is associated with mica, red garnet, and ilmenite. In addition to these, epidote is said to occur in the hypersthenites of the same series, in northern New York; and olivine, in those of Sweden and the isle of Skye. Hornblende is also, in some localities, associated with the hypersthene. The hyperites, although indigenous rocks in Canada, are described as forming, in other regions, eruptive masses.

Those varieties of diabase or hyperite which contain diallage, have, by the Italian lithologists, been called granitone; but by Rose and others, they have been described by the name of gabbro. This rock sometimes contains hornblende, mica, and a mixture of epidote; which is generally finely granular or compact, and white, or greenish-white, in color. This compact epidote, or zoisite, which has the hardness of quartz, and a specific gravity of 3·3–3·4, is the true saussurite. With smaragdite, which is an emerald-green pyroxene, often mingled with hornblende, and sometimes passing into diallage, saussurite forms the euphotide of Haüy, from Mont Rosa. The compact varieties of labradorite, and of similar triclinic feldspars, have, by most modern lithologists, been confounded with saussurite; and hence the name of euphotide is frequently given to the so-called granitone or gabbro, which is really only a diallagic variety of diabase. The true euphotide often contains a portion of talc, and sometimes encloses crystals of a triclinic feldspar, apparently labradorite; thus offering a transition to diabase. (Amer. Jour. of Science [2], xxvii, 336.)

Euphotide.

Dolerite. Under the title of dolerite, it is proposed to class those rocks which consist chiefly of feldspar, and of black ferruginous pyroxene, or augite. These rocks, which are sometimes coarsely granular or granitoid in their structure, pass into fine grained or compact varieties, which are distinguished by the names of anamesite and basalt. To the latter varieties **Basalt.** belong a great part of the greenstone traps; although, in rocks of this texture, it is often impossible to determine whether it is hornblende or pyroxene which is mingled with the feldspar. Olivine, in grains and in crystals, occurs both in the fine grained basaltic dolerites, and in the granitoid varieties; giving rise, by its predominance, to what is called peridotite. Some fine grained dolerites are porphyritic, from the presence of crystals of black cleavable augite, and often pass into augite-rock. The carbonates of lime and iron are occasionally present in these rocks to the extent of twenty per cent., or more. In like manner, magnetite and ilmenite, which are often associated in the coarser dolerites, may constitute several hundredths of the mass. Many fine grained dolerites contain, like phonolite, large portions of some zeolitic mineral; and they often abound in chlorite, which seems, in certain cases, almost entirely to replace the pyroxene. Something analogous to this is seen in the greenstones noticed on page 605, whose analysis shows the presence of a basic hydrous silicate, allied to chlorite in composition. The name of melaphyre is often given to certain varieties of dolerite, but there seems no sufficient reason for retaining the term. The fine grained dolerites are often cellular, giving rise to amygdaloid or spilite; the cavities of which are generally filled with calcite, quartz, or some zeolitic minerals. The earthy varieties of basalt, which are perhaps a result of partial decomposition, constitute the wacke of some authors. Both nepheline and leucite occasionally replace the feldspar in dolerite; the latter admixture giving rise to what has been named leucitophyre. Analcimite is a doleritic rock, containing analcime and olivine.

While very many of these rocks occur as intrusive masses, the undoubted indigenous character of at least a great portion of the diabase, makes it probable that a large part of the dolerites have had a similar origin. Those which occur in beds, and were regarded as having been poured out from the earth in a molten state, have come to be regarded, in many cases, as sediments altered *in situ*. Many of the so-called melaphyres, the porphyries, and the spilites of the Alps, once regarded as eruptive, are considered by recent investigators to be indigenous rocks.

The dense aluminous silicates epidote and garnet, and perhaps idocrase, **Garnet and epidote.** give rise to a variety of compound rocks, in which they may be regarded as replacing the feldspars. In the epidosites and the red garnet-rock, already noticed, these minerals occur with quartz; while in euphotide, as above described, a white epidote, or zoisite, is associated with smaragdite. Related to these, is the white garnet-rock described on page 496; in which garnet is mingled with serpentine, or with hornblende and feldspar. In this connection may also be mentioned omphazite or eklogite; which consists of smaragdite and red garnet, sometimes mixed with mica, quartz, and kyanite, and passing, through an increase of the latter, into disthenite or kyanite-rock. The latter occurs in the state of Georgia, as the gangue of crystallized rutile; and mixtures of hornblende and red garnet occur in the Green Mountains in Vermont. Red garnet, with lievrite and some mica, forms a rock in the Laurentian series, as described on page 460. This is evidently related to eulysite, a rock forming strata in gneiss in Sweden, and made up of garnet, augite, and a mineral having the composition of an olivine, in which a great part of the magnesia is replaced by the protoxyds of iron and manganese. Related to this is an apparently undescribed rock from the Tyrol, consisting of red garnet, green pyroxene, and yellowish-green olivine, the latter greatly predominating; and also a coarsely crystalline rock from central France, recently described by the name of cameleonite, and consisting of olivine, with pyroxene, and enstatite, a magnesian augite; these minerals being accompanied by spinel, sphene, and ilmenite. These rocks form a connecting link between some of those just noticed, and the granitoid dolerites containing olivine, which are about to be described. Through the disappearance of the aluminous element, they are related to the amphibolites and pyroxenites; which pass into diorite and diabase on the one hand, and, through diallage-rock, into ophiolite on the other.

INTRUSIVE ROCKS OF THE LAURENTIAN SERIES.

The intrusive rocks of Canada present great varieties in composition, structure, and geological antiquity. Some of them were erupted through the Laurentian series before the deposition of the Lower Silurian rocks, and are among the oldest intrusive masses known. In the county of Grenville there is a considerable area which abounds in eruptive dolerites, syenite, and orthophyre. These have been described with some detail on page 37, and the succeeding pages. The oldest is a fine grained dolerite, numerous dykes of which intersect the crystalline limestone and the gneiss of the Laurentian series. The eruption of this rock was succeeded by that of a great mass of red syenite, passing, through an admixture of mica, into granite. Dykes branching from this rock cut both the gneiss and the dolerite, and are in their turn intersected by others of orthophyre, or quartziferous porphyry, which traverse both the syenite and the gneiss. Nothing corresponding to the syenite, or to the porphyry, is met with among the adjacent Lower Silurian strata; which are seen to repose upon the worn surfaces of these intrusive rocks. A fourth series of dykes of a porphyritic dolerite is however found to cut all of the preceding rocks, and is perhaps identical with some of the dolerites which intersect the Silurian rocks of the island of Montreal. In the other parts of the Laurentian series, so far as yet examined, intrusive rocks have been

Rocks of Grenville.

but seldom met with. Much of what has been called syenite and granite in various parts of this series, seems, like the hypersthenite and other anorthic feldspar rocks, to be indigenous.

Older dolerite.

The most ancient dykes of dolerite or greenstone, from Grenville, are fine grained, dark greenish-grey in color, and weather greyish-white. Under a lens, the rock is seen to consist of a greenish-white feldspar, with a scaly fracture, mingled with grains of pyroxene, occasional plates of mica, and grains of pyrites. It contains no carbonates. Two analyses of portions of the dolerite, from dykes differing a little in texture, gave as follows:

	I.	II.
Silica,	50·35	50·25
Alumina,	17·35	32·10
Peroxyd of iron,	12·50	
Lime,	10·19	9·63
Magnesia,	4·93	5·04
Potash,	·69	·58
Soda,	2·28	2·12
Volatile,	·75	1·00
	99·04	100·72

The iron, although given above as peroxyd, exists in the form of protoxyd; and in the second specimen, in part as a sulphuret. These rocks, which appear to have the composition of mixtures of a basic feldspar with pyroxene, do not differ from ordinary dolerite.

Newer dolerite.

The newer dolerite which cuts the three other classes of eruptive rocks in the Laurentian series, has a greyish-black, very fine grained base, earthy and sub-conchoidal in fracture, and resembling somewhat the preceding. It contains small brilliant black grains of ilmenite, with others of sphene, and small scales of mica. Occasional masses of black cleavable augite, sometimes half an inch in diameter, give to the rock a porphyritic character. It contains, besides, small cleavable masses of white carbonate of lime, with which the whole rock seems penetrated. When in powder, it effervesces freely in the cold with dilute nitric acid, and the solution evolves red fumes on heating. In this way there were dissolved, lime, equal to 8·70 per cent. of carbonate, 0·50 of magnesia, and 6·50 of alumina and oxyd of iron = 15·70 per cent. The residue, dried at 212° F., equalled 83·80 per cent. A portion of aluminous silicate had evidently been attacked by the acid. The dried residue gave on analysis, silica 52·20, alumina 18·50, peroxyd of iron, with some titanic acid, 10·00, lime 7·34, magnesia 4·17, potash 2·14, soda 2·41, volatile 2·50 = 99·26. Except in the somewhat greater proportion of potash, it will be seen that the insoluble portion of this rock differs but little from the older dolerite described above.

Syenite. The intrusive syenite of this region is generally made up of flesh-red orthoclase, and greyish vitreous quartz, with a portion of blackish-green hornblende; which is sometimes almost or altogether wanting. The feldspar is sometimes distinctly crystalline, and cleavable; at other times, it is nearly compact. In some portions, the syenite has undergone a peculiar decomposition, which has reduced it to a soft unctuous greenish matter, having somewhat the aspect of serpentine, or rather of steatite. This change is observed in the vicinity of the remarkable veins of chert, which are here found cutting the syenite, and is more or less complete for a distance of two hundred yards on either side of them. In specimens of this altered rock, the quartz remains unchanged; while the feldspar, still preserving its cleavages, has a hardness no greater than carbonate of lime. It is somewhat unctuous to the touch, with a feeble waxy lustre; and its color is occasionally reddish, but more often of a pale green. Such a specimen was selected for analysis, and gave of silica 80·65, alumina 12·60, lime ·60, soda and a little potash 2·65, volatile 2·10, magnesia and oxyd of iron, traces = 98·60. From this result, it appears that the feldspar of the syenite has lost nearly two thirds of its alkali; the iron and other bases having also for the most part disappeared. This change is therefore in fact a partial conversion of the feldspar into kaolin; and as such a process involves a separation of silica in the form of a soluble alkaline silicate, it is not impossible that this decomposition may have been the source of the chert of this locality; which is nearly pure quartz, approaching to chalcedony in its characters.

Orthophyre. The orthophyre, or quartziferous porphyry, of Grenville, has a fine grained base, which appears to be an intimate mixture of orthoclase and quartz, colored by oxyd of iron, and varying in color from dark green to various shades of red, purple and black, according to the state of oxydation of this metal. Throughout this paste are disseminated well-defined crystals of a rose-red or flesh-red feldspar, apparently orthoclase; and, although less frequently, small grains of nearly colorless translucent quartz. Some masses of this porphyry include fragments of gneiss and syenite, forming a veritable breccia. For analysis, a characteristic variety was selected, the paste of which was greenish-black, jasper-like, conchoidal in fracture, and feebly translucent on the edges, with a somewhat waxy lustre. The hardness of the rock was nearly equal to that of quartz, and the specific gravity 2·62. It contained a few distinct crystals of red feldspar, and some grains of quartz. The base, freed as much as possible from both of these, gave silica 72·20, alumina 12·50, protoxyd of iron 3·70, lime ·90, potash 3·88, soda 5·30, volatile ·60 = 99·08. The oxygen ratio of the alkalies and the alumina is 2·02 : 5·84; or very nearly as 1 : 3. The alumina requires 43·80 parts of silica to form with the alkalies, 65·48 parts of a feldspar having the oxygen ratios 1 : 3 : 12; which are those of orthoclase and albite. There will then remain 28·40 parts of silica. This, with the exception of a small amount which is probably united with the oxyd of iron and lime, may be regarded as uncombined.

INTRUSIVE ROCKS OF THE PALÆOZOIC SERIES.

The palæozoic strata of the district of Montreal afford a great variety of intrusive rocks, which may be classed under the heads of trachyte, phonolite, diorite, and dolerite. These various rocks appear along a line of disturbance, which is nearly transverse to the undulations of the Notre Dame Mountains. Commencing at the hills of Brome and Shefford, which are nearly on the line dividing the eastern and western districts of palæozoic rocks, this disturbance may be traced for a distance of 180 miles, nearly westward, to the Lac des Chats, upon the Ottawa (page 9). In this vicinity, the undulation, which is more gentle to the eastward, gives place to a break in the strata. Vicinity of Montreal.

The most important of the intrusive masses appear along this line, in the form of hills, breaking through the Lower Silurian strata; and are as follows, commencing with the contiguous mountains of Brome and Shefford, and going westward: Yamaska, Rougemont, Belœil, Montarville, Mount Royal and Rigaud; the last being about ninety miles distant from the first. A few miles to the south of Belœil, is Mount Johnson, or Monnoir, another intrusive mass: which, although out of the range of those just mentioned, apparently belongs to the same series. The mineral composition of these rocks varies greatly, not only for the different hills, but for different parts of the same one. Thus, Shefford and Brome mountains consist of a granitoid trachyte; while the succeeding one of Yamaska, and Rigaud, at the other extremity of the line, are partly of trachyte and partly of diorite. Monnoir and Belœil are made up of diorite; while Rougemont, Boucherville, and Mount Royal consist in great part of dolerite; presenting, however, many varieties in composition, and sometimes passing into pyroxenite. The dolerites of Rougemont and Mount Royal are cut by dykes of trachyte: similar dykes also traverse the diorite of Yamaska, and may perhaps be connected with the trachytic portion of the mountain. It is probable, judging from some specimens from Rougemont, that the dolerite is there intersected by veins of diorite; some of which resemble that of Belœil, and others that of Mount Johnson. Dykes both of trachyte and of dolerite are also found traversing the sedimentary strata, in many localities, in the vicinity of these great eruptive masses. The principal varieties of intrusive rocks in this region will now be described; commencing with the trachytes, and thence passing to the diorites and the dolerites.

TRACHYTES AND PHONOLITE.

The trachytes of Brome and Shefford occupy two mountainous areas near to each other. The larger one covers about twenty square miles in the township of Brome, and the western part of the township of Shefford; and consists of several rounded hills, of which Brome and Gale Mountains are the principal, and rise boldly to an elevation of about 1000 feet above the surrounding plain. The rock shows divisional planes, giving it an aspect of stratification, and is divided by other joints into rectangular blocks. Another similar mass, covering an area of about nine miles, is met with in the township of Shefford, a little to the north-west of the last, and distant at the nearest point only about two miles from it. These trachytes break through the strata of the Quebec group, and are near the limit of the eastern palæozoic district.

The rocks of these two mountainous areas present but very slight differences; being everywhere made up in great part of a crystalline feldspar, with small portions of brownish-black mica, or of black hornblende, which are sometimes associated. The proportion of these two minerals is never above a few hundredths, and is often less than one hundredth. The other mineral species are small brilliant crystals of yellowish sphene, and others of magnetic iron, amounting together probably to one thousandth of the mass. In some finer grained varieties, a few rare crystals of sodalite and of nepheline are met with. But for the absence of quartz, these rocks might be taken for varieties of granite and syenite. They are very friable, and subject to disintegration; so that the soil, for some distance around the mountains, is almost entirely made up of the separated crystals of feldspar; which, however, show but little tendency to decomposition, and retain their lustre. The rock is sometimes rather finely granular; but is often composed of cleavable masses, which are from one fifth to one half of an inch in breadth, and sometimes nearly an inch in length. The cleavages of the feldspar are those of orthoclase. The lustre is vitreous, and, in the more opaque varieties, pearly; but the crystals never exhibit the eminently glassy lustre, nor the fissured appearance, that characterizes the feldspars of many foreign trachytes, which are identical with these in composition. The color of the feldspars of these rocks is white, passing to reddish on the one hand, and to pearl-grey or lavender-grey on the other.

Brome. Specimens of the rock of Brome Mountain were taken from the side near to the village of West Shefford. It was coarsely crystalline, lavender-grey in color, and contained a little brown mica, sphene, and magnetic iron, but no hornblende. The density of fragments of the rock was found to be 2·632–2·638. Selected grains of the feldspar had a specific gravity of 2·575: its analysis has already been given, on page 476, V. A second specimen, from another portion of the rock, gave silica 65·30, alumina 20·70, lime ·84; showing an identity in composition.

A specimen from the south side of Shefford Mountain was next examined. A little above the place where it was collected, the rock was a coarse greyish-white feldspar, with a little black mica, and closely resembled that just described; but the portion selected contained a little black hornblende in brilliant crystalline grains about the size of those of rice, with very small portions of magnetite and of yellow sphene. These were disseminated in a base, which, although completely crystalline, was more coherent, and finer grained than that of Brome; rarely exhibiting cleavage planes more than one fourth of an inch in length. Its color was yellowish-white, and it was sub-translucent, with a somewhat pearly lustre. Fragments of the rock had a specific gravity of 2·607 – 2·657. By crushing and washing the mass, the white feldspar grains were separated from the heavier minerals, and had a specific gravity of 2·561. The composition of this feldspar, which scarcely differs from the last, is given on page 476, VI. Shefford.

The greater part of the mountain of Yamaska may be described as a micaceous trachytic rock; which differs from that of Brome and Shefford in being somewhat more micaceous, and more fissile. The dark brown mica is in elongated flakes, and there is no hornblende in the specimens collected; which however hold small portions of magnetite, and minute crystals of amber-yellow sphene. These seem to be disseminated in veins of segregation, which are of a lighter color than the mass. The feldspar grains which make up this rock are brilliant, of a vitreous lustre, and often yellowish or reddish-grey in color. A portion of this feldspar, separated by washing from the crushed mass of the rock, had a density of 2·563. The analysis of this, and of another portion of selected grains, is given on page 479, XIII and XIV. These feldspars will be seen to differ widely in composition from those of the previous trachytes, and to approach oligoclase and andesine in composition. The sphene from this rock is described on page 502. Yamaska.

At Chambly, a mass of porphyritic trachyte is intruded in the form of a bed, among the strata of the Hudson River formation; and about mid-way on the Chambly canal, a similar trachyte is met with, which contains, in drusy cavities, crystals of quartz, calcite, analcime, and chabazite. The base of this rock is of a pale fawn color, and appears at first sight to be micaceous; but on closer examination it is seen to be almost entirely feldspathic. Minute portions of pyrites, and grains of magnetic iron, are rarely met with, and small scales of a dark green micaceous mineral are very sparsely disseminated. The crystals of feldspar, which are very abundant, are sometimes an inch in length, and one fourth of an inch in thickness; they are more or less modified, and terminated at both ends. They are easily Chambly.

detached from the rock, and are yellowish and opaque on the exterior; but the inner portions of the larger crystals are transparent and vitreous. Their composition, which is given at page 476, IV, will be seen to be almost identical with that of the feldspars of Brome and Shefford. The base of this porphyry, carefully freed from crystals, lost by ignition 2·1 per cent. When pulverized, and digested with dilute nitric acid, it effervesced slightly, giving off carbonic acid, together with red fumes from the oxydation of the pyrites; and yielded carbonate of lime 1·70 per cent., carbonate of magnesia 0·98, and peroxyd of iron, with a trace of alumina, 2·12 per cent. The residue, dried at 300° F., gave by analysis, silica 67·60, alumina 18·30, peroxyd of iron 1·40, lime ·45, potash 5·10, soda 5·85, volatile ·25 = 98·95. The fine grained portion of this rock therefore differs but little from the crystals in composition. It contains only a very slight excess of silica, and seems to be made up of lamellæ of orthoclase, mingled with small portions of carbonates of lime and magnesia. A part of the iron also is probably present as carbonate, which, by its decomposition, gives rise to the rusty red color of the weathered surface of the trachyte.

Rigaud. A large part of Rigaud Mountain is composed of a reddish orthoclase rock, coarsely crystalline like that of Shefford, and sometimes holding quartz. Other portions are a feldspathic porphyry, with a fine grained greyish base, like the trachyte of Chambly. These trachytes are cut by thin veins or dykes of a hard reddish-brown jaspery feldspathic rock.

The island of Montreal offers a great variety of trachytic rocks, which traverse both the Lower Silurian strata, and the dolerite of Mount Royal. Some of these dykes are finely granular, occasionally crumbling to sand; and they are frequently earthy in texture. In some cases, they assume a concretionary structure, and they are often porphyritic from the presence of feldspar or of hornblende. One variety exhibits large feldspar crystals in a compact purplish or lavender-grey base, with a waxy lustre. This effervesces with acids, from an admixture of earthy carbonates; and closely resembles in its aspect certain trachytes from the Siebengebirge, on the Rhine. Other varieties can scarcely be distinguished from the so-called domite, the trachyte of the Puy de Dôme, and exhibit small drusy cavities. The presence of carbonates in trachytic rocks has generally been overlooked; Deville, however, found seven per cent. of carbonate of lime in a trachytic rock from Hungary, and it occurs disseminated in some of the trachytes of the Siebengebirge. Some of the trachytes about to be described, contain, moreover, carbonates of magnesia and protoxyd of iron, and weather to some depth of a reddish-brown color, from the peroxydation of the latter; like the trachyte from Chambly just noticed. Acids remove from many of these rocks, in addition to the carbonates, portions of alumina and alkalies. These are derived from a soluble silicate, which

Calcareous trachytes.

is not met with in the trachytes already described, if the occasional presence of nepheline be excepted. In some of the compact and earthy varieties about Montreal, however, this soluble silicate exists to a large extent, and has the composition of natrolite. By this admixture of a zeolite the trachytes pass into phonolite. **Phonolite.**

The first of these trachytes which will be noticed forms a dyke near McGill College. The rock is divided by joints, into irregular fragments, whose surfaces are often coated with thin bladed crystals of an aluminous mineral, apparently zeolitic. Small brilliant crystals of cubic iron pyrites, often highly modified, are disseminated through the mass. The rock has the hardness of feldspar, and a specific gravity of from 2·617 to 2·632. It has a feebly shining lustre, and is slightly translucent on the edges, with a compact or finely granular texture, and an uneven sub-conchoidal fracture. Before the blow-pipe it fuses, with intumescence, into a white enamel. The rock in powder, is attacked even by acetic acid, which removes 0·8 per cent. of carbonate of lime, besides 1·5 per cent. of alumina and oxyd of iron; the latter apparently derived from a carbonate. Nitric acid dissolves a little more lime, oxydizes the pyrites, and takes up, besides alumina and alkalies, a considerable portion of manganese. This apparently exists in the form of sulphuret, since, while it is soluble in dilute nitric acid, the white portions of the rock afford no trace of manganese before the blow-pipe; although minute dark colored grains, associated with the pyrites, were found to give an intense manganese reaction. From the residue, after the action of the nitric acid, a solution of carbonate of soda removed a portion of silica; and the remainder, dried at 300° F., was free from iron and from manganese. Its analysis is given on the next page, under I. That of the matters dissolved by nitric acid from 100 parts of the rock, will be found under I, A. **Montreal.**

A dyke near to the last, and very similar to it in appearance, was submitted to the action of nitric acid, but the insoluble residue was not treated by carbonate of soda. Its analysis is given under II, while that of the soluble matters is to be found under II, A. A white trachyte from a dyke at Lachine, resembled the preceding, but was somewhat earthy in its aspect, and effervesced with nitric acid; which removed a portion of lime equal to 7·40 per cent. of carbonate. On boiling the pulverized rock with nitrate of ammonia, an amount of lime equal to 5·33 per cent. of carbonate was dissolved. An accident prevented the complete determination of the alkalies in the feldspathic residue of this trachyte; and the soluble silica was not removed previous to the analysis, whose result is given under III. The proportion of the potash to the soda was, however, found to be, by weight, nearly as two to three. The matter dissolved by nitric acid will be found under III, A. **Lachine.**

Another dyke of trachyte from Lachine was concretionary, and stained by infiltration: the interior of the concretions was white and earthy. The substances removed from 100 parts of the rock by nitric acid, and by carbonate of soda, are given in IV, A. A partial analysis of the insoluble residue showed it to be a feldspar allied to those of the preceding trachytes: the quantities of potash and soda were, however, nearly in the ratio of four to three.

Montreal. A large dyke of trachyte in the limestone quarries at the Mile End, near Montreal, is remarkable for the amount of carbonates which it contains. It is greyish-white, with dark grey spots, granular, sub-vitreous in lustre, and holds a few crystals of hornblende. By ignition, it loses 11·0 per cent. of its weight. In powder, it effervesces freely with nitric acid, disengaging carbonic acid, and, when heat is applied, red fumes from the peroxydation of the iron. 100 parts of the rock yielded in this way 4·84 per cent. of alumina; besides lime, magnesia, and peroxyd of iron. These, represented as carbonates, equalled carbonate of lime 11·60, carbonate of magnesia 3·58, carbonate of iron 3·82 = 19·00. The alkalies in the solution were not determined. The composition of the residue from nitric acid, from which the soluble silica was not removed, is given in IV. V and VI are the analyses of the feldspathic residues from two specimens of the phonolite of Lachine, which is described below.

	I.	II.	III.	IV.	V.	VI.
Silica,	63·25	62·90	58·50	61·62	59·70	60·90
Alumina,	22·12	23·10	24·90	21·00	23·25	24·45
Lime,	·56	·45	·45	2·69	·99	·45
Potash,	5·92	2·43	undet.	4·66	9·16	undet.
Soda	6·29	8·69	"	5·35	2·97	"
Volatile,	·93	1·40	2·10	2·37	2·23	2·10
	99·07	98·97		97·69	98·30	

A second determination of the alkalies in a portion of the trachyte, I, which had not previously been treated by acid, gave potash 5·40, and soda 6·49. A second analysis of II gave potash 2·28, and soda 7·95.

	I, A.	II, A.	III, A.	IV, A.
Silica,	1·43	undet.	undet.	5·00
Alumina,	2·43	2·84	0·27	1·32
Peroxyd of iron,	2·40		1·47	2·51
Lime,	·60	1·86	4·14	3·50
Magnesia,	....	....	1·34	1·35
Potash,	·40	·25	undet.	undet.
Soda,	·98	·21	"	"
Red oxyd of manganese,	1·31	·87	....	....

Associated with the trachytic dykes at Lachine is one of the phonolite, already referred to. It is brittle, and somewhat schistose, breaking into angular fragments; and appears to consist of a reddish-fawn colored base, in which are disseminated greenish-white rounded masses, often grouped, and apparently concretionary in their nature. These greenish portions are sometimes half an inch or more in diameter, and cover from one third to one half of the surface. They are not very distinctly seen unless the rock is moistened. The hardness of the different portions does not greatly vary, and is nearly that of apatite. The specific gravity is very low, being only 2·414. The mass contains small cavities filled with carbonate of lime, which is rarely stained purple: it is also found in small films in the joints. The rock is granular in its fracture, without lustre, and is feebly translucent at the edges. When pulverized, and treated with nitric acid, of specific gravity 1·25, a slight effervescence ensues, with abundant red fumes. The mass grows warm, and gelatinizes; and on washing out the acid solution, and treating the insoluble portion with a solution of caustic soda, a white granular residue remains. These reactions are obtained both with the fawn-colored and the greenish portions, but the amount of insoluble matter is greater from the last. The rock is but slightly hygroscopic: a portion of it in powder lost only 0·2 per cent. by a prolonged exposure to 300° F.; but 7·10 per cent. at a red heat. Phonolite Lachine.

For the quantitative analysis, the method already indicated was followed. It was found, that, while a dilute solution of caustic soda removed all the gelatinous silica, it took up only a trace of alumina; leaving a feldspathic residue, which was no longer attacked by nitric acid. The silica was separated from the alkaline liquid. The acid solution was found to contain, besides alumina and soda, a little potash, some lime, magnesia, and iron, and traces of manganese. The greater part of the lime is evidently present as carbonate; for when a portion of the pulverized phonolite, which gave to nitric acid, lime equal to 4·36 per cent. of carbonate, was boiled with a solution of nitrate of ammonia, there were dissolved 3·87 per cent. of carbonate of lime; besides which, there was a separation of a considerable amount of oxyd from the decomposed carbonate of iron. From this reaction, and from the entire absence of sulphur, which was carefully sought for, it is probable that the whole of the iron, except the small portion of peroxyd which colors the rock, exists in the state of carbonate. In the following analyses, therefore, the lime and the iron, as well as a little magnesia, are calculated as carbonates. I, on the next page, is the result obtained with four grams of the reddish portion of the phonolite, as free as possible from the green; and II was obtained with two and a half grams of a mixture of the two colors.

In order to fix the composition of the soluble silicate, the amounts of the insoluble portion, the silica, the alumina, and the alkalies, having been carefully determined, and the lime, magnesia, and oxyd of iron calculated as carbonates, the water was estimated by the loss. In this way there were obtained from I and II the results given under I. A and II. A.

	I.	II.
Insoluble silicate, ...	45·75	55·40
Soluble " (by difference), ...	46·57	36·16
Carbonate of lime, ...	3.63	4·36
" iron, ...	3·52	3·72
" magnesia, ...	·53	·36
	100·00	100·00

The composition of the soluble zeolitic mineral, and the readiness with which it gelatinizes with acids, lead to the conclusion that it is natrolite. This, in the phonolite, is mingled with carbonates of lime, magnesia,

	I, A.	II, A.
Silica, ...	51·96	51·66
Alumina, ...	24·42	24·88
Soda, ...	12·93	13·05
Potash, ...	1·15	1·28
Water, ...	9·54	9·13
	100·00	100·00

and iron, and with a potash feldspar, whose composition has already been given above, under V and VI on page 660. The excess of silica in the soluble portion, over that required to form natrolite, is probably due to a partial decomposition of the feldspar.

Nature of the feldspars.

The feldspars of the above trachytes and phonolites offer some considerable variations in their composition, especially in the proportions of the alkalies. In I, on page 660, the proportions of potash and soda are nearly the same as in the trachytes of Brome, Shefford, and Chambly; and the same is true of IV. These are doubtless to be regarded as varieties of orthoclase, with a large amount of soda: while in the feldspar from the phonolite the proportion of soda is very small. In II, on the contrary, the large predominance of soda indicates a composition approaching that of albite. It is further apparent, from a comparison of the feldspars of the other trachytes, whose complete analyses are not given, that the proportions of the alkalies are liable to considerable variation, even in adjacent and apparently similar dykes. All of the above feldspars are probably to be referred to orthoclase or to albite: but these, in the earthy trachytes, have undergone a commencement of decomposition, which consists in the loss of a portion of silica and of alkali, and the fixing of water; resulting in the formation of kaolin. An admixture of this substance will explain the increased amount of alumina, the deficiency of silica, and the presence of water in the feldspars of the more earthy of these trachytes.

These trachytic dykes are not confined to the vicinity of Montreal. To the southward, on the shore of Lake Champlain, there is found in and about Burlington, Vermont, a great number of dykes of intrusive rock;

some of which appear to intersect the strata of the Quebec group, and others those of the Trenton group. Some of these dykes are described as being of greenstone; and others, as a white or yellowish-white feldspathic rock, often porphyritic from the presence of feldspar crystals. The base of a yellowish-grey porphyritic dyke from Shelburne, having a rough fracture, and a specific gravity of 2·60, gave to Prof. G. F. Barker, silica 67·30, alumina and peroxyd of iron 19·10, lime ·79, magnesia, traces, potash 4·74, soda 6·04, volatile 1·70 = 99·67. It contained a little intermingled quartz; and the mass resulting from the fusion of the rock with an alkaline carbonate, contained traces of a sulphuret. (Geology of Vermont, pages 579–707.) **Trachytes of Vermont.**

Somewhat to the south of Burlington, on the west side of Lake Champlain, and near to Essex, there is a great mass of intrusive rock, found in the slates of the Hudson River formation. As described by Emmons, it is interstratified in an irregular manner among the layers of the unaltered sedimentary rocks, and has a fissile and schistose structure, which gives, at first sight, the aspect of stratification to what is undoubtedly an intrusive rock. When exposed to the action of the waves on the lake-shore, its structure appears to be columnar, and sometimes concretionary. This rock is described as composed of a reddish or pale leek-green compact feldspar, holding crystals of the same mineral. (Geology of New York, vol. ii, page 84.) These intrusive feldspathic rocks on Lake Champlain resemble closely the trachytes of Montreal and Chambly,—with the latter of which, the rock of Shelburne, the only one of them which has been chemically examined, closely agrees in composition. **New York.**

DIORITES.

Those diorites of the Eastern Townships, which are found in the metamorphic region, and are regarded as indigenous rocks, have already been noticed on page 604. It now remains to describe those which break up through the unaltered strata, and are clearly intrusive rocks. The first to be noticed is that of Yamaska. The greater part of this mountain consists, as already described, of a micaceous granitoid trachyte ; but the south-eastern portion is entirely different, being a diorite made up of a pearly white crystalline translucent feldspar, with black brilliant hornblende, ilmenite, and magnetic iron. This rock is in some parts rather fine grained, though the elements are always very distinct to the naked eye. In other parts are seen large cleavage surfaces of feldspar half an inch in breadth, which exhibit in a very beautiful manner the striæ characteristic of the polysynthetic macles of the triclinic feldspars. The associated crystals of hornblende are always much smaller, and less distinct; forming with grains of feldspar, a base, to which the larger feldspar crystals give a porphyritic aspect. Finer grained bands, in which magnetite and ilmenite predominate, traverse the coarser portions, often reticulating; and the

Diorites.

Yamaska.

whole mass is also occasionally cut by dykes of a whitish or brownish grey trachytic rock; which are often porphyritic, and may perhaps be branches from the trachytic part of the mountain.

A portion of the coarse grained diorite selected for examination, contained, besides the minerals already enumerated, small portions of black mica, with grains of pyrites, and a little disseminated carbonate of lime, which caused the mass to effervesce slightly with nitric acid. The macled feldspar crystals, sometimes half an inch in length, were so much penetrated by hornblende that they were not fit for analysis; but by crushing and washing the rock, a portion of the feldspar was obtained, which did not effervesce with nitric acid, and contained no visible impurity, except a few scales of mica. It was decomposed by hydrochloric acid, with separation of pulverulent silica; and its analysis, which is given on page 479, shows it to be near to anorthite, and identical in composition with the feldspar of diorite from Bogoslowsk, in the Ural Mountains. This is associated with a greenish-black hornblende, containing some soda and titanic acid, with a little mica, and some quartz. (Scott; L. E. and D. Philos. Magazine [4], xv, 518.)

Mount Johnson. Mount Johnson, or Monnoir, is composed of a diorite, which, in its general aspect, greatly resembles that of Yamaska, just described, except that it is rather more feldspathic. The finer grained varieties are greyish in color, and exhibit a mixture of grains and small crystals of feldspar, with hornblende, brown mica, and magnetite. Frequently, however, the rock is much coarser grained, consisting of feldspar grains, with slender prisms of black hornblende, often half an inch long and one tenth of an inch broad, and numerous small crystals of amber-colored sphene. In this aggregate, there are imbedded cleavable masses of the feldspar, often an inch long by half an inch in breadth. At the southern foot of the mountain, large blocks of the coarse grained diorite are found in a state of disintegration; affording detached crystals of feldspar, with rounded angles, and weathered externally to an opaque white, from a partial decomposition. Near to the base of the mountain, a coarse grained variety of the diorite encloses small but distinct crystals of brown mica; and a fine grained micaceous variety, containing sphene, occurs near the summit.

The feldspar, in all the specimens examined from this mountain, appears to be uniform in character. Its color is white, rarely greenish or greyish; it has a vitreous lustre, inclining to pearly; and it is somewhat translucent. The cleavages of this feldspar resemble those of oligoclase, with which species it also agrees in specific gravity and chemical composition. The macled forms, so common in the crystals of triclinic feldspars, have not, however, been detected in this variety, whose description and analysis will be found on page 477.

Specimens of the rock of Belœil Mountain consist of a kind of micaceous diorite. The feldspar, which so far predominates as to give a light grey color to the mass, is in white translucent vitreous cleavable grains; associated with small distinct prisms of black hornblende, scales of copper-colored mica, and grains of magnetite. The analysis of the feldspar, extracted by washing a portion of the crushed rock, and still containing a little mica, is given on page 479, XV. It resembles in composition the feldspars XIII and XIV, on the same page, from the micaceous portion of Yamaska; which has been described above as a trachyte, and which, with the rock of Belœil, seems to constitute a passage between trachyte and diorite. **Belœil.**

A portion of Rigaud Mountain consists of a rather coarse grained diorite, which is made up of a crystalline feldspar, white or greenish in color, with small prisms of brilliant black hornblende, and crystals of black mica. In some specimens the feldspar, and in others the hornblende, predominates. This rock resembles the diorites of Belœil and Mount Johnson. **Rigaud.**

DOLERITES AND PYROXENITE.

In describing the intrusive rocks of the county of Grenville, it has been shown that the dolerites there met with are of two ages, one anterior to the syenite and the orthophyre, and the other, more recent than all of these, and containing carbonate of lime and crystals of augite. This last rock may be contemporaneous with some of the dolerites about to be noticed, which, besides forming numerous dykes, constitute great portions of the mountains of Rougemont, Montarville, and Mount Royal. In all of these, however, great diversities of composition are met with, which will be successively noticed. **Dolerite.**

The greater part of Montarville is composed of a coarse grained granitoid dolerite, in which black cleavable augite predominates,—sometimes almost to the exclusion of any other mineral. Small portions of white feldspar, and scales of brown mica, are sparsely scattered through the rock, with grains of carbonate of lime. The solution of these from the weathered surface often gives to it a pitted character. In other portions, the feldspathic element predominates, and the rock becomes porphyritic from the presence of large crystals of augite. The worn surfaces of the dolerite sometimes show alternations of this variety, with another, which is finer grained and whiter. The two are arranged in bands, whose varying thickness and curving lines suggest the notion that they have been produced by the flow and the partial commingling of two semi-fluid masses. **Montarville.**

Another and a remarkable variety of dolerite, found at Montarville, appears to be confined to a hill on the shore of the little lake, about half a mile northward from the manor-house. The whole of this hill, with the exception of some adherent portions of indurated shale, seems to be composed of a granitoid dolerite, containing large proportions of olivine. **Olivine.**

Peridotite. This mineral occurs in yellowish-brown rounded crystalline masses, from one tenth to one half an inch in diameter; associated with a white or greenish-white crystalline feldspar, black augite, a little brown mica, and magnetite. The augite appears in the form of small grains, and also in well defined and terminated crystals; which are often an inch in length by half an inch in diameter, and are sometimes partially coated by a film of brown mica. A further description, with an analysis of this augite, will be found on page 468. The olivine varies in amount; but, in some portions of the rock, it is the predominant mineral. An account of its chemical characters, and the results of its analysis, are given on page 464.

An average specimen of this olivinitic dolerite, or peridotite, was reduced to powder: it did not effervesce with nitric acid, and when ignited lost only ·5 per cent. When gently warmed with sulphuric acid, the olivine was readily decomposed, with the separation of flocculent silica; and by the subsequent use of a dilute solution of soda, followed by hydrochloric acid, and a second treatment with the alkaline ley, 55·0 per cent. of the whole were dissolved. This portion consisted of silica 37·30, magnesia 33·50, protoxyd of iron 26·20, alumina 3·00 = 100·00; being equal to 18·4 of magnesia for the entire mass. In another experiment, 18·0 per cent. were obtained. Taking the mean of the two analyses of olivine above referred to, which gives 39·5 per cent. of magnesia; 18.0 parts of this base correspond to 45·5 parts of olivine. The remaining 9·5 parts represent alumina and silica from the feldspar, and oxyd of iron from the magnetite; both of which were somewhat attacked by the acids. The undissolved portion of the rock equalled 44·7 per cent.; and appeared to consist of a feldspar, with pyroxene, some mica, and a little magnetite. Its analysis afforded silica 49·35, alumina 18·92, protoxyd of iron 4·51, lime 18·36, magnesia 6·36, loss (alkalies?) 2·50 = 100·00.

In some portions of the dolerite of Montarville, the feldspar is more abundant, and appears in slender crystals, with augite, and with a smaller proportion of olivine than the last. A specimen of this variety, being crushed and washed, gave 3·9 per cent. of magnetite, and 10·0 per cent. of a mixture of ilmenite with olivine. The feldspar was obtained almost pure, in the form of yellowish vitreous grains, having nearly the composition of labradorite. Its analysis is given on page 479, XVI; where, by an error, the amount of potash is said to be 9·71, instead of 0.71 per cent.

The dolerite of Montarville is traversed by veins belonging to several different periods. In one instance, the black highly augitic rock is cut by a dyke of a fine grained greyish-white dolerite. This is intersected by a dyke of a fine greenish rock, which, in its turn, is cut off by another small vein like the first. The altered shales from Montarville have been described on page 634.

The rocks of Rougemont offer a general resemblance to those of Montarville. Some portions are a coarse grained dolerite, in which augite greatly predominates; with grains of feldspar, and a little disseminated carbonate of lime. In some parts, the augite crystals are an inch or more in diameter, with brilliant cleavages; and grains of pyrites are abundant, with calcite, in the interstices. This rock resembles the highly augitic dolerite of Montarville. Olivine is very abundant in two varieties of dolerite from Rougemont. One of these has a greyish-white finely granular feldspathic base, in which are disseminated black augite and amber-colored olivine; the latter sometimes in distinct crystals. The proportions of these elements sometimes vary in the same specimen; the feldspar forming more than half the mass in one part, while in another the augite and olivine predominate. By the action of the weather, the feldspar acquires an opaque white surface; upon which the black shining augite, and the rusty-red decomposing olivine, appear in strong contrast. Rougemont.

Fine grained granitoid dykes are said to traverse the dolerite of Rougemont; and among the specimens brought from it, is a light grey rock; which is made up of a white crystalline feldspar, with small prisms of black hornblende, and scales of brown mica; resembling somewhat the finer grained diorite of Mount Johnson. Other specimens, which are more micaceous, approach in aspect to that of Belœil. A dyke of compact dolerite, holding crystals of feldspar, and grains of olivine, cuts the strata of the Hudson River formation at St. Hyacinth, and has been noticed on page 210.

Mount Royal consists for the most part of a mass of highly augitic dolerite. In some parts, large crystals of augite, like those of Montarville, are disseminated through a fine grained base; which is dark ash-grey in color, and often effervesces freely with acids, from the presence of a portion of disseminated carbonate of lime. At other times this is wanting, and the rock is a mass of black crystalline augite, constituting a veritable pyroxenite, from which feldspar is absent. Mixtures of augite with feldspar are also met with, constituting a granitoid dolerite; in parts of which, the feldspar predominates, giving rise to a light greyish rock. Portions of this are sometimes found, limited on either side by bands of nearly pure black pyroxenite, giving at first sight an aspect of stratification. The bands of these two varieties are found curiously contorted and interrupted, and, as at Montarville, seem to have resulted from movements in a heterogeneous pasty mass; which has effected a partial blending of an augitic magma with another more feldspathic in its nature. Mount Royal. Pyroxenite.

The more augitic parts of Mount Royal contain, like the similar varieties from Rougemont and Montarville, considerable portions of magnetite, and some ilmenite. At the north end of the mountain, a variety of dolerite containing olivine, occurs. It consists of a base of greyish-white granular

Mount Royal.

feldspar; which, in the specimen examined, constitutes about one half of the mass, and incloses crystals of brilliant black augite, and semi-transparent amber-yellow olivine. This rock closely resembles the feldspathic peridotite of Rougemont, described above; but the imbedded crystals are somewhat larger, although less than those in the dolerite of Montarville. A portion of the feldspar, freed as much as possible from augite, gave by analysis the following result; which shows that it approaches labradorite in composition:—silica 53·60, alumina 25·40, peroxyd of iron 4·60, lime 8·62, magnesia ·86, alkalies, by difference, 6·12, volatile ·80 = 100·00. The silica contained 1·60 per cent. of a substance, which was insoluble in a solution of carbonate of soda, and was apparently titanic acid.

Newer dolerites.

These granitoid dolerites, containing coarsely crystalline augite and olivine, break through the Lower Silurian strata; and portions of these two minerals, probably derived from these intrusive rocks, are found in the dolomitic conglomerates near Montreal; which in some cases include masses of Upper Silurian limestone, as on St. Helen's Island. Here the conglomerate is cut by dykes of a fine-grained dolerite. These, which perhaps correspond to the newer dykes of the same rock at Grenville, show that there were at least three distinct eruptions of dolerite,—one during the Silurian period, one before it, and another after it. The trachytes of Montreal and Chambly appear to be still more recent, and to traverse the newest dolerites.

The trachytes of Brome and Shefford seem to constitute a group apart; but the diorites of Yamaska and Mount Johnson; although similar in aspect, differ widely in chemical composition. Facts are still wanting to establish the geological age of these intrusive masses. Rocks which, like the different dolerites, are related in mineral composition, have been seen to belong to different geological periods; and it would not be safe to affirm that the different diorites or the different trachytes of this vicinity are contemporaneous. Nor, on the other hand, should even great discordances in chemical or mineralogical constitution be necessarily regarded as establishing a difference in the age of eruptive rocks. Evidence to the contrary of this is seen in the contiguous and intermingled masses of black pyroxenite and grey feldspathic dolerite, of Mount Royal and Montarville; and it is not improbable that the olivinitic dolerite which is associated with these, may be contemporaneous. If, as has been already suggested in this chapter, the various intrusive rocks are only displaced sediments of deeply-buried and unconformable strata, it will readily be conceived that plastic masses of very unlike characters may be ejected simultaneously along a line of disruption. The appearance, along a similar line, of mineral springs, unlike in constitution, and coming from different stratigraphical horizons, as already explained on page 562, is a somewhat analogous phenomenon.

The various intrusive masses of the palæozoic series which have been described in this chapter, appear, from their compact and crystalline structure, to have been ejected and consolidated under the pressure of a considerable mass of superincumbent strata. The fact, that even their summits, which are in some cases more than 1000 feet above the present level of the plain, appear equally solid and crystalline with their bases, implies the removal, by denudation, since the eruption of these masses, of a thickness of sedimentary strata, much exceeding their present height. This denudation must however have taken place before the eruption of the later trachytes and dolerites; since the dolomitic conglomerates, which enclose the fragments both of the olivinitic dolerite and of the Lower Helderberg limestone, repose unconformably upon the Laurentian and the various Lower Silurian strata; in such a manner as to show that these offered nearly their present distribution at the epoch of the deposition of the conglomerates (page 358). If, then, as is probable, the exposure, by denudation, of the whole of the eight hills which have been described, took place at one epoch, these are all shown to have a greater antiquity than the trachytes and the dolerites which traverse the conglomerate. The fine grained and earthy trachytes of Montreal are consequently far more recent than the crystalline ones of Brome and Shefford; with which, however, some of them agree in chemical composition.

Age of trachytes.

The general absence of granite from among these intrusive masses is a fact worthy of notice. Quartz has not yet been detected in the feldspathic rocks of Brome and Shefford; although, as above mentioned, the base of the feldspathic porphyries of Chambly, and of Shelburne, contains a slight excess of silica. The granitic rocks of Shipton, and of St. Joseph on the Chaudière, appear to be indigenous masses, belonging to the strata of the Quebec group; but the higher fossiliferous formations to the east of the Notre Dame Mountains, are traversed in various places by veins and great masses of intrusive granite, whose characters and distribution have been described on pages 430 and 434. It is worthy of note, that the intrusive masses on the two sides of the mountain range are, so far as yet observed, entirely distinct in character; and that eruptive rocks are generally wanting among the Notre Dame Mountains, which consist chiefly of stratified rocks. It is also to be remarked, that the intrusive granites at their eastern base, are not unlike, in mineralogical characters, to the indigenous granites of the mountains; thus suggesting the view that these are possibly the source of the intrusive granites which break through the Devonian strata. A similar relation has been pointed out by Durocher, in Scandinavia, where the palæozoic strata are broken by intrusive masses of granite, orthophyre, zircon-syenite, and diorite. These rocks, according to him, are specifically analogous to those of the underlying primitive gniess, but petrographically distinct. (Bull. Soc. Geôl. de France,

Granites.

[2,] vi, 33.) These facts are in accordance with the theory of eruptive rocks developed at the commencement of this chapter; and it would be easy to extend the comparison to the intrusive diorites and dolerites about Montreal, and to show their resemblance to the stratified feldspathic rocks of the Laurentian series. (Amer. Jour. of Science [2], xxix, 283, and xxxi, 414.)

The intrusive rocks of Lake Superior, which are very curious and varied in their characters, for the most part remain to be studied. The little which is known of their composition, including the researches of Prof. Whitney, has already been given in this chapter. The intrusive rocks of the peninsula of Gaspé, have also yet to be investigated. The greenstone dykes, which intersect the limestones and sandstones in the vicinity of Gaspé Basin, have been noticed on page 402. Some of them are of columnar greenstone; and others, which are amygdaloidal, contain calcite, crystalline quartz, and chalcedony, and often present cavities filled with petroleum. The trappean rocks interstratified with the conglomerates of the Bonaventure formation, are noticed on page 441; and the numerous trap dykes found near New Carlisle are mentioned on page 446. The nature of the adjacent crystalline rocks, and their relations to the intrusive masses, have yet to be determined. They are perhaps metamorphic strata, like those of Cape Maquereau described on page 272. Great portions of trap are also associated with the sandstone of this formation at Black Cape; and the singular brecciated beds of the intrusive rock, which are found in the section at this place, have been described on page 447.

CHAPTER XXI.

ECONOMIC GEOLOGY.

CLASSIFICATION: I, METALS AND THEIR ORES; II, MINERALS USED IN CERTAIN CHEMICAL MANUFACTURES; III, MINERALS USED IN AGRICULTURE; IV, MINERALS USED AS PIGMENTS; V, COMBUSTIBLE AND CARBONACEOUS MATERIALS; VI, REFRACTORY MATERIALS, AND OTHERS USED IN SMELTING METALS; VII, MATERIALS FOR BRICKS, POTTERY, AND GLASS; VIII, MATERIALS FOR CEMENTS AND MORTARS; IX, GRINDING AND POLISHING MATERIALS; X, BUILDING MATERIALS; XI, MATERIALS FOR ORNAMENTAL PURPOSES; XII, LITHOGRAPHIC STONE.

Under this head it is proposed to notice those mineral substances found in the province, which are susceptible of economic application. In the previous portions of the volume many of these have been mentioned in describing the distribution of the various geological formations, or in the subsequent chapters on the minerals, rocks, and mineral waters. The economic value of the latter as remedial agents is very considerable, but its discussion would lead to considerations foreign to the plan of the present work. The possible uses in the arts, to which some of these waters may be applied, have already been noticed on page 564. A convenient classification of the other economic minerals of the province presents no small difficulties. The following scheme is essentially that followed in the arrangement of the collections of mineral products sent from Canada to the Exhibitions of 1851 and 1855, and to the International Exhibition of 1862. Like all technical arrangements, it has a disadvantage arising from the fact that many substances, from their various applications, have claims to be considered in more classes than one. Classification.

I. Metals and their ores: iron, lead, copper, nickel, silver, gold.
II. Minerals used in certain chemical manufactures: iron pyrites, chrome, cobalt, manganese, titanium, molybdenum, carbonate of magnesia, etc.
III. Minerals used in agriculture: phosphate of lime, gypsum, marl.

IV. Minerals used as pigments: ochres, sulphate of barytes, etc.
V. Combustible and carbonaceous minerals: peat, bituminous shale, petroleum.
VI. Refractory materials used in constructing furnaces, or in smelting metals: plumbago, soapstone, potstone, mica, sandstone, fire-clay, moulding sand.
VII. Materials for bricks, pottery, and glass.
VIII. Materials for cements and mortars.
IX. Grinding and polishing materials: millstones, grindstones, hone-stones, garnet.
X. Building materials: granites, sandstones, limestones, marbles, serpentines, roofing slates, flagstones.
XI. Materials for ornamental purposes: porphyries, feldspars, agates, jaspers.
XII. Lithographic stones.

I. METALS AND THEIR ORES.

Metals. Under this head will be considered those substances which are used in the arts in their reduced or metallic state, including iron, lead, copper, nickel, silver, and gold. Of the other metals enumerated on page 501 as being found in Canada, cobalt, manganese, chromium, titanium, molybdenum, and arsenic are chiefly used in the arts in their oxydized compounds, and will be considered in the second class. The remaining elements of this class,—cerium, tungsten, uranium, mercury, platinum, and iridium,—are as yet known to exist only in minute quantities in Canada, and the facts in their history will be found in the seventeenth chapter; to which the reader is also referred for many mineralogical details with regard to the matters about to be described.

IRON.

Iron The ores of iron, of economic importance in Canada, are the magnetic oxyd, the anhydrous peroxyd, and the hydrous peroxyd. The carbonate of iron has not been observed in any considerable quantity; and the sulphuret, which is not used as an ore of iron, but is valuable for other purposes, will be noticed in the second class.

The most abundant ore of iron in the province is probably the magnetic oxyd, or magnetite; which receives its name from the fact that it is attracted by the magnet. It is sometimes endowed with polarity, and then constitutes the native magnet or lodestone. This ore has a specific gravity of a little over five times that of water, is iron-black in color, and gives a black powder. It is hard, brittle, and with a shining, more or less metallic lustre. When pure, it consists of 72·4 parts of iron, and 27·6 parts of oxygen; but it often contains foreign matters, either mechanically mingled or chemically combined, which reduce more or less the percentage of the ore. The magnetic oxyd sometimes occurs in masses made up of coarse grains; at other times, the ore is fine grained and almost compact; more rarely, it occurs in regular octahedral crystals. This ore is found only in crystalline or metamorphic rocks; and the deposits of it in Canada occur in the Laurentian series, or in the crystalline rocks of the eastern palæozoic basin. In the former, it is met with in beds of great extent and thickness, which have been noticed on pages 26, 509, and 593. A detailed description of the principal deposits of this ore in the Laurentian series will now be given, commencing with those on the Ottawa, and thence proceeding along the Rideau, to those of Bedford and the region about Marmora.

Grenville. On the south half of the third lot of the fifth range of Grenville, a bed of magnetic iron ore, six or eight yards wide, occurs in a micaceous gneiss, which is interstratified with numerous bands of quartzite. It was traced for about 150 yards westward, and then north-westward. The accompanying strata are cut off, and limited on either side, by a mass of intrusive syenite; leaving only about 350 yards on the strike, which would thus be the extent of the iron bed. The ore is somewhat mingled with the earthy minerals of the gneiss, but an average sample gave 52·23 per cent. of metallic iron.

On the north half of the third lot of the fourth range of the same township, is a similar bed of magnetic ore in gneiss, from a few inches to a foot in breadth. It was traced for about 100 yards, and was apparently parallel with the last-mentioned band. Small portions of the same ore have also been met with in the fourth lot of the seventh, and in the fifth lot of the eighth range, forming only small seams in the gneiss. They are probably of no economic importance, except in so far as they show the distribution of the ore, and not improbably belong to the same band as the wider one mentioned above. The ore in Grenville occurs in the vicinity of the limestones of the series.

Wentworth. On the south side of Gate Lake, in the twenty-sixth lot of the sixth range of Wentworth, two sets of beds of this ore, about 100 yards apart, have been traced for half a mile on the strike: which is N. 10° E. The ore occurs in bands of gneiss interstratified in the limestone, and forms several small irregular layers, not more than an inch or two in thickness. It is possible that in other portions of this limestone band the ores may become of economic importance. Specimens of magnetic iron ore have been received from a bed about twenty feet in thickness, which occurs in gneiss, in the township of Grandison.

Hull. A large deposit of magnetic iron ore is met with in the southern half of the eleventh lot of the seventh range of Hull; and it is said to have been met with again a mile beyond, in the rear of the twelfth lot of the same range. The ore occurs in syenitic gneiss, which is interstratified with white crystalline limestone holding mica and graphite, and forms a bed about ninety feet in thickness. This seems to be brought to the surface on the crown of an anticlinal, through which an underlying bed of crystalline limestone appears. The ore is coarsely granular and very pure, but is in some parts mingled with scales of graphite. An analysis of what was deemed an average specimen gave for one hundred parts, 3·18 of quartz and graphite, and 96·09 of magnetic oxyd of iron; = 99·27. This equals 69·65 per cent. of metallic iron.

In 1854, this deposit of ore was opened by Messrs. Forsyth & Co., of Pittsburg, Pennsylvania, for the supply of their furnaces at that place, where it was used in connection with the iron from the ores of that region. It was shipped by the Rideau Canal to Kingston, and thence by the lakes to Cleveland. Up to 1858 about 8000 tons of the ore had been thus exported, when the opening of the Newborough mine in South Crosby, which afforded greater facilities for shipping the ore, caused the Hull mine to be abandoned.

South Crosby. An important deposit of magnetic iron occurs on an island in Mud Lake, on the Rideau Canal, not far from Newborough, on the twenty-sixth and twenty-seventh lots of the sixth range of South Crosby. It forms a bed 200 feet thick, running northeast and southwest, in gneiss, adjoining the crystalline limestone, and, according to Messrs. G. Chaffey & Brothers, has been traced from the lake, on to the first and second lots on the same range. This ore has, within the last few years, been mined, like that of Hull, for shipment to Pittsburg, and during the years 1858 and 1859 about 6000 tons of it were forwarded thence by the way of Kingston.

South Sherbrooke. On the fourteenth lot of the first range of South Sherbrooke, a bed of twelve feet of magnetic iron occurs in gneiss. A few hundred tons of it have been raised, and it has been used with advantage in lining the hearths at Mr. Gzowski's iron works at Toronto. A large deposit of this ore is also said to occur on the north shore of Myers's Lake, in front of the seventeenth, eighteenth, and nineteenth lots of the third range of this township. These lots lie nearly to the north of the last, and the bed, which, according to Dr. Wilson of Perth, has a thickness of about sixty feet, may be a continuation of that just mentioned. A specimen of the ore from this locality was found to contain 63·0 per cent. of iron, equal to 87·0 of magnetic oxyd, and 12·1 of insoluble quartz and mica; = 99·1.

Bedford. On the twenty-first lot of the ninth range of Bedford, a bed of magnetic iron ore, three or four feet in thickness, occurs at or near the junction of the gneiss with the crystalline limestone. Deposits of this ore are also said to have been recently discovered on the sixth lot of the third range, and on Black Lake in the eighth lot of the fourth range of the same township; but no details are yet known with regard to them. Another locality where this ore has been observed is near the northeast end of Bob's Lake, supposed to be in the twenty-fifth lot of the fifth range of the same township. Fragments of the ore were here found at the foot of a ridge of crystalline limestone, but it was not met with in place.

On the seventh lot of the second range of Escott, magnetic iron ore occurs in a reddish feldspathic gneiss, which encloses micaceous layers. The strata, running northeast, dip at a high angle to the northwest, and are much contorted, and traversed by small veins of white quartz with flesh-red feldspar. The ore is found both in the veins, and interstratified; the largest mass of it being clasped in one of the folds of the strata, and running in its axis, where it forms reticulating strings. The whole quantity exposed occupies a length of about fifty yards, with a maximum breadth of six or seven inches. The iron ore is mixed with specks of copper pyrites; and in an attempt made to mine it, a considerable deposit of copper ore was found, from which some eighteen or twenty tons are said to have been taken. The locality is probably unimportant as a source of iron ore. Escott.

The contiguous townships of Madoc, Marmora, Belmont, and Seymour contain several beds of magnetic iron ore, some of which have been wrought to a small extent. On the eleventh lot of the fifth range of Madoc is a bed, from which ore was formerly raised and brought to the village of Madoc, where it was smelted in a blast furnace by Messrs. Seymour & Co., and yielded excellent iron. The bed appears to be enclosed in a soft black micaceous rock, and holds a course, which, as far as could be traced, is about east by south; while the slope of the bed, which is towards the south, is between seventy-five and eighty degrees. The greatest observed breadth of the bed was found to be about thirty feet, and it would probably average twenty feet. A material similar to the black micaceous rock which encloses the bed, appears to cut it diagonally at short intervals. In one portion, the bed is said to have been thus divided at distances of from three to ten feet, and in another there was an unbroken portion of fifty feet. The ore is black, fine grained, and apparently very pure. It is not only magnetic, but in parts possessed of magnetic polarity: these portions appear to run across the ore-bed, at right angles to it. Nodules of green radiating actinolite are disseminated in the ore, and yellow uranite occurs in small quantities in the fissures. On either side of the above-named lot, the ore is said to have been traced, westward on the twelfth lot of the fourth range, and eastward on the tenth lot of the sixth, and the ninth lot of the seventh range; the distance between the extreme points being about two miles. Madoc.

On the north side of Crow Lake, about 300 yards from the shore, on the twelfth lot of the third range of Marmora, magnetic iron ore is met with thickly imbedded in a pale green epidotic rock. An opening, which has been made here, exposes a breadth of from twenty to thirty feet, through which the ore is irregularly disseminated in lumps and masses, running with Marmora.

the stratification, which is nearly east and west, and apparently with a southward dip. The bed was traced for about 300 yards to a clearing, where it terminates in a sharp cliff. Portions of this ore, which were used at the Marmora furnace, were said to have been of excellent quality, and it is very free from pyrites. The course of this ore-bed, westward, would carry it to an intersection with the northwestward course of the big ore-bed of Belmont, next to be described: and the dip of the one being northeast, and the other south, it seems probable that they may be different parts of the same bed, in opposite sides of a synclinal.

Belmont. The magnetic ore formerly smelted at the Marmora iron furnace was obtained from the eighth lot of the first range of Belmont. This deposit, known as the big ore-bed, has usually been called 100 feet thick. It appears however not to be a single bed, but a succession of beds of ore, interstratified with layers of greenish talcoid slate and of crystalline limestone, occupying a breadth across the strike, and back from Crow Lake, into which it runs obliquely, of about 500 feet. Serpentine, chlorite, diallage, and a greenish epidotic rock are also met with in this association. The general strike of the strata appears to be about S. 35° E., and the slope towards the northeastward from 25° to 50°. Crystalline limestone overlies the mass; and the first hundred feet of the iron-bearing strata show a vast bulk of ore, often very nearly pure, the upper part of which chiefly was mined for smelting. The upper beds of ore contain an admixture of iron pyrites, from which the lower portion of the mass is free. The ore from a layer of thirteen feet thick at the base, seems superior to the upper portion, but was not mined until a short time before the works were abandoned. Many years ago a blast furnace was erected at the village of Marmora, for the purpose of smelting the ore from this deposit, and iron of a superior quality was manufactured. More recently different companies have, for short periods, made renewed attempts to smelt the ore, with very satisfactory results so far as the quality of the metal was concerned. The distance of the place from a shipping port was, however, found a serious obstacle to success, and the furnace is for the present abandoned.

Seymour. At Allan's Mills, on the twenty-fifth lot of the twelfth range of Seymour, a dome of Laurentian rock, of two or three acres in extent, protrudes through the fossiliferous limestone, and contains disseminated magnetic iron ore. The rock is in part a conglomerate, holding only small crystals and strings of the ore; but apparently overlying it, and with a dip to the southeast, is a rock made up of feldspar, pyroxene and epidote, holding magnetic iron in considerable abundance, for a breadth of about thirty yards. It is however doubtful whether the quantity is sufficient to be wrought to advantage. There are several other places in these townships where iron ore has been observed and mined to a small extent. One is on the ninth lot of the eighth concession of Marmora, where a fine grained and pure red hematite occurs in patches disseminated through the rock.

Among the altered rocks of the Eastern Townships, magnetic iron is met with, massive, or disseminated in crystals, and sometimes forming workable deposits. On the ninth lot of the ninth range of Sutton, there is a bed of dolomite, whose analysis has been given on page 613. It is twelve feet in breadth, and holds octahedral crystals of magnetite, which amount, in many specimens, to fifty-six per cent of the mass; corresponding thus to about thirty-eight per cent. of iron. The dolomite contains, moreover, a large amount of carbonate of iron, besides carbonate of manganese; and it is not improbable that this ore may sometimes be used to advantage for smelting with other ores. This iron-bearing belt is interstratified with a large thickness of magnesian limestone, in one part of which is an irregular bed of red hematite ore, from one to two feet in thickness. Magnetite also occurs on the second lot of the fourteenth range of Bolton, in minute crystals disseminated in a fine chloritic rock. The specimens contain a little more than one half their weight of the ore. A similar deposit is said to occur near the twenty-first or twenty-second lot of the fifteenth range of Orford. Large loose blocks of magnetic ore, sometimes half a ton in weight, are found on the second lot of the tenth range of Leeds. They are near a band of serpentine, and probably not far removed from the parent rock. The presence of magnetic iron, mixed with titanium, in the serpentines of this series of rocks, has already been mentioned on page 501, and will be again considered under the head of Titanium. The iron ores of the Eastern Townships belong, for the most part, to the species about to be described.

Sutton.

Leeds.

The anhydrous peroxyd of iron assumes very different forms. When uncrystalline, it is dark-red and earthy in appearance, constituting the varieties known as red hematite and earthy red iron ore. At other times it forms scaly masses made up of small crystalline scales with a metallic lustre, and is known as micaceous iron ore; while the varieties offering distinct crystals, or large crystalline faces, are known by the name of specular iron, from their brilliant metallic lustre. When in this form, it is dark steel-grey, or even iron-black in color; and granular varieties of it sometimes resemble magnetite, but are distinguished by their red powder, and by being slightly or not at all attracted by the magnet.

Red hematite.

This ore frequently replaces the magnetic species among the crystalline rocks of the Laurentian series. An important deposit of it is known on the sixth lot of the ranges C and D in the township of MacNab. It occurs near the Fall of the Dochart, and about a quarter of a mile from the shore of the Lac des Chats. The bed of ore, which is thirty feet in thickness, dips S. 17° W. at an angle of 70°, and rests upon crystalline Laurentian limestone; while it is limited at the top by a magnesian limestone,

MacNab.

belonging to the Calciferous formation. To the westward, the bed has been traced about one hundred yards; but to the eastward, it is concealed by a marsh. Specimens of the ore are however said to have been found in the soil a mile farther to the eastward. The ore is purplish-red and compact, but occasionally exhibits in its fracture a finely crystalline structure. It is very pure, containing only small disseminated portions of quartz and carbonate of lime. The analysis of an average specimen of this ore gave for 100 parts: peroxyd of iron 84·10, silica 4·00, carbonate of lime 8·80, water and loss 3·10. This is equal to 58·8 per cent. of iron.

Bristol. At Hudson's Wharf, on the Lac des Chats, on the second lot of the first range of Bristol, micaceous specular iron occurs in contact with a bed of white crystalline limestone, which is overlaid by reddish syenitic gneiss. The ore, which is partially mixed up with the limestone, has a maximum thickness of about six inches. A small bed of the same ore occurs in the overlying gneiss, at the south point of the bay, near the wharf; where it forms an interstratified bed, mingled with quartz. Neither of these deposits however are of economic importance.

Lake Nipissing. The name of Iron Island has been given to an island in Lake Nipissing, from the large amount of red hematite which is there met with. For a breadth of about forty yards along the cliff, on the east side, the rock holds portions of the ore of various sizes; sometimes running in strings of an inch or more in thickness, and at other times forming masses of more than half a ton weight, imbedded in the crystalline Laurentian limestones. Great quantities of the ore in rounded masses, from the disintegration of the limestone, are here scattered along the beach. At various other points on the island the ore is observed, either disseminated in the limestone, or covering the shore in rolled masses. It is finely granular in texture, of an iron-grey color, and apparently very pure. In the red feldspathic gneiss along the north shore of the island, magnetic iron ore is disseminated in considerable abundance.

The great beds of red hematite which occur at Marquette, in northern Michigan, belong to the Huronian series of rocks; but these, in Canada, have as yet presented only a single small bed of the ore, which is at the Wallace copper mine on Lake Huron (page 66).

Specular schists. The red hematite ores which belong to the altered strata of the Quebec group, have been described on pages 245 and 615, by the names of itabirite and specular schist. They are generally composed of small crystalline scales of the micaceous variety of the red oxyd, mingled with grains of quartz, and often with chlorite; these foreign minerals being present in very variable quantities, so that the schist is sometimes a rich iron ore, and sometimes so poor as to be of little value. The most southern locality observed in Canada is on the forty-fifth lot of St. Armand East, adjoining the south-eastern corner of Sutton. Here a bed, of which only five feet were visible, is interstratified with chloritic and epidotic rocks, the dip of the strata being to the eastward, at an angle of 84°. The bed was traced thirty feet, and then became covered up. A portion of the ore yielded 50·0 per cent. of peroxyd of iron, and another 54·8 per cent.: the mean of these would give 37·0 per cent. of iron. On the fifteenth lot of St. Armand West, and on the west side of the Pinnacle Mountain, very beautiful specimens of coarsely foliated specular iron are met with. Unlike the last, however, the ore here occurs, not in a bed, but in a transverse vein, with quartz, cutting argillaceous and chloritic slates. The ore appeared to form a bunch in the vein; and although fourteen inches thick in one part, it thins out rapidly in either direction, and is not of economic importance. **St. Armand.**

Several exposures of these iron slates occur in the township of Sutton. **Sutton.** The first to be mentioned is on the seventh lot of the ninth range, where the same bed is apparently repeated several times by undulations, which present three distinct anticlinal folds, showing exposures of ore, fifteen, eighteen, and fifty-seven feet in width. The thickness of the bed is probably about eight feet, and the proportion of iron varies considerably in different parts. A specimen from the western side of the lot contained only 24·0 per cent. of peroxyd. Another portion gave 39·0, and a third yielded of peroxyd of iron 38·07, insoluble matter 55·70, volatile 0·20, loss, consisting of alumina and magnesia 4·03; = 100·00. In the sixth lot of the ninth range of Sutton, is another exposure of the iron slate, at a distance of not much over one hundred yards from the last, of which it is perhaps a repetition. It here presents an anticlinal fold, spanning an arch of thirty feet, and has a thickness of about seven feet. In the southwest corner of the same lot, and near the line of the fifth, a bed of iron slate, six feet in thickness, is met with. A specimen from this gave 59·4 per cent. of peroxyd, equal to 41·6 per cent of iron. Again, on the fifth lot of the ninth range, and but a few yards from the last locality, a smoothly worn, nearly vertical bluff of the ore is exposed, with a breadth of twenty, by a height of fifteen feet. The slaty laminæ of this mass exhibit very curious contortions, and the rock often splits into curved plates. A portion of the ore from this mass yielded nearly 70·0 per cent. of peroxyd, which contains seven tenths its weight of iron, equal to 49·0 per cent.

In the tenth range of Sutton, two beds of the iron slate have been examined. In one of these, on the northeast corner of the seventh lot, a breadth of one foot of ore is exposed, which contained 56·0 per cent. of peroxyd. The other bed is met with on the northeast corner of the eighth lot, and has a thickness of seven feet. A specimen, which was regarded as an average, gave 45·0 per cent. of peroxyd. In the eleventh, and most northern range of Sutton, a bed of the iron slate, seven feet in thickness, occurs in the centre of the ninth lot. Two portions of it gave respectively 31·0 and 57·0 per cent. of peroxyd. This ore is very chloritic in its aspect; and the examination of a third specimen gave 47·4 of peroxyd, and 44·6 of insoluble residue; besides 2·1 per cent. of magnesia, together with alumina and a little lime. Near the south end of the seventh lot of the above range is an exposure of the ore, the thickness of which has has not been ascertained. It gave 41·0 per cent. of peroxyd.

Brome. The same iron slates are again met with in the adjoining township of Brome. On the eastern part of the first lot of the third range are three parallel exposures of the ore, the most western of which is about five feet wide, and is bounded on either side by glossy black slates. About two hundred yards to the east of this, is the second exposure, of which only three feet are seen; but a little to the southwestward, on the strike, a band of ore, supposed to be the same, shows a breadth of eighteen feet. This was formerly mined, and carried a distance of between thirty and forty miles to Troy, in Vermont; where it was smelted with an admixture of the magnetic ore, which there occurs in serpentine. About thirty yards from the eastern limit of the lot, a third exposure occurs, which has been mined for the same purpose as the last. The thickness of the bed is here about five feet, but it presents an anticlinal fold, which gives it a breadth of ten feet. Cracks occur in the fold, which are filled with white quartz; and both these and the joints of the ore are sometimes lined with films of green carbonate of copper.

On the second lot of the third range of Brome, and probably in continuation of one of the exposures just mentioned, is a bed of the iron slate, five feet in thickness. It is traversed by veins, which hold quartz, chlorite, and yellowish sphene, occasionally stained green by carbonate of copper. A specimen of this ore gave 4·10 per cent. of peroxyd. Another yielded peroxyd of iron, 45·4; insoluble, chiefly quartz, 52·5; volatile, 2·00; = 99·9. The latter equals 31·8 per cent. of iron. On the fifth lot of the fourth range of Brome, a band of iron slate crosses the Yamaska, just above the fall. It is eight feet thick, but is divided by a thin bed of chloritic slate, and holds strings and masses of quartz. On the sixth lot, on the line between the third and fourth ranges, the following section is seen:—

	Ft.	*in.*
1. Chloritic schist,	10	0
2. Specular schist,	1	0
3. Dolomite,	18	0
4. Chloritic schist,	90	0
5. Specular schist,	1	0
6. Chloritic schist and glossy argillite,	230	0
7. Specular schist,	3	0
8. Dolomite,	9	0
9. Chloritic schist and glossy argillite,	180	0
10. Specular schist,	0	6
11. Dolomite,	12	0
12. Specular schist,	0	6
13. Chloritic schist,	10	0
	565	0

The strata of the above section, which includes the whole dolomitic belt, are nearly vertical, and are given in their order from east to west. A thin layer of quartz runs with the bed No. 7, and shows stains of carbonate of copper, and flakes of talc. The ore of this bed was formerly mined, and sent to Troy in Vermont, to be smelted. The assay of two samples of it gave respectively 56·0 and 78·0 per cent. of peroxyd of iron. Another small excavation, from which ore was formerly mined for the same purpose as the last, occurs on the fourth lot of the fifth range of Brome, near its western limit. The bed of ore, which lies in chloritic slates, is five feet in thickness, laminated in structure, and divided by thin layers of granular quartz and chloritic slate. The ore is dark purple-red in color, and much richer in its aspect than most of those previously noticed. A specimen of it was found to contain 70·6 per cent. of peroxyd of iron. On the fifth lot of the fifth range, a bed of ore, which is probably a continuation of the last, is met with, but its extent has not been determined.

A bed of iron slate, two feet in thickness, is said to occur in chloritic schist on the fourth lot of the second range of Inverness; and it is probable that these ores, which are so abundant in the townships of Brome and Sutton, will be found in many intermediate localities. These slaty iron ores, as will be seen from the assays, although less rich than the ores of the Laurentian series, are sufficiently so to be smelted with advantage. The considerable admixture of silicious matter which they contain, will render it necessary to use some calcareous matter as a flux. In North Carolina, where similar ores, probably belonging to the same geological series, are met with, they are smelted, and are said to yield an iron which is convertible into steel of very superior quality. In Plymouth, Vermont, a specular schist, similar to those of Brome and Sutton, is mined; and it is mixed with the hydrous peroxyd or brown hematite, for the purpose of smelting. The only attempt as yet made to work these ores of Canada, is that just mentioned, in which they were carried to Vermont to be smelted with the magnetic iron of Troy. Small quantities of titanium are frequently found in these ores, as has been mentioned on page 501; and as small portions of this element in iron appear, from some late experiments of Mr. Mushet, to render it peculiarly fitted for the manufacture of steel, it is not improbable that its presence in these ores may give to them a peculiar value. **Inverness.**

The presence of small amounts of red hematite among unaltered palæozoic rocks in various localities, has been noticed on page 510. On the twenty-fifth lot of the tenth range of Bastard, there is an exposure of about thirty feet of horizontal strata, belonging to the Potsdam formation, and more or less colored by intermingled peroxyd of iron, which near the top is found in considerable abundance, through a thickness of about three feet; where it takes the form of a finely micaceous red iron ore, sometimes soft **Bastard** and staining the fingers, and at other times strongly coherent, and containing thin seams and scales of crystalline specular iron. In some parts lenticular masses of this pure hematite, of an inch or two in thickness, occur. Many years since an attempt was made to mine the ore for the supply of a blast furnace erected at Furnace Falls, but the supply was found to be insufficient. Similar indications of iron are also met with in the adjacent township of Lansdowne (page 93), and in Ramsay; and it is not improbable that in some parts of the distribution of this formation, the quantity of ore may be such as to be economically available; especially as deposits of this ore which are wrought in northern New York, are said to belong to the same formation.

The Clinton formation in the state of New York contains a bed of fossiliferous red hematite, which, in the extension of the formation into Canada, is represented by an impure ferruginous bed, noticed on page 314. Near Ancaster, however, a thin bed of the ore is exposed, which gave by assay 54·0 per cent. of peroxyd of iron. It does not yet appear that the ore in this formation in Canada is of economic importance.

Ancaster.

In the section of the Gaspé sandstones, given on page 395, it is mentioned that nodules of argillaceous carbonate of iron, or clay iron-stone, occur in some of the beds. Further examinations of these strata may show that, in some parts of their distribution, this important ore occurs in workable quantities.

Gaspé.

Limonite.

The ores which consist of hydrated peroxyd of iron are, for the most part, included under the specific name of limonite. This mineral, in its purest form, consists, in 100 parts, of peroxyd of iron 85·6, water 14·4. It is distinguished from the anhydrous oxyds by its inferior hardness, and its yellowish-brown powder. Limonite is never crystallized, but often fibrous in structure, and sometimes forms concretionary masses. To the purer and more solid varieties the name of brown hematite is often given, while the less pure and more earthy varieties are known by the names of bog iron ore and iron ochre. These latter often contain, besides admixtures of clay or sand, a variable proportion of organic matter in chemical combination. On page 512 will be found the description of an ochre of this kind, which contains not less than fifteen per cent. of an organic acid, and on the preceding page are given analyses of several bog ores; from which it will be seen that they sometimes include small amounts of oxyd of manganese, and of phosphoric acid, which last detracts from their value as iron ores. The more solid varieties of limonite, or brown hematite, have not been met with in Canada. The ochres will be farther noticed under the head of Mineral Pigments. Bog iron ore, which is of recent formation, and is found at or near the surface of the soil, is widely distributed throughout Canada; and as it is an important ore of iron, its principal known localities will now be indicated.

Bog iron ore.

On the shore of Lake Erie this ore is found in various localities, especially in the townships of Charlotteville, Middleton, and Windham. A smelting-furnace at Normandale in this region was formerly supplied with ore from Charlotteville, where it was mined on the fourth lot of the third range, and on the sixth, thirteenth, and fourteenth lots of the sixth range. In Middleton, the ore is known on the seventeenth lot of the first range north of the Talbot road; and in the third range, on Venison Creek. In Windham, it is met with on the twelfth lot of the fourteenth range. At Thamesville, on the Longwood road, between London and Chatham, indications of the ore were observed on the banks of Mill Creek, which falls into the Thames on the thirteenth lot of range B of Campden. The ore occurs at intervals for about a mile above the mouth of the stream, and probably in sufficient abundance to be worth working. **Lake Erie.**

In the seigniory of Vaudreuil, on the sixteenth and seventeenth west lots of Côte St. Charles, is a deposit of bog iron, which has been traced over an area of three acres, and probably extends much farther, as it is found in many other lots in the vicinity. The bed of ore has in some parts a thickness of four feet, and in one place a small brook exposes a section of it eight feet thick. The ore is also found in the sixteenth east lot of Côte St. Charles; and in the centre of the seigniory, on the west side of Côte St. Louis. Bog iron ore is said to occur in the adjoining seigniory of Rigaud, in Côte St. Guillaume, on the third concession; and has been observed in scattered fragments on the south side of the road, on the twelfth, thirteenth, and fourteenth lots. The analysis of these ores will be found on page 511: they are very pure, and contain about 52·0 per cent. of iron. **Vaudreuil.**

A bed of bog ore, about two feet thick, occurs on the twenty-first lot of the seventh range of Bastard, not far from Beverley, but its extent is not known. The same ore was observed on the twenty-first lot of the eighth range of Eardley, at Upper Rocky Point, where it forms a bed of six inches, made up of nodular masses. The extent of the deposit is not known. Analyses of the ore from these two deposits will be found as above. Other localities of this ore on the Ottawa are said to be as follows:—Templeton, on the Rivière Blanche, above McArthur's mills; Hull, on the fourteenth lot, of the seventeenth range; March, on Lake Constance; and in Fitzroy, near the Chats. **Bastard.**

In the Eastern Townships, bog iron ore occurs in considerable abundance in Stanbridge, on the thirteenth lot of the sixth, and the twenty-seventh lot of the seventh range, and probably in other parts. It is also met with in the adjoining township of Farnham. The ore from Stanbridge was formerly mined, and carried to Alburg in Vermont, where it was smelted to some extent. Another deposit of bog ore, said to be of some importance, occurs on the eighth lot of the twelfth range of Simpson. Other localities, apparently of less note, are the sixteenth lot of the ninth range of Ascot, **Stanbridge.**

the twenty-fourth lot of the third range of Stanstead, the twelfth lot of the fourth range of Ireland, and the seigniory of Lotbinière, at the mouth of the Grande Rivière du Chêne. In St. Lambert, in the seigniory of Lauzon, on the east side of the Chaudière, is a bed of bog ore about twenty inches in thickness, which has a breadth of thirty yards on the road, and was traced for sixty yards to the south-east, but may probably extend very much farther.

St. Vallier. This ore also occurs in several localities in the seigniory of St. Vallier, and in quantities which may become economically available. Two deposits were examined about a mile above the junction of the two branches of the Rivière du Sud. One was about 300 yards northwest from the mill on the main branch, about a mile and a quarter above the junction. It extended northward thirty yards, with a breadth of twenty-eight yards, and a thickness of about twenty inches. The second area, about forty yards farther west, was measured 1200 yards northward, with an average breadth of twenty-four yards, and a thickness of from twelve to twenty inches. Other beds of the ore are said to occur about two miles to the southeast of the main branch: and also to the northwest of the smaller branch, in St. Michel.

Green Island. Bog iron ore is found in abundance on the second concession of Green Island, on the land of Mr. Felix Avril. It occurs in patches of from three to eight inches in diameter, and from twelve to twenty inches thick, scattered at intervals of thirty or forty paces. These were traced, with a breadth of about 100 yards, across ten lots, in a southwest course, and in less abundance for half a mile in a contrary direction. In the seigniory of Villeray, about three miles west from Green Island River, on the land of Mr. Narcisse Marquis, there is a bed of ore about 270 feet long, and from twenty to thirty feet wide, with a thickness of from six to twelve inches. It also occurs in smaller quantities on several of the farms in the neighborhood. Again, in the seigniory of Cacouna, in the village of La Plaine, on the land of Mr. Stanislaus Roy, a small bed of the ore was observed, measuring fifty by fifteen feet, and four inches thick. A similar bed was also observed on the adjoining lot to the east. Traces of the ore have been met with in several other places in the seigniories of Green Island, Villeray, Cacouna, and Rivière du Loup, as well as in the townships of Viger and Wentworth. The ore-bearing tract in this region measures about twenty-five miles east and west, by five or six miles north and south. Whether the ore occurs here in sufficient quantities to warrant the establishment of a smelting-furnace is perhaps doubtful.

Saguenay. Small quantities of bog ore have been found on the east side of the Ha-ha River, about a mile from the Bay of that name, on the road leading to Bay St. Paul. It has also been observed in this region, on the land of Mr. Joseph Tremblay, in the second range of Bagot, beyond the river St. Alphonse. These localities are mentioned, as they may lead to the discovery of more important deposits in the vicinity.

The St. Maurice Forges, in the vicinity of Three Rivers, were for more than a century supplied with bog ore collected in that vicinity. One locality, now nearly exhausted, was in the Augmentation of Caxton, chiefly on the land of Mr. Pierre Boivin. About four miles to the northeast of this, in the fourth range of the fief St. Etienne, is a marsh covering about 1200 acres, from which during the dry weather of summer a good deal of ore was extracted a few years since: it occured scattered in irregular patches. Two and a half miles southeast from this, in the second range of St. Etienne, on the land of Mr. Louis Bellefeuille, is a bed, extending in patches from six to nine inches thick, over an area of thirty or forty acres, from which ore was extracted in 1852. The ore has also been obtained in considerable quantity from several localities in the adjacent seigniory of Pointe du Lac; and it is also said to have been brought from near Nicolet, on the south side of the St. Lawrence. Two analyses of selected specimens of the ore formerly used at the furnace, are given on page 511, and show 52·0 and 54·2 per cent. of iron. St. Maurice.

Between the St. Maurice and Batiscan rivers some important deposits of ore have been met with, especially in a triangular area of about six square miles, lying in the ranges of St. Felix and Ste. Marguerite, partly in the seigniory of Champlain, and partly in that of Cap de la Madeleine. Over this surface, the ore is scattered in irregular patches of from four to ten inches in thickness; and for several years large quantities were obtained for smelting at St. Maurice. The piles of ore obtained from several patches included in three fourths of an acre, were estimated by measure at 390 tons; while two other piles in the vicinity contained about 750 tons. Champlain.

In the seigniory of Champlain, and on the south side of the river of the same name, there is an area extending northeast, from near Richardson's mills, for a distance of nearly three miles, occupying about 1100 acres; and another parallel band on the northwest, covering about seventy-five acres. Over both of these the ore is distributed in patches or small beds of from three to twelve inches in thickness. The northeast portion of this reaches the Rivière à la Lime, in the seigniory of Batiscan, and has been wrought to supply the forges on the Batiscan river. To the east of this, river numerous patches of the ore are found in the seigniories of Batiscan and Ste. Anne de la Pérade; as also on the road between Portneuf and St. Basil, on the Jacques Cartier, at Cap Santé, and elsewhere. Batiscan.

Within four or five miles of the village of Industry, there are several places in which bog iron ore is met with. One of these is partly in the township of Kildare, and partly in the Augmentation of the seigniories of Lanoraie and Dautraye, comprising a superficies of about nine square miles; and it exhibits patches of ore in so many of the parts which have been Industry.

cleared of forest, as to lead to the hope that it may become profitable. Among other localities in this region, the ore is found on the line between the first and second ranges of Kildare, on the seventh and eighth lots; and on the seventh lot, on the road between the fourth and fifth ranges. Other localities where the ore was observed were in Côte Ste. Emelie, and Côte Ste. Rose; but these portions being still in part covered with wood, it is difficult to determine the extent of the ore, although it appears to be considerable. Farther to the east, this ore was also met with between the rivers Ste. Marie and Achigan, and in the seigniory of Lachenaye.

It will be seen from the preceding description that bog iron ore in considerable quantities is spread along the north shore of the St. Lawrence, from the vicinity of Montreal nearly to Quebec. Many of these deposits have been long known, and a furnace for smelting the ore was established in St. Maurice in the year 1737, where the manufacture of iron was continued until the year 1858. In 1831, according to Bouchette, from 250 to 300 persons were employed at the establishment, which was famed for the fine quality of its castings, and also for a superior wrought iron; but, owing to the growing scarcity of ore and charcoal in the immediate vicinity, the St. Maurice Forges were finally abandoned.

Radnor Forges.

The Radnor Forges have within a few years been erected at Batiscan, in the seigniory of Cap de la Madeleine, and are supplied with ore and charcoal from this and the adjoining seigniory of Champlain. The crude ore is brought to the furnace, partly by the workmen of the company, and partly by the farmers on whose land it is found. It is washed to free it from adhering earth, and then yields from forty to fifty per cent. of metal; about 2,000 tons of cast iron being now produced annually from between 4,000 and 5,000 tons of ore. The number of workmen employed at the Radnor Forges varies from 200 to 400; a great many hands being required at certain seasons, to dig up and bring in the ore, and to prepare and transport the charcoal.

The chief manufacture of the company has, of late, been cast-iron wheels for railway cars, for which the metal appears well adapted. A pair of car-wheels, with an axle, of this manufacture, were sent by Messrs. Larue & Co., the proprietors of the Forges, to the International Exhibition of 1862, which were said to have run 150,000 miles. Wrought iron is also made at this establishment; and a rolling-mill has recently been erected here, which furnishes iron for the manufacture of scythes, and nail-rod iron. Limestone, which is used as a flux for the ore, is obtained from the Trenton formation in the vicinity; and a refractory sandstone for the furnace hearths is obtained from the Grès Rapids, on the St. Maurice. This rock belongs to the Potsdam formation; and being here of a freer texture than in most other parts of the province, it is better fitted for resisting fire. Blocks of from twelve to fourteen inches thick, four feet long, and twenty inches wide, are found not to require renewal oftener than once in two years. A sand which is used for moulding is found in the neighborhood.

It will be seen from the preceding pages, that, with the exception of St. Maurice and Batiscan, but little has been done to turn to advantage the iron ores of Canada. The exportation of iron ores from Brome and Stanbridge to Vermont in former times, and more recently of those from Hull and Newborough to Pittsburg, has been mentioned; as also the furnace for smelting the bog ore at Normandale, and those erected at Madoc and Marmora. Canada, however, possesses in the crystalline ores of the Laurentian rocks, and in the iron slates of the Eastern Townships, inexhaustible supplies of rich ores of this precious metal, which may compare with those of the United States, or with Sweden. It is from these magnetite and red hematite ores, reduced by charcoal, that the finest iron of the world is manufactured; and it cannot be doubted that skilled labor and capital will one day make the iron mines of Canada great sources of national wealth.

LEAD.

The chief ore of lead is the sulphuret, commonly called galena, which, **Galena.** when pure, contains in one hundred parts, 86·6 of lead and 13·4 of sulphur. Galena almost always holds small portions of silver; and in some cases the amount of this metal is sufficient to render the galena valuable as a silver ore. The principal facts with regard to the occurrence of sulphuret of lead in Canada have already been given on page 516; and it now remains to notice in greater detail such of the veins as have been examined, and promise to be of economic importance. Well-defined veins holding galena are met with in many localities traversing the rocks of the Laurentian series; and in some cases they pass upwards through the overlying Potsdam and Calciferous formations, showing them to be younger than the latter. The veins at Bay St. Paul, mentioned on page 516, traverse the limestones of the Trenton group; and the great lead-bearing stratum of Wisconsin is newer than the Trenton group (page 623).

Several veins containing galena, are met with cutting the Laurentian **Bedford.** limestone in the township of Bedford. One of them, on the twenty-first lot of the eighth range, has a direction about east and west, with an underlie to the north, $< 80°$. It is four feet wide, and consists chiefly of calcspar, through which galena is disseminated in crystals or in seams, sometimes an inch or two in thickness. A shaft was formerly sunk here to a depth of twenty-five feet. Two other veins similar in character are met with near the line between the eighteenth and nineteenth lots of the same range, the one running N. 20° W., and the other N. 37° W. A little to the west of these, and on the nineteenth lot of the seventh range, on the property of Mr. Weston Hunt of Quebec, are five nearly parallel lodes, running northwest, and included in a breadth of a quarter of a mile. They traverse crystalline limestone, and include galena in a mixture of calc-spar and heavy spar. A specimen from one of them shows a breadth, across the vein, of five inches of solid galena. About a mile to the eastward of these lodes, there are others on land belonging to the proprietor of the last. Shallow trial shafts were, many years ago, sunk upon these, but the amount of lead ore obtained from them is not known. On lot thirteen of the fifth range of Bedford, Messrs. Foley & Co. of Montreal have sunk a trial shaft to a depth of sixteen feet, on a lode of six inches, the gangue of which is heavy-spar. The lode traverses the crystalline limestone, and enters the gneiss, in both of which rocks it holds good masses of galena.

Lansdowne. Similar veins of lead ore are found in Lansdowne. One of these, on the second lot of the eighth range, has been traced for a quarter of a mile, running nearly N. W. and S. E., and has an average breadth of two feet. Through the gangue, which is of calc-spar and heavy spar, galena is irregularly distributed in crystals and small masses; and it is also found disseminated in the crystalline limestone which forms the walls of the vein. Trial shafts were at one time sunk here; but the mine was abandoned. Another lode running N. 65° W., was subsequently found on the third lot of the same range. It traverses crystalline limestone, and has a breadth of from six to twelve inches. Through the gangue, which is calc-spar, galena is found in masses sometimes five or six inches in diameter. A trial shaft of fifty feet, which was sunk upon this lode in 1854, on the land of Mr. Buel, is said to have yielded sufficient ore to pay the expenses of sinking. A branch lode diverges from the main one near the shaft; and in the same neighborhood there occur four other lead-bearing lodes parallel with the main, the whole being included in a breadth of about 1000 feet. These run obliquely across the lots, and thus intersect the lands of several proprietors. On the fourth lot of the eighth range, Messrs. Foley & Co. have sunk a small shaft upon one of the lodes.

Ramsay. On the third lot of the sixth range of Ramsay, a mine has been opened upon a vein holding galena, and cutting a grey dolomite which belongs to the Calciferous formation. The beds of this are nearly horizontal; and they repose conformably upon the sandstone of the Potsdam formation, the outcrop of which is seen at a distance of about a mile from the mine, where it reposes upon the upturned limestone and gneiss of the Laurentian series. The lode has a bearing of from N. 50° W. to N. 55° W., with an underlie to the northeast of about a foot in a fathom; and it has a breadth of from two and a half to five feet, the ore-bearing part varying from eight to twenty-four inches. The galena occurs in a gangue of calc-spar, with small portions of iron pyrites, copper pyrites, and blende. A shaft of thirty-seven feet was sunk upon this vein, and about seventy-five fathoms in the plane of it having been excavated, twenty-six tons of ore, yielding eighty per cent. of lead, were obtained. Some portions of the lode were nearly destitute of ore, while in other parts its amount was estimated at nearly two tons to the fathom.

This trial was made in 1858, when a smelting furnace was built, and a ten horse-power engine erected for the purposes of a blast, and to remove the water from the mine. The influx of water was however so considerable, that this was found insufficient, and the mine was for a time abandoned. More recently however a new engine of fifty horse-power has been erected. About 105 fathoms southeastward from the main shaft, a counter-lode joins the main one, at an angle of about 20°; its course being nearly N.N.E. and S.S.W. At the junction of the two lodes, a shaft has been sunk in sandstone to a depth of twenty-one feet; and in the excavation, in which the united lodes attain a breadth of ten feet, there were obtained about ten tons of twenty per cent. ore. Other lodes holding lead ores, and nearly parallel with the ones described, have since been noticed in the vicinity.

A lead-bearing lode occurs on the twentieth lot of the eighth range of Fitzroy, which traverses a crystalline limestone containing mica and graphite. There is a well-defined vein, apparently about six inches wide, in which masses of galena are disseminated through a gangue of calcspar. The existence of galena in several other localities in the region of the Ottawa has been reported. Among others a vein of six or eight inches is said to exist upon the North Petite Nation River, on the seigniory of the Hon. L. J. Papineau. Galena has also been brought from the Gatineau and the Black River; in the former case, associated with purple fluor-spar. The distance between the lodes of Lansdowne and those of Bedford is about twenty-five miles; and as they bear for one another, it is not improbable that they may be continuous, or may belong to one group of veins. If the line which connects these two localities of lead ore were continued for twenty-five miles farther, it would traverse the St. Lawrence, and reach Rossie, in St. Lawrence County, New York; where a similar group of lead-bearing veins is found traversing Laurentian gneiss. These veins, although now abandoned, were at one time extensively wrought, and two of them afforded for a time great quantities of ore. One, in particular, yielded as much as $142 worth to a fathom. In this vicinity, at Redwood in New York, a lead-bearing lode is found cutting the Potsdam formation. The Ramsay lode belongs to another series of veins, which would run parallel to the Bedford and Rossie group, about forty miles to the north-eastward; and that of Fitzroy may belong to a third series.

Fitzroy.

Rossie.

Veins holding lead ore are found in several localities on the north shore of Lake Superior. Some of these traverse the granitic gneiss of

Lake Superior.

Granite Islet. the Laurentian series, as on Granite Islet, in Black Bay, where a vein of twelve inches in breadth carries a considerable quantity of galena in a breccia of fragments of the wall-rock, cemented by drusy crystalline quartz. This ore does not appear to contain much silver. Farther to the east, and at a mining location at the mouth of the Black River, to the north of the Slate Islands, the Laurentian rocks are seen near their contact with the Huronian series. Here a vein of quartz oocurs in the granitic gneiss. It runs nearly east and west, with a breadth of from one and a half to five feet, and holds galena and iron pyrites. The latter is more abundant near the shore; but about twenty rods beyond, in the hill, the galena predominates. According to Prof. Hadley, this ore is extremely rich in silver; the lead reduced from it containing from two to three per cent. of the precious metal. This galena, according to the same authority, contains a trace of selenium.

Black River.

In the description of the copper deposits of Lake Superior, mention will be made of several localities where galena occurs in small quantities, generally with blende or with sulphurets of copper. One of these is at Meredith's location, Mamainse, where three veins, holding considerable quantities of argentiferous galena, with vitreous copper ore, have been observed. These localities are in the upper copper-bearing rocks. In the Quebec group of Eastern Canada, which is regarded as their equivalent, ores of lead have been occasionally met with associated with the copper deposits of the region whose distribution and relation to the stratification will presently be described. In these localities galena is found in small interstratified masses or layers. One of these is on the fifty-first lot of the twenty-first range of Upton, where irregularly distributed patches of fine-grained galena, from one to four inches in thickness, occur in the copper-bearing magnesian limestone (page 712). They are sometimes distinctly interstratified with the rock, and overlaid by portions of copper pyrites. Galena occurs in similar masses, also with copper pyrites, and with a little blende, on the thirty-second lot of the fifth range of Acton. A like variety of fine-grained galena is found with copper pyrites on the ninth lot of the ninth range of Ascot. These ores of lead contain but little silver. Although the galena in none of these deposits appears to be in workable quantity, its presence in interstratified masses is not to be overlooked in a region where the numerous deposits of copper ore, which occur under similar conditions, are occasionally found to be of very great extent and importance.

Mamainse.

Upton.

Acton.

St. Armand. At Cook's Corner, in St. Armand, a vein of white quartz running with the strike, cuts the black slates and limestone of the region (page 240). It has a breadth of five or six inches, and contains small portions of galena, with a little copper pyrites and blende. The lead of this ore was found to contain a notable proportion of silver.

Veins holding lead ore have been found in the slates which belong to the Upper Silurian or Devonian strata, whose position to the southeast of the Quebec group is defined on page 709. One of these localities is described on page 517. The galena is here associated with native gold, mispickel, and sulphurets of iron and zinc, both containing gold. Another locality is at Moulton Hill, on the fifteenth lot of the fourth range of Ascot. Here a vein of white quartz, about four and a half feet wide, **Ascot.** occurs in a black shale, which is also traversed by numerous small seams of quartz. The galena is here, as at Vaudreuil, associated with mispickel, and is argentiferous. It is too sparingly distributed in the vein to be of importance as an ore of lead, although it may perhaps be wrought for the silver, of which it contains a considerable proportion.

A similar quartz vein occurs in black slates of the same age as the last, **Owl's Head, Potton.** on the eighth lot of the eleventh range of Potton. It is on the shore of Lake Memphremagog, and is described as being about ten feet wide. The galena is however confined to a small portion of this breadth; from which fine specimens of solid ore, two or three inches in thickness, have been extracted. Little is however as yet known of the extent of this deposit. The ore, like that from the last two localities mentioned, contains silver; and this fact, together with the presence of gold in one of these, leads to the expectation that the upper rocks of this region may, when farther explored, become important as sources of the precious metals.

The veins holding galena, which occur at Indian Cove, and at Little Gaspé Cove, have been noticed on page 400. Attempts are said to have been made, before the conquest of the country, to mine for lead at Little Gaspé Cove; and others have lately been made by Mr. George Desbarats, and since by Mr. C. C. Closter. The lode occurs in a mass of stratified limestone, which dips about S. W. $< 24°$, and rises northward into a hill 700 feet in height, which constitutes Gaspé promontory. It has a breadth of about eighteen inches; and is composed of calc-spar holding masses of galena, together with small portions of blende and copper ore. A trial shaft was sunk here to the depth of twenty feet upon the main vein; from which, and from several smaller parallel veins in the vicinity, about twenty tons of sixty per cent. ore were recently obtained. Besides the two localities already mentioned, galena has been observed in veins in several other localities in the limestones on the south side of Gaspé Promontory; and also on the north side, in a vein which may perhaps be a continuation of that of Little Gaspé Cove. Small quantities of galena have been found in veins in the limestones at Percé; and also at the Ance Cousin, in a vein cutting the sandstone, in the vicinity of the greenstone dyke mentioned on page 402.

COPPER.

This metal occurs in Canada in the form of native or metallic copper; the workable deposits of which are confined to the rocks of the Upper Copper-bearing series on Lake Superior. The three sulphuretted ores are however, more abundant, and widely distributed. They are, first, copper glance, or vitreous copper ore, which is a simple sulphuret, consisting, in its purest state, of copper 79·8, sulphur 20·2. From its blackish-grey color, this mineral is often incorrectly called the grey sulphuret, or grey ore; but it is not to be confounded with the tetrahedrite, which is also designated grey copper, or fahlerz, and is a comparatively rare ore of copper and antimony, not known in Canada. The second ore to be noticed is the erubescite or phillipsite. This, from the color which its surface assumes by exposure to the air, is known by the different names of purple copper, variegated copper, and peacock or horse-flesh ore. In its purest form it contains from fifty-six to sixty-two per cent. of copper, the remainder being sulphur and iron. The third ore to be mentioned is chalcopyrite, or yellow copper pyrites, known also by the names of pyritous copper and yellow copper ore. Like the last, it is a double sulphuret of copper and iron, the purer varieties of which contain from thirty-two to thirty-four per cent. of copper. It is however often mixed with iron pyrites.

Copper ores have been observed in several localities among the rocks of the Laurentian series. In North Burgess, on the second lot of the ninth range, copper pyrites has been met with in three places, within a distance of a few hundred feet, in the crystalline limestone. So far as the slight excavations show, it seems to occur, not in well-defined veins, but in irregular masses, or in strings throughout the rock. Some of these are, however, four or five inches in diameter. The ore is generally pure and crystalline, mingled with a little calcareous spar, and occasionally stained with blue and green carbonates. An average specimen of one of these masses gave 27·5 per cent. of copper. The same ore is said to occur, under similar conditions, in the limestone, on the fifth lot of the eighth, and on the first lot of the sixth range of North Burgess.

Burgess.

Bastard.

Small quantities of copper ore were some years since found on the twenty-fourth lot of the tenth range of Bastard, near to where a bed of conglomerate is interstratified with the Laurentian limestone, as described on page 31. Several veins of calc-spar, one of them two or three inches wide, here intersect the strata, and a shaft of twenty feet, and two others of seven or eight feet, were sunk. It is said that a vein of ore, an inch or two in thickness, was visible near the surface; but the portions now exposed contain only small disseminated grains of copper pyrites.

Considerable deposits of copper pyrites have also been observed in the township of Escott. One of these is on the seventh lot of the second range, and is associated with a bed of magnetic oxyd of iron about six inches in thickness, which is interstratified with gneiss. The mass of copper ore was said to be lenticular in shape, and to have been traced continuously for about twelve feet, with a maximum thickness of ten inches. It consisted of nearly pure copper pyrites; containing in parts, however, thin veins and grains of calc-spar, together with portions of iron pyrites. This increased in amount towards the northwest side, into which the copper ore appeared to run in small strings for short distances. About twenty tons of rich copper ore were quarried from this place; when the mass seemed to be exhausted, and the working was abandoned. The iron pyrites from this locality contain traces of cobalt. Another deposit of copper ore is described as existing on the sixteenth and seventeenth lots of the second range of Escott; and, according to the description of Mr. Macfarlane, it occurs in a vein, or interstratified bed, running northeast, and traversing a micaceous schist. It consists of orthoclase, with quartz, tourmaline, and a little mica, and has a thickness of four or five feet, including about fifteen inches of solid copper pyrites, mingled only with some iron pyrites and quartz. This vein is seen in the roof of a drift which has been made here. About eighty fathoms to the southwest, in the direction of the strike, is another opening, said to contain a vein three feet in breadth, and to include copper and iron pyrites with tourmaline, quartz, and feldspar. These interesting localities require further investigation. Other deposits of copper ore probably occur in this region, since several rolled masses of copper pyrites have been found on the shore of Gananoque Lake; one of which, weighing seven or eight pounds, is very pure and crystalline, and closely resembles that found in the first described locality in Escott. Escott.

In the augmentation of Lanoraie and D'Autraye, on the left bank of the Assumption River, and about three miles above the point where this enters the fifth range of Kildare, an evenly bedded mass of micaceous gneiss, dipping N. 44° W. $<$ 26°, is cut by a vein running N. 24° W., which consists of calc-spar mingled with pearl spar, and has a breadth of about nine inches. Three reticulating strings of iron pyrites, with a little copper pyrites, run through the vein; and small portions of these minerals, with others of blende, are observed sparingly scattered through the spar of the vein. A shaft, with a breadth of about nine feet, has been sunk to a depth of sixteen feet on this vein, which appears pretty uniform in character throughout, and exhibits, on either side, numerous strings or leaders of an inch and less in thickness, holding copper pyrites, and sometimes intersecting, which run into the main vein. The quantity of ore in this locality does not appear sufficient to warrant farther exploration; yet the presence of such a well defined metalliferous lode in this region is not without a certain interest. Lanoraie.

Among the copper-bearing veins on Lake Superior, those near the Black

Lake Superior.

Black River.

River, which are described as cutting a stratified granitoid gneiss, composed of red feldspar and vitreous quartz, are supposed to belong to the Laurentian series. They contain in a gangue of quartz, sometimes with calc-spar and fluor spar, small portions of yellow and vitreous copper ores, with a little molybdenite, blende, and galena, the latter sometimes argentiferous. Copper-bearing veins in a granitoid rock, probably Laurentian, are also described as occurring on the Dorée River, in Michipicoten Bay; but the principal copper veins at this location are in greenstone and slate, supposed to be Huronian; and the slates in which some of the copper veins of the Black River region occur, are perhaps of the same age. It would appear that both of these localities are at the contact of the Laurentian and Huronian rocks.

Dorée River.

The copper deposits of the Huronian series, and their relations to the stratification, have already been described in a general way on pages 59 and 515. The few examples of copper veins in the rocks of this series on Lake Superior, just alluded to, will be mentioned in a more detailed manner when describing, farther on, the copper deposits of that region, which belong for the greater part to more recent rocks. The most important deposits of copper in this series are met with on the shores of Lake Huron, where the Bruce Mines were discovered in 1846, since which time ores of copper have been found there in a great many other localities. Scarcely any large area throughout this region is destitute of copper-bearing veins, the gangue of which is generally white quartz, sometimes with pearl-spar and sulphate of barytes. None of these have, however, as yet been wrought to any considerable extent, except those of the Bruce Mines, and the adjoining locations.

Bruce Mines.

The copper-bearing veins of the Bruce Mines occur along the crown of an anticlinal fold, and traverse a mass of interstratified greenstone, or diorite. The veins, which are numerous and generally parallel, have a gangue of quartz, occasionally mingled with pearl spar and heavy spar. The ore is chiefly copper pyrites, although near the surface both the vitreous and variegated sulphurets were met with. Two of the lodes have been wrought, and have an average breadth of from two to four feet. The proportion of ore contained in these veins is very large. From the results of a careful examination made in 1848, by sampling the rough ores which had been raised, and by borings into the lodes, both at the surface, and at various depths down to twelve fathoms, it was computed that about 3,000 square fathoms of these lodes contained an average of six and a half per cent. of copper. The deepest working is now at fifty fathoms from the surface. The total quantity of ore raised from this mine, since its opening in 1847, is stated to be about 9,400 tons of eighteen per cent. In 1861, thirty-five men were employed at the mine, and 477 tons of eighteen per cent. ore were raised. In 1862, the produce was 380 tons. Smelting works were at one time erected at the mine, by its proprietors, the Montreal Mining Company. Bituminous coal for the purpose of fuel was brought from Cleveland in Ohio, and laid down at the mine at a cost of four dollars the ton. The attempt to smelt the ores on the spot was however abandoned, and they are now shipped in part to Baltimore, and in part to England.

Adjoining the Bruce Mines location, to the northwest, and on the lands of the Montreal Mining Company, is the Wellington Mine, which is leased to the West Canada Mining Company. The veins at this point resemble those of the Bruce, of which they are probably a continuation, but sometimes attain a width of ten feet. They are continued into the adjoining location, which is known as that of Huron Copper Bay, and is worked by the same company as the last. The ore obtained by this company from the Wellington mine, from 1857 to 1862, is stated at a little over 5,700 tons, averaging twenty per cent. In 1861 this mine furnished 1,175 tons, and the Huron Copper Bay mine 1,300 tons. The deepest shaft at the Wellington mine, in 1861, was twenty fathoms, and the number of men employed was about 260. In 1862, it yielded 1277 tons of ore. **Wellington Mine.**

What is called the Wallace Mine is on the shore of Lake Huron, about a mile to the west of the mouth of White-Fish River, and on the north side of a great bay. The strata here consists of quartzose and chloritic slates, dipping northward at a high angle, and including a large mass of greenstone, running with the strike. Strings and bunches of copper pyrites are found in some abundance, both interlaminated with the schists and disseminated in the greenstone. In 1848, a shaft was sunk to a depth of six feet in the chloritic schists, and a quantity of copper pyrites obtained; together with an arsenical ore of nickel, which was found in small ramifying veins adjacent to the southern wall of the mine, and will be further described in speaking of that metal. According to the report of Mr. O. B. Dibble, a vein of from six to sixteen feet in width was traced for half a mile, and ten tons of copper ore were raised from the shaft. The working of the mine has since been abandoned; although the presence of a rich ore of nickel should, even in the absence of large quantities of copper, encourage further trials. A mile and a half farther to the east, near the base of the hills, two veins, of ten and sixteen feet, were observed, similar in aspect to that of the Wallace Mine, and holding iron pyrites, with a little yellow copper ore. Adjoining this location to the eastward, a second one, in which were found three similar veins holding yellow copper ore, was taken by the Upper Canada Mining Company, who were also the explorers of the Wallace Mine. **Wallace Mine.**

About ten miles to the west of the mouth of the Spanish River, the same company acquired another location, which embraced a portion of the main land and a few islands adjacent. One of these, to the west of the

Spanish River.

location, is said to be traversed, near its southern extremity, by five well-defined quartz veins, which run in greenstone, and are from one to two and a half feet in breadth. One of these contained a mixture of yellow and variegated copper ores; while in the others the vitreous ore occurs in strings and grains disseminated through portions of the veins, which are stained throughout by green carbonate of copper. These veins run nearly eastward, showing however a slight convergence, which if continued would cause them to unite in a larger island about 200 yards to the eastward. In the face of this was observed a vein of quartz, four feet in breadth, running also east and west, and supposed to be the continuation of the veins just mentioned. A mile farther to the east, on the south shore of the island, a quartz vein two and a half feet wide, occurs in a cliff of forty feet, containing considerable quantities of copper pyrites, and stained with green carbonate. It was traced for about a quarter of a mile. Several other veins, similar to these, are seen upon the islands and also upon the mainland. Three of the latter were found to contain yellow copper ore. Another lode is described as running northwest, with an underlie to the north-east. It corresponds in dip and strike with the slates which form the walls, but appears to be a true vein, and contains, in a gangue of quartz and pearl spar, considerable quantities of copper pyrites. Delicate crystals of what appears to be rutile also occur in druses in the vein. Quartz veins holding copper ore were also observed in two localities in the Rivière aux Sables, about three miles back from the mouth of Spanish River.

Echo Lake.

On the north side of Echo Lake, about three miles from Lake George, the Huronian quartzites are seen interstratified with the slates and conglomerates of the series; and numerous veins of quartz, from one to five feet in breadth, are found cutting the strata. These veins contain yellow copper ore, and more rarely the vitreous and variegated species, in a gangue of quartz, sometimes with pearl spar, and it is said with carbonate of iron. They are described as running nearly west, with a high dip to the north, and traversing alike the chloritic slates and the quartzites of the formation. Some years since an opening was made, and a few tons of ore were raised; but the working was abandoned. The vein which was wrought runs nearly east and west, and has a thickness of about three feet. On the east branch of the Caribou River, which traverses the location and falls into Echo Lake, several other veins, from two to four feet in thickness, and containing copper ore, have been observed. Another vein of two feet in width, composed chiefly of pink calc-spar, is seen at the eastern extremity of the bluff near the river, which flows into the east end of Echo Lake; and still another vein, holding a little yellow copper ore, is described as occurring in the limestone rock at Limestone Point, on this location.

A mine has been opened on Root River, by Mr. A. Rankin, on what is called the Emerald location. Here a nearly vertical vein is described as occurring in greenstone, and running N. 75° W., apparently with the strike of the rocks. Two shafts have been sunk within a distance of about a hundred yards, and from each a considerable amount of yellow copper ore has been raised. The western shaft, when examined, had been sunk thirty feet, and presented the ore imbedded in soft greenish material, which has the aspect of a chloritic slate. At a depth of seventy feet however, this is said to be almost entirely replaced by quartz. The eastern shaft at a depth of fifty feet showed the vein to have a breadth of more than three feet, with an increase in the quantity of copper ore, the gangue of which was a mixture of quartz and a chloritic substance. **Root River.**

Small portions of yellow copper ore are met with in many places, disseminated in the slates, on the lower lakes of the Maskinongi; and both there and in the region around Lakes Matagamishing and Wahnapitaeping, the various rocks of the Huronian series are traversed by numerous quartz veins, in which iron and copper pyrites are often met with. The greenstone to the north of White-Fish Lake, as already described on page 595, was found to contain disseminated small portions of the sulphurets of copper and iron, with traces of nickel, showing the distribution of these minerals throughout the region; and numerous quartz veins, for the most part however holding only iron pyrites, were met with on the lower lake of the White-Fish River. A promising copper lode is said to exist immediately to the west of Shibahahnahning, but little is known with regard to it. **Maskinongi.**

Indications of copper ore are met with in a great many other places throughout this region, especially on the Mississagui River. Besides the disseminated copper pyrites observed at various points in the greenstone, the following localities have been noticed. Half a mile above the Hudson Bay Company's post, granitic dykes or veins, running N. 24° E., contain small portions of copper pyrites. The same ore occurs in small calcareous veins, a mile below the Pakowagaming River, which run N. 70° W.; and in a vein of quartz and bitter spar, having nearly the same direction, and a mile and a half above the same river. Copper pyrites occurs at the second fall of the Mississagui, in a similar vein, two inches in breadth, which traverses greenstone, and runs N. 50° W. At the east end of Lake Wabiquekobing, the same ore occurs in a two-feet vein of quartz, running N. 84° W.; and in the north portage to the same lake, within twelve or fourteen chains of the Mississagui, is a similar quartz vein, from one to two feet wide, which holds yellow copper, and runs N. 15° W. Like the last two, it cuts greenstone. At the fourth fall is a vein of quartz and bitter spar, a foot wide, with copper pyrites. It runs N. 55° W., and is in quartzite. At the upper end of the portage around this fall, the quartzite is also traversed by several quartz veins holding copper pyrites. The principal one is from one to two feet in width, and runs N. 72° W. At **Mississagui.**

the Grand Portage, on the Mississagui, numerous veins are met with, having a general bearing of about N. 60° W. The largest, which is at the foot of the portage, is from one to three feet in width, and consists of quartz, stained red by scaly hematite, which also discolors the adjacent greenstone. It contains strings and spots of copper pyrites. Near the head of the portage a vein of bitter spar, holding copper pyrites, traverses both the slate and the quartzite. Most of the principal veins here occur in the greenstone, but also run into the other rocks of the series. At the turn of the river, three miles above the Grand Portage, on the right bank, the greenstone is intersected by a calcareous vein, two or three feet wide, which holds portions of copper pyrites, and runs N. 70° W. At the eighth fall of the river, several veins of quartz are seen in the slate conglomerate. The main ones have a width of from one to two feet, and run from 67° to 77° N. of W. They however exhibit only traces of copper.

Lake Superior.

The copper ores of Lake Superior occur, with some few exceptions, in a group of strata which are more recent than the Huronian series, and have been described in the fifth chapter, as the Upper Copper-bearing rocks. They are regarded as of the age of the Quebec group, being the inferior portion of the Lower Silurian series: and they are divided into two parts, both of which are intersected by numerous metalliferous veins, whose general characters have been noticed on page 74. These veins contain the sulphurets of copper, associated with blende, galena, and native silver; and more rarely with ores of nickel, cobalt, uranium, molybdenum, and a little gold.

Mines of the south shore.

The most important copper deposits of this group, however, contain the metal in the native state. Of this kind are the mines on the south shore of Lake Superior. As described by Prof. Whitney, the native copper there sometimes occurs in true veins, which cut the strata, and have a gangue of quartz, calc spar, prehnite, and more rarely of datholite. These veins, according to him, occur chiefly in the finer-grained and somewhat amygdaloidal traps or dolerites; but they may be traced across the intercalated beds of sandstone, conglomerate, and crystalline greenstone. They seldom however extend any great distance in the sandstone, where the gangue is generally calcareous; and neither in this rock nor in the crystalline greenstone are they very rich in copper. The width of the productive veins is from one to three feet; and occasionally, for short distances, much greater. In the Keweenaw Point region, where these veins prevail, their underlie seldom varies very much from the perpendicular, and their direction is a little north of west. In some parts, however, the metal is found disseminated in the beds of trap; and more rarely, in the sandstone or conglomerate. In one case, at Copper Falls, copper forms the cement or matrix of a bed of conglomerate. Large and small masses of native copper are met with in the trap, without any connection with a vein or fissure, and sometimes unaccompanied by any vein-stone. Such metalliferous beds of trap are common in the Ontanagan region; and they constitute the whole of the workable deposits of the Portage Lake district, where great beds of an earthy amygdaloidal rock are found to be richly impregnated with native copper for distances of a mile or more. Epidote is frequently associated with the copper, both in the veins and in the amygdaloidal beds. In many cases, the copper forms what are called contact deposits, between the beds of trap and those of sandstone or conglomerate. These are probably, in some cases, veins segregated in fissures running with the stratification; but more frequently they belong to the same class with the beds just described. Certain of the sedimentary beds thus impregnated with native copper, are often designated as volcanic tufa or volcanic ash. From whatever source derived, however, the amygdaloidal rocks were deposited from water; and the copper which is disseminated in them, as well as in the sandstones and conglomerates, was separated by chemical processes from aqueous solutions, either contemporaneously or by subsequent infiltration. There appears to be no doubt that the traps which are interstratified with the sandstones and amygdaloids of this region, are eruptive rocks; and the sedimentary material of which the amygdaloids and tufas are composed may perhaps have been, to a greater or less extent, erupted in the form of volcanic mud, as many geologists suppose. This origin of the sediment has probably, however, no connection with the source of the copper; inasmuch as in the Quebec group, which is regarded as the equivalent of this series, and which over great areas. is destitute of intrusive rocks, the sulphurets of this metal, and even native copper, are found disseminated throughout limestones, diorites, slates, and quartzites.

Cupriferous beds.

Amygdaloids.

The investigations of the copper deposits along the north shore of Lake Superior have been much less minute and extended than those on the south side. A preliminary examination of the region was however made by the Geological Survey in 1846, and from that time until 1850, numerous explorations were made, with a view to the establishment of mining companies. From the results of the survey in 1846, and of a partial examination in 1861, together with the published reports of the early explorations already mentioned of Messrs. Forrest Shepherd, Hadley, Cobb, Bristol, Dibble, and others, as well as from notes kindly furnished by Mr. J. S. Willson, who has spent much time in exploring that region, and also by Mr. Hugh R. Fletcher, now and for many years connected with the mining interests of Lake Superior, the following notices of the principal mineral deposits of that region have been compiled.

North shore of the lake.

Beginning to the eastward, along the south shore of Bachewanung Bay, is a location of the Upper Canada Mining Company, which exhibits beds of amygdaloid and compact trap, with red sandstone and conglomerate. The last, according to Professor Hadley, contains boulders which are

Bachewanung Bay.

themselves of a conglomerate rock, consisting of red, yellow, and dark colored jaspers, imbedded in a uniform quartzose mass, and identical with the jasper conglomerate of Lake Huron. The hills in the rear are described as gneissic, with chloritic and hornblendic slates, traversed by quartz veins, in which molybdenite occurs. The amygdaloidal trap contains in its cells calc-spar, agate, and portions of vitreous copper ore. Large veins of calc-spar are found cutting the trap and sandstone strata. They however generally contain but little copper ore, which is chiefly in the rock, or in small strings leading to the principal veins. A considerable deposit of manganese ore, which will be described under its proper head, occurs on this location. At the east end of the bay, and about a mile from the shore, a perpendicular cliff, facing the bay, exhibits on its surface great adhering masses of a quartzose veinstone, which hold specular iron and vitreous copper ore, and are stained with green and blue carbonates of copper. At the base of the cliff is a vein eighteen inches wide, holding vitreous and variegated copper ores. Small veins containing portions of these ores are also found on many of the streams which fall into this bay, and the region may not improbably become a valuable mining district.

Mamainse.

From the north side of Sand Bay to the south side of Mica Bay, along a distance of about twenty miles, bands of tufaceous rock occupy the greater part of the shore line. About mid distance is the promontory of Mamainse, where explorations have been made on a considerable scale by the Montreal Mining Company. The following is a partial section of the strata at this place, as observed, in descending order, from the northwest extremity of the bay of Mamainse, inland. The dips are to the westward, at from 25° to 35°, and the rocks are very unevenly bedded. I. Alternations of trap and tufa, with a bed of conglomerate sandstone, the whole occupying a breadth of 300 yards. Large veins of calc-spar, quartz, and laumontite occur in the trap, and sometimes hold small portions of native copper and silver, with galena. Native copper is found in the vesicles of an amygdaloidal bed. II. Argillo-arenaceous beds, passing in some cases into a fawn-colored jaspery rock, and in other parts into mottled argillaceous sandstone, the whole occupying a breadth of 220 yards. III. Crystalline and amygdaloidal traps, with a bed of conglomerate, occupying together a breadth of 440 yards, and rising to an elevation of 300 feet; the lower parts being apparently tufaceous. This includes the workable deposit of copper. IV. A very coarse syenitic conglomerate, forming, like the last, a ridge, and having a breadth of 160 yards. The whole section probably represents a thickness of about 2000 feet. According to Dr. Dawson, to whom this description is due, the principal deposit of native copper occurs in a fissure running nearly north and south, along the summit of the ridge of hard semi-crystalline greenstone, III. The greatest

Section of strata.

breadth of this fissure is about six inches; and in some parts it is nearly filled with native copper, which occurs in a vein-stone of calc-spar and quartz. A shaft was sunk here to the depth of twenty-seven feet, without galleries, and yielded about a ton of native copper; the largest mass weighing 600 pounds. The shaft was sunk upon an excavation, which seems to have been the work of some aboriginal miners. A little to the west of this, the vein of native copper divides into two parts. These, like many other veins along this coast, are marked by depressions or trenches, resulting, according to Dr. Dawson, from the effects of erosion by the waters of the lake, at a former period, acting upon the soft materials of the veins. They are often regarded as excavations of ancient miners; but these, which are also frequently met with, are distinguished by being surrounded with broken fragments of veinstone, along with which are occasionally found stone hammers. These are merely rounded pebbles of hard rock from the beach, around which shallow grooves have been made, to hold the withes used as handles. Some of these hammers measure from five to twelve inches in their longest diameter. About a hundred yards from the shaft, excavations have been made at the intersection of two veins, one running north-west and the other north. The former is unproductive; but the latter, which is six inches in width, contains small masses of variegated copper, and a little copper pyrites, in a gangue of quartz and calc-spar. About thirty yards farther to the east is another vein, running northeast, and wider than the others. It is very irregular in its width; and it contains, besides the two ores just mentioned, a little native copper. At the place where it has been opened, one of the walls of the vein is of amygdaloid, and the other of compact trap; indicating apparently a fault in the strata.

Native copper.

Ancient workings.

On the north side of the bay at Mamainse, a vein of calc-spar, three or four feet wide, rises from the water, cutting the upturned strata, and after crossing a part of the location of the Montreal Mining Company, appears on the adjoining one belonging to the Quebec Mining Company, where it was found by Mr. Fletcher to contain sulphurets of copper in considerable quantity. On the northwest corner of this location, a vein of calc-spar rises from the shallow water of the lake, and is seen on the shore cutting an inclined band of conglomerate. This vein is described as containing argentiferous galena and copper pyrites. On the Meredith location, belonging to the Montreal Mining Company, three veins of calc-spar and laumontite contained variegated copper ore and galena. The lead from the latter yielded thirty ounces of silver to the ton. An open cutting, twenty feet long and four wide, supposed to have been made by early French explorers, was found upon this vein, near the lake; and when discovered a few years since, the marks of the drills were still visible upon the rock. Other pits, apparently of a similar origin, were found several hundred feet to the east of the cutting, on what appeared to be another small vein, in which

Meredith location.

no ore could be detected. The beds of tufa in this vicinity sometimes contain native copper in fine grains, and in pieces an ounce in weight. At Mamainse also occurs the vein of uranium ore described on page 504. It is evident, from these abundant metalliferous indications, that this locality is deserving of further and careful exploration.

Pointe aux Mines.

At Pointe aux Mines, eight miles to the north of Mamainse Island, several interesting veins are met with; and trials of some of them were made a few years since by the Quebec Mining Company. At the base of the point, according to Mr. Willson, a shaft has been sunk to the depth of seventy feet, on a small vein running east and west. Its gangue consists of calc-spar, with quartz and mica, containing small quantities of native copper with the yellow and variegated sulphurets, and occasionally small scales of native silver. About 120 fathoms north of this shaft, on the pathway leading to the miners' houses, are two parallel veins, from three to four feet wide, and four or five yards asunder. They exhibit, at the surface, a large amount of gozzan, with some green carbonate and vitreous copper ore. About half way down the point, and eighty fathoms from the water, at the foot of a bluff, occurs a vein, eight or ten inches wide, which contains a considerable proportion of vitreous copper ore, and zinc blende. Near to the end of the point, on the south side, a similar vein is found, which, in addition to blende and vitreous copper, contains small amounts of copper pyrites. The ore, which is unmixed with gangue, hangs from the west wall; while an open space of four or five feet intervenes between it and the east or foot wall, which is at the level of the lake. It would seem probable that this space was once filled with some vein-stone, which has been washed out by the waters of the lake. Some early miners, probably the French, had blasted out a considerable quantity of the ore from this vein; and about three tons of blende, left by them, are said to have been found in the chasm.

Mica Bay.

On the north side of the Pointe aux Mines, in Mica Bay, the quartzose gneiss is described by Mr. Willson as being overlaid successively by a bed of grey tufa, one of greenstone, and one of a reddish-brown tufa, all dipping to the north at an angle of about fifty degrees. Between the greenstone and the underlying tufa, were found rich bunches of vitreous copper ore, seven or eight inches in thickness; but on sinking to a distance of ten fathoms, the ore was found sparingly diffused through a thickness of eight or ten feet of the rock. A considerable sum of money was here expended by the Quebec Mining Company, and a quantity of rich ore obtained. Three shafts were sunk, and an adit was driven 200 feet; but the working was finally abandoned. The reddish tufa contains disseminated a small amount of native copper; but a shaft of seventy feet sunk in it, showed a quantity too small to be remunerative.

Proceeding northward along the coast, at Cape Gargantua an amygdaloid containing native copper forms the projecting point; and in the older rocks near, small veins holding copper pyrites and vitreous ore are met with. In the green slates on the east side of Michipicoten Bay, Mr. Willson mentions two interstratified beds containing small portions of yellow copper ore, with iron pyrites. On the north side of Michipicoten Bay, and upon the Dorée River, is a location which was formerly examined by the Upper Canada Mining Company. Here, on the west side of the river, is seen the contact between what appears to be the Laurentian gneiss, occupying the western part of the location, and the chloritic slate and slate conglomerate of the Huronian series, interstratified with two beds of what appears to be greenstone. The latter rock is traversed by numerous quartz veins holding yellow copper ore, and more rarely the vitreous species. The slate is much impregnated with iron pyrites; and numerous quartz veins, often of considerable size, and running in an east and west direction, are seen cutting this rock, and including iron pyrites, with a little yellow copper ore: others have a gangue of calc-spar. Irregular quartz veins in the gneiss are found to contain a little iron and copper pyrites; and in one case, specular iron ore. The gneiss is traversed by numerous trap dykes running about north and south. **Michipicoten Bay.**

The island of Michipicoten may next be noticed. On the north side of this island there is a considerable mass of greenstone and amygdaloid interstratified with sandstones, the whole dipping eastwardly. Towards the west end of the island, the rocks present a low surface for a breadth of four or five hundred feet, and then rise into a cliff two or three hundred feet in height, in which the greenstone is marked by druses containing analcime and quartz. A soft amygdaloidal bed holding native copper, is traceable for some miles along the shore, sometimes beneath the surface of the water in the bays, and again running a little distance inland. In this bed in the North Bay, an attempt was made, a few years since, to work a remarkable deposit of native copper and silver, which were found disseminated in grains through a green hydrous silicate of nickel. The ore being stamped, the nickel, whose value was not suspected, was washed away from the residue of native metals, which gave, in one trial, twelve parts of silver and eighty-eight of copper. A shaft was sunk here to a depth of seventy feet; but after a considerable outlay, the working was abandoned. Nothing very definite is known as to the mode of occurrence of this curious metallic deposit, which is stated however to have been associated with calc-spar. From the same mine were said to be obtained the specimens of mingled arseniurets of nickel and copper, which, with the preceding nickeliferous ore, are noticed on page 506, and again on page 737. At a point near the west end of the island, and about seven miles from the working just mentioned, the cupriferous stratum again appears, and fragments of the native metal are scattered along the shore. Mining operations on a small scale were under- **Michipicoten Island.** **Native copper.** **Nickel and silver.**

Fletcher's Mine. taken here ten years since by the Quebec Mining Company, and a shaft was sunk at a little distance from the shore, by which the copper-bearing beds were reached at a depth of forty-five feet. The mine is now leased to Mr. Hugh R. Fletcher, who is engaged in working it, and has kindly furnished the following particulars. Beneath the principal copper-bearing bed, is a soft argillaceous rock known as an ash-bed, which is six feet, and perhaps much more, in thickness, and is underlaid by a massive greenstone. The ash-bed itself contains from one half to one per cent. of disseminated metallic copper, which it is supposed can be economically extracted by crushing and washing the soft rock. Upon this reposes the principal copper deposit. The metal is found in a bed of greyish amygdaloid of from eight to eighteen inches in thickness, and an overlying bed of sandstone of from twelve to twenty-four inches; the united thickness of the two being on an average about three feet. The proportion of copper is the same in the two rocks, and averages two and a half per cent. The copper is in larger grains in the amygdaloid, and is sometimes surrounded by calc-spar; while in the quartzose sandstone, it is in fine particles, or in filaments. Small specimens of the sandstone are occasionally found containing ten or fifteen per cent. of copper. This bed is overlaid by a massive compact greenstone, to which succeed amygdaloid and conglomerate. The dip of the copper-bearing stratum is about three feet in a fathom. Three shafts have been sunk upon it, one to sixteen fathoms, one to twelve and a half, and a third to eight and a half fathoms. From 300 to 400 tons of two and a half per cent. ore have been raised; and in the spring of 1863 it is proposed commence operations on a larger scale, with proper machinery. Small portions of native silver and of vitreous copper ore have been found in this vicinity; and according to Mr. Willson, native copper occurs in a second band of amygdaloid about a mile and a half south of Mr. Fletcher's mine, and 200 feet above the surface of the lake. Vitreous copper ore is also found with calc-spar and sulphate of barytes on the eastern extremity of the island, in a reddish porphyritic rock, near which occurs a pitchstone porphyry, and pitchstone with veins of agate.

On the mainland to the north of the west end of Michipicoten Island is a location of the Upper Canada Mining Company, the southwestern corner of which is on the shore of Lake Superior, in longitude 85° 49′ W. Rocks which appear to belong to the Huronian series extend along this coast from Otter Head, which is about ten miles west of this location, to some distance to the east. Dykes of granite and trap are said to intersect the slates; and along the whole extent, veins of calc-spar and quartz are frequently met with, but are most abundant and rich in ores at the location just named. The veins are described as of two classes. The one runs east and west, parallel to the dykes of trap, and holds iron pyrites, with a little yellow copper, in a gangue of

Near Otter Head

quartz. The veins of the second class, running north and south, are divided by the trap dykes, generally with but slight dislocations. These veins are very numerous and well defined, and three among them have a width of ten feet. They contain, in a gangue of quartz and calc-spar, a great variety of ores. Besides yellow and vitreous sulphurets of copper, iron pyrites, blende, and galena were met with, and in one vein, molybdenite. The galena is said to be somewhat argentiferous. The above description is taken from the reports of Messrs. Cobb and Hadley.

A locality is mentioned by Mr. Willson, in a shallow bay along the coast in this vicinity, where several well-defined veins are observed to radiate from a point, which is distant about a hundred feet from the shore, and in shallow water. Three of these veins run to the shore. The first vein is about eighteen inches wide; and, in a gangue of calc-spar and quartz, it holds a considerable quantity of blende, with copper pyrites. The second vein, of calc-spar, is ten feet wide, but exhibits no metallic ores. The third, which runs in a north and south course, directly inland, is from five to six feet wide. The vein-stone near the water is calc-spar; which, in ascending the hill, is replaced by quartz. In the shoal water, the vein contains variegated and yellow copper ores, with blende and galena. A few feet above the water the copper disappears; a little higher up, the galena; and finally, the blende: so that before reaching the top of the hill, which is not more than forty feet above the lake, the vein appears destitute of metallic ores.

Farther to the northwest occur the Slate Islands, which are described as affording roofing slates, white satiny talcoid schists, and a pale green amorphous epidote rock; all of which recall the strata of the Quebec group. On the shore to the north-east, at Ance à la Bouteille, well-characterized mica schists and roofing slates are said to occur. About five miles to the northwest of this place is a location belonging to the Upper Canada Mining Company, which includes the mouth of the Black River, and is joined on the west by a second location, belonging to the same company, and including a part of Terrace Bay. The rock of the first of these is described as granitic gneiss, with slates and greenstone; and presents along the lake a great number of metalliferous veins, remarkable for regularity and persistence in width and direction. Near the centre of the front are two veins, of twenty-five and thirty feet, in gneiss; in one of which, portions of copper pyrites and blende were found in a breadth of two feet, near the centre of the veins. These veins are said to have been traced about two miles, and to appear in the river bluffs. Several veins holding purple fluor-spar are also noticed as being equally continuous; and numerous small veins along the lake and the river were observed, holding yellow and vitreous copper ores.

Slate Islands.

Black River.

The adjoining location to the west is described as consisting of red feldspathic gneiss, traversed by large dykes of black trap, and intersected by

Terrace Bay.

two sets of veins. One of these appears to occupy the joints of the rock, dipping at a high angle to the northward. These veins are from one to three or four inches in breadth; and they carry, in a gangue of quartz, considerable quantities of yellow and vitreous copper ores, with molybdenite. One vein is however described as having a breadth of eight inches, and as having been traced N. 15° E. for a mile and a half, bearing a considerable amount of yellow copper ore, with molybdenite. The other veins are described as running from the shore to a considerable distance inland, and as in many cases remarkable for a breadth of from ten to thirty feet: others attain but a few inches. The gangue of this series of veins is quartz, containing copper pyrites, with occasionally a little galena and blende. In the larger veins, calc-spar and purple fluor spar were observed. These however were less rich in ore than the smaller ones.

St. Ignace Island.

The next region to be mentioned is the island of St. Ignace, to the south of Neepigon Bay, with the mainland to the west, and Simpson's Island to the east. Here, in 1846, explorations were made, and numerous locations taken up by the Montreal Mining Company. Instead of the older rocks of Laurentian and Huronian age, which occur in the vicinity of the Black River, the Upper Copper-bearing series is met with, with its sandstones, greenstones, and amygdaloids, as on the south shore, and at Michipicoten Island and Mamainse. The strata are intersected by dykes of trap (see pages 72 and 78). At the eastern extremity of St. Ignace Island, on the Chenal Ecarté, copper occurs in a vein cutting a thick mass of amygdaloidal trap, which lies conformably to the strata, here dipping south at an angle of nine degrees. The vein, which has an underlie of seventy degrees to the north, is four or five inches wide, and holds masses of native copper, occasionally more than one hundred pounds in weight, in a gangue of calc-spar, sometimes with native silver. About forty-seven feet to the south of this vein, is another about twelve inches wide, of which the veinstone is calc-spar, with a little quartz, including fragments of the wall-rock, and holding imbedded masses of vitreous copper ore, with native silver. The underlie of this vein is sixty degrees to the north, so that it should meet the former one at a depth of about twenty-five fathoms. In 1846, the Montreal Mining Company, to whom this location belongs, sunk a shaft about twenty-four feet, to the north of the vein of native copper, to the depth of ten fathoms. A drift to the southward then intersected the vein at a distance of about twenty feet, thus showing its continuance to a depth of ten fathoms. Having however directed their whole attention to the Bruce Mine, the company abandoned this working. The veins just described can be traced to the westward for nine miles, along the whole length of St. Ignace Island; carrying native copper and silver, with the vitreous sulphuret of copper, in greater or less quantity, the whole distance. Crossing Neepigon Strait, the same minerals are met with at two locations

Native copper.

on the mainland opposite. Fluor Island, at the southern extremity of the Strait, consists of the same rock as the adjoining country; and it is traversed by numerous veins, in which vitreous copper ore has been found. It receives its name from the fluor spar which is said to abound in these veins. To the eastward of St. Ignace, the copper-bearing strata are traced across to Simpson's Island; where the vitreous and yellow ores, with native copper, have been found in several localities. The latter is often associated with laumontite, or imbedded in prehnite. These minerals, together with agates, are common in the amygdaloid, which is here interstratified with sandstone. Native copper has also been found on the Battle Islands. Specimens of the native copper from St. Ignace, and from the mainland opposite, gave, in several assays, from one fourth to one fifth of one per cent. of silver. In other specimens from the same region, the quantity of silver was scarcely appreciable. It exists in the native state, and is irregularly distributed. Metallic silver likewise sometimes occurs in grains with the sulphurets of copper from this region.

Fluor Island.

Simpson's Island.

Proceeding southwestwardly along the coast to Point Porphyry, at the entrance to Black Bay, is a mining location, which includes several small islands, the largest of which is known as Edward's Island. Here the amygdaloidal rocks are described as being traversed by numerous brecciated veins, containing yellow, variegated, and vitreous copper ores, in a gangue of quartz, calc-spar, and sulphate of barytes. Besides these, are veins of calc-spar, which are sometimes seven or eight feet in thickness, and often contain vitreous copper ore. Native copper is also met with here. The veins appear to be most developed on the west side of Edward's Island. Another location in this vicinity includes the coast and the adjacent islands, lying immediately to the northeast of Thunder Cape. Several metalliferous veins are said to have been observed on these islands; and among them is a very prominent lode, holding galena and green carbonate of copper, which crosses a long narrow island near the shore. A valuable deposit of limestone occurs interstratified with sandstone in the northern part of this location.

Point Porphyry.

Edward's Island.

Thunder Cape.

Metalliferous veins are observed in various localities along the shores of Thunder Bay. One of these, which is noticed on page 76, is coincident with the stratification, and has a breadth of sixty feet. In a gangue of amethystine quartz, calc-spar, and sulphate of barytes, it contains small quantities of iron and copper pyrites, with blende and galena. To the southwest of the mouth of the Kaministiquia, several mining locations have been taken along the coast. The most interesting of these is that known as Prince's Mine, where there occurs a remarkable metalliferous vein, which is seen both on the mainland, and on Spar Island opposite. On the south side of this island the vein has a breadth of fourteen and a half feet; and from its whiteness, it contrasts strongly with the

Thunder Bay.

Prince's Mine. wall-rock, which is a dark-colored slate holding cone-in-cone. Its course is about N. 32° W. The greater part of the vein is here occupied by a coarsely crystalline calc-spar; but near the middle are two bands, each of about twelve inches, the one composed of heavy-spar, and the other of quartz, mixed with calc-spar. Between these, is a band of six inches of calc-spar, which is the only metalliferous part of the lode, and contains small quantities of yellow and variegated copper ores, with native silver. Two shafts, one of twenty-four, and the other of forty-seven feet, were sunk here. On the mainland, about two miles distant, and a little way back from the shore, the vein re-appears, somewhat split up; but a few rods farther to the northwest the parts re-unite, and the vein is wider than on the island, and more quartzose, affording fine specimens of amethyst. It here contains small quantities of variegated and vitreous sulphurets of copper, with blende, and some native silver. A level was driven 165 feet in this vein; and at one place, in sinking a shaft of ninety feet, a bunch of several hundred pounds of ore was met with, which contained native silver disseminated in thin laminæ through the calcareous spar and blende. This mass yielded, on an average, three and a half parts of silver for one hundred of the rock. The silver, in one assay, yielded an amount of gold equal to one part in seven thousand, but is said in another sample to have given nearly eight parts of gold to one thousand of silver. This mass of rich ore was soon exhausted. Crystallized sulphuret of silver was also found in this vein; and the calcareous spar was stained with blue and green carbonates of copper, and with red arseniate of cobalt. Some farther explorations were attempted after the discovery of this silver, but without success; and the mine has since been abandoned, although the characters of the lode are certainly such as should encourage farther working for silver, if not as a copper mine. Adjoining this location to the westward, is another in which the slates are intersected by large veins of calc-spar, sometimes associated with quartz, fluor-spar, and sulphate of barytes, and holding yellow and vitreous copper ores. At the mouth of Pigeon River is another location, where numerous veins holding yellow and vitreous copper ores are met with, sometimes associated with blende.

Native copper.

Pigeon River.

Kamanistiquia. The argillaceous slates on the Kamanistiquia River are traversed by numerous mineral veins, some of which have a course to the north of east, while others have a transverse direction. They vary from a few inches to two or three feet in thickness, and usually contain a breccia of the wall-rock cemented by calc-spar, together with quartz, sometimes amethystine, heavy spar, and occasionally purple fluor spar. Blende, galena, copper ores, and iron pyrites are met with in these veins.

In Eastern Canada the rocks of the Quebec group, which is regarded as the equivalent of the Upper Copper-bearing strata of Lake Superior, constitute an important metalliferous region, in which numerous deposits of copper ore occur. The characters and distribution of this group have already been described with considerable detail in the eleventh chapter of this volume, while the chemical and mineralogical history of its constituent rocks will be found on pages 598–618. To render more intelligible the order which will be followed in describing the copper deposits of this region, it may be well to recall the principal facts relative to the geographical distribution of this series of rocks. The Quebec group, with the exception of a small portion on the north shore, between Cape Rouge and Quebec, and the greater part of the island of Orleans, is entirely confined to the south side of the St. Lawrence; where its northwestern limit may be nearly defined by a line running from the northern extremity of Missisquoi Bay to Cape Rouge. This boundary corresponds to the great dislocation, which has been described on page 233 as bringing up this lower group to overlie, along their southeastern border, the newer formations belonging to the upper portion of the Lower Silurian series. The southeastern limit of the Quebec group in Canada is the band of slates and limestones of Upper Silurian and Devonian age, which, starting from Stanstead, passes to the east of Lake Massawippi, thence along the river St. Francis to the lake of that name. From this the southern boundary of the group is traced to Vaudreuil, on the Chaudière; thence to the northern part of Lake Temiscouata; and following closely the province line, to Lake Metis. The Quebec group thence stretches eastward, including the Shickshock Mountains, to the extremity of the continent at Cape Rosier. Quebec group. Distribution.

This long belt of rocks thus defined attains its greatest breadth, which is about sixty miles, on the Chaudière; while near Rimouski, in one place it is not more than seven miles wide. It is a continuation of the Green Mountains of Vermont, and includes in Canada the Shickshock and Notre Dame Mountains. The strata of this region, which include both the Quebec group and some dark colored slates supposed to underlie it, are, from the effect of undulations, arranged in long narrow parallel synclinal and anticlinal forms, with many overturn dips. The latter circumstance renders it difficult to determine which of these folds are synclinal, and which anticlinal, inasmuch as the outcrop in both cases present a similar arrangement. The weight of evidence, however, at present, goes to show that the strata dip toward the centre of the areas about to be described, and they will therefore be designated as synclinals. These, in the part of the region which has been most examined (extending from the boundary line of Vermont to the Chaudière River), are three in number; and although they are described at length in the eleventh chapter, they may be briefly defined as follows:— Structure.

I. The synclinal extending from the township of Farnham, near Missisquoi Bay, to the seigniory of Lauzon, on the St. Lawrence. This, where it

First synclinal.

is traversed by the St. Francis, is nearly or quite separated into two parts, by the appearance of the underlying slates. The southwestern portion appears to be divided by an undulation into at least two subordinate troughs, thus giving in Roxton and Ely an additional breadth to the exposure of these rocks. The copper deposits of Upton, Acton, Wickham, Roxton, and Durham occur in this synclinal; while in its northeastern extension are those of Wendover, Somerset, Nelson, and St. Flavien.

Second synclinal.

II. The second synclinal extends from St. Armand to the seigniory of St. Mary, on the Chaudière. In it are the copper deposits of Sutton, Shefford, Stukley, Melbourne, Cleveland, Shipton, Halifax, Leeds, Inverness, and St. Mary. In its southern extremity this synclinal is divided into two by Sutton Mountain; and while one part occupies Sutton valley, the other extends southward into Potton.

Third synclinal.

III. Farther to the southeastward is the third synclinal, extending from the Owl's Head Mountain, on Lake Memphremagog, to Ham, and includes the Stoke Mountains. An extension of this is traced northeastward to Vaudreuil and St. Joseph, on the Chaudière; and beyond it, into Buckland. Between the southwestern portion of this synclinal and the second one, is a large area occupied by newer rocks, of the same age as those which limit the belt to the southeast. They include the slates and limestones which occupy the northern part of Lake Memphremagog, and, extending through parts of Orford and Brompton, cover a considerable area in the contiguous parts of the townships of Windsor, Wotton, Ham, and Stoke. These unconformable rocks overlie and conceal a large portion of the strata of the third synclinal; but along the eastern limit of this are exposed the copper deposits of Ascot, Ham, and Garthby.

Undulations.

The contour of these synclinal areas is very irregular, and they vary considerably in breadth in different parts of their extension. Their structure is such, that the strata which dip down on one side come up again on the other side of the basin; and they may also be repeated in the intermediate portions by subordinate undulations. The copper is confined to certain beds in the series; so that it becomes of great importance to trace out the undulations of the region, which govern the distribution of the metalliferous deposits. Various other important mineral products accompany the copper-bearing strata. Such are the iron slates of this region, already described on page 679, which are chiefly found among the altered rocks of the second synclinal. The serpentine, steatite, and magnesite, with their associated chromic iron and nickel, belong also to a portion of the series near to the copper, and have a similar distribution. Besides the newer unconformable rocks above mentioned, the accumulations of sand and gravel in many parts conceal the outcrop of the copper-bearing strata. It should however be remarked, that these newer rocks are not destitute of metals; but in some places they are cut by metalliferous veins, containing argentiferous galena, blende, and native gold, as at Potton, Ascot, and Vaudreuil, localities which have already been noticed under the head of Lead. At Barford also, they contain copper ore in well-defined lodes; which will be described farther on.

Copper-bearing rocks.

The copper of the Quebec group occurs chiefly in interstratified beds. These are often in the limestones of the series, which are generally magnesian; and are frequently associated with serpentines and diorites, both of which also sometimes contain copper. These rocks are accompanied by slates, which in many localities are themselves the copper-bearing strata; and in certain parts of their distribution are so much altered as to take the form of chloritic or micaceous schists. The latter are sometimes soft, with a pearly lustre, and are called nacreous or talcoid slates. At other times they are highly silicious, so that the copper-bearing bed is occasionally a micaceous quartzite. Beds of a true talc-slate or steatite also sometimes contain copper; and the metal is also found in the red and green argillites of the series. The chloritic schist is occasionally calcareous, and passes into an impure limestone. The great mass of the chloritic rocks is supposed to overlie the magnesian limestone of the series; but chloritic schists also to occur beneath it.

The metal throughout these various rocks is generally in the form of the yellow, variegated, or vitreous sulphuret. The blue and green carbonates of copper, and the red oxyd, are only met with in small quantities, and near to the surface. The native metal, which is so abundant in the rocks of this group on Lake Superior, is rare in Eastern Canada. It is however sometimes seen in the red slates; and at St. Flavien it occurs with calc-spar in an amygdaloidal rock, under conditions which resemble closely those of the western region.

Copper ores.

In many parts of the country, the copper-bearing beds are traversed by quartz veins; but these are often destitute of metal. In other districts they carry large quantities of very rich ore, in a gangue of quartz or of bitter spar, more rarely with orthoclase. The ores of these veins are the yellow, variegated, and vitreous sulphurets. At Harvey's Hill, however, a dark steel-grey foliated ore, with a black streak, has recently been met with, which is a sulpharseniuret of copper and iron, with a trace of zinc, and may belong to the rare species enargite. Sulphuret of molybdenum, specular iron, and native gold have also been met with in these veins, or courses, as they are locally called. They are seldom continuous for great distances; and the most reliable source of copper in this region has hitherto been found in the beds. The relations of the two will be readily understood from the plans and description of the Harvey Hill mine, to be given farther on. The copper in the slaty beds generally occurs in disseminated grains, or in thin, irregular, and interrupted layers. In some cases, as in Sutton and Melbourne, beds of a dark colored slate occur, in which the sulphuret of copper is so finely divided as to be visible only on minute inspection, and which nevertheless contains from five to ten per cent. of copper. In the magnesian limestones or dolomites, a schistose structure is sometimes seen, and the copper is occasionally arranged as in the slates; but more often these dolomites are massive, and the ore is found in nodules, or is irregularly intermingled with the substances of the rock. In these rocks however, as well as in the more schistose strata, veins often occur, in which the copper ores appear to be concentrated, generally in a gangue of calc-spar, and occasionally with quartz. Sometimes, as in Acton, the sulphurets of copper form the cement of a limestone breccia or conglomerate. Many other peculiarities connected with the occurrence of the ores will be mentioned in describing different localities, and other facts will be found on page 515.

First synclinal.

In describing the various copper deposits of this region, it is proposed to follow the three synclinals just enumerated, beginning with each at its southwestern extremity, and proceeding towards the northeast. On the eastern margin of the Farnham and Lauzon synclinal, small portions of copper pyrites and of galena have been observed in a quartz vein, cutting chloritic slate, on the eighth lot of the eighth range of Granby. On the western border of this synclinal, small portions of vitreous copper ore are found in the red slates in Milton; but copper first appears in considerable quantity in Upton. It here occurs in the magnesian limestone or dolomite of the series, which in this portion of the synclinal has a thickness of from 200 to 300 feet. It is somewhat crystalline; and is divided into massive beds, which often contain chert. The upper portion of this limestone often presents a brecciated or conglomerate character; and it consists of rounded or irregular masses of limestone intermixed with irregular fragments of chert, the whole re-cemented. This structure may in some cases have resulted from the breaking up and re-aggregation of previously formed conglomerates, such as are common in this group, as may be seen in the section on page 227. It is chiefly in this upper portion of the limestone that the copper ores most abound. The copper of Upton was first described and reported upon by the Survey in 1847 (and again in 1849), when an assay of the ore was given, and the place recommended for a crop trial. These early examinations at Upton were made on the fifty-first lot of the twenty-first range. On this two shafts have since been sunk in the limestone, to the depths of twenty-five and forty-two feet. Good specimens of ore were obtained from these; but the working is for the present suspended. Within about one hundred feet from one of these excavations, explorations have been made for copper on the fifty-first lot of the twentieth range, in what is called the Prince of Wales mine. Here about twenty feet of the upper portion of the limestone band contain copper pyrites, which is most abundant in the lower part of this thickness. In

Upton.

some places bunches of pure ore, eight or ten inches in thickness, are met with. The bed is intersected with reticulating veins or strings, which also hold yellow copper ore, with calc-spar and quartz, sometimes with small portions of the blue carbonate. Copper pyrites is also found in shales which here accompany the dolomite. The only working of this mine has hitherto been by an open cut, which was carried to a depth of forty and a width of thirty feet. According to Mr. Robb, about 900 tons of rock, holding more or less copper, have been excavated. This has been sorted, and a considerable quantity of ore got ready for the market, estimated in all at forty tons, yielding twelve and a half per cent. of copper. One lot of fifteen tons gave to his assay fourteen and three quarters per cent. The value of this ore is much more than is required to pay the whole expense of mining and dressing; besides which, there remains a large quantity of rock, less rich in copper, which requires machinery for stamping and washing. Prince of Wales Mine.

The limestone band in this vicinity is sometimes associated with red slates; and it occasionally takes the form of a breccia, in which yellow copper ore appears to enter into the cement. It is traced to the northeastward for nearly a mile; when it is carried half a mile to the northwest, apparently by a dislocation. Here, on the forty-ninth lot of the twentieth range, at Bissonette's Mine, copper pyrites again appears in a bed, which seems, as before, to be at the top of the limestone. The bed is about three and a half feet thick; and the ore lies in disseminated masses of various sizes, up to twenty inches long by six and nine inches thick. It may probably yield from ten to fifteen hundred-weight of ten per cent. ore to the fathom. Yellow copper ore has also been found in limestone on the fourteenth lot of the twentieth range of Upton, and variegated ore on the twenty-sixth or twenty-seventh lot of the twelfth range of Wickham. Bissonette's Mine.

These localities are all on the west side of the supposed synclinal. About six miles to the southeast, the limestone re-appears in Acton; where at the Actonvale mine, which is on the thirty-second lot of the third range, it is seen dipping to the northwest at an angle of from 35° to 40°. The hill to the southeast of the mine is composed of the massive beds which, as already mentioned, make up the lower portion of the band. The copper-bearing limestone overlies this, and occurs in irregular elongated masses, running parallel with the great body of the limestone beneath, but variable both in thickness and texture. As may be seen in the section given below, it is interstratified with portions which are nearly destitute of copper. This upper limestone, at the mine, is underlaid by shales, which contain more or less copper ore, and are sometimes interstratified to a small extent with the limestone. With these shales also occur masses and beds of greenstone or diorite, whose description and analysis have been given on page 604. This rock has an olive-green color, with darker spots, and Acton Vale.

Diorite.

weathers of a yellowish-brown, resembling many of the serpentines of the region. Some masses of the diorite seen at the Acton mine are one hundred and fifty feet in length by thirty feet in thickness; but thin layers of it are occasionally interstratified with the slates. In some portions of this diorite, masses of calc-spar are disseminated, giving it the characters of an amygdaloid, and, on the weathered surfaces, a cellular aspect. At other times it appears to be a conglomerate, with small pebbles running in the direction of the bedding, which is in some cases very apparent in this rock. Diorites similar in character to that of Acton, and occupying the same stratigraphical position, occur with the copper-bearing limestones in Upton, Wickham, Somerset, Nelson, and St. Flavien; and the fact that at the latter place, and at Drummondville, they are found to contain copper ore, gives to these rocks an economic importance.

Section at Acton Vale.

The following descending section of the copper-bearing strata at Acton was obtained in an early surface cutting at right angles to the strike, made at the mine. The measurements of the beds are reduced to the vertical thickness.

		Feet.
1.	Limestone partially concealed, enclosing small portions of copper pyrites,	8
2.	Aggregations of angular fragments of limestone and variegated copper ore, dipping with the stratification, but terminating in a wedge below,	2
3.	Brecciated limestone, in which fissures, from a quarter of an inch to three inches wide, are filled with variegated copper ore, calc-spar, and quartz crystals,	15
4.	Aggregations of fragments of limestone and chert, both rounded and angular, united by a paste of variegated and vitreous copper ores, mingled with silicious matter. The sulphurets were seen, on polished surfaces. to run in more or less parallel bands through the matrix,	4
5.	Limestone,	2
6.	Breccia or conglomerate, like 4,	4
7.	Limestone,	3
8.	Slate, with green stains of copper	12
9.	Fin-egrained diorlte,	14
10.	Slate, like 8,	4
11.	Concealed to the underlying limestone,	25
		93

Shales.

The limestone of the above section is overlaid by a considerable thickness of black shales, containing small quantities of copper pyrites, which often fills little veins, and are sometimes stained with red oxyd of copper. These overlying shales, three or four miles to the northward, contain numerous and well-preserved fucoids (page 244). Masses of the diorite are sometimes found above, as well as below the copper-bearing limestone; which in the above section is shown to have an aggregate thickness of thirty-eight feet. This, however, as will be seen in the succeeding description, is subject to great variations; being sometimes reduced to a few feet, or even a few inches. Portions of a cupriferous slate are sometimes interlaminated with the base of the limestone, and with the underlying diorite.

Several faults or dislocations, not however of great magnitude, are found to cut the strata at this locality. Some of them appear to run with the strike; and others in two parallel series, oblique to the strata and to one another. These disturb the regular continuity of the copper-bearing limestone, producing apparent undulations in the dip, and causing the diorite and the upper portions of the limestone to protrude into the ore-bearing beds, or to interrupt them. The underlying limestone at this mine is intersected by quartz veins, which occasionally hold small portions of galena and of copper pyrites; but the workable ore of copper is found in the conglomerate already described, of which it sometimes forms the cement; or in portions of limestone highly charged with sulphuret of copper, which occur in the immediate vicinity of the conglomerate masses, and partially surrounding them. The limestone is often cut by short irregular veins, holding the sulphurets of copper mixed with calc-spar; and sometimes enclosing small masses of the black carbonaceous matter, whose description and analysis have been given on page 525. The ores which have been wrought up to the present time were found concentrated in three large masses, occurring in a length of about 120 fathoms. These may belong to one continuous stratum which has been divided by dislocations, or may have been originally distinct.

Faults.

Veins.

Of these masses, the most northern one, beginning with a breadth of a few inches, gradually extended, in a distance of about forty fathoms along the surface, to forty-five feet. Upon this a long open working, known as Flowers's Pit, was made to a depth of twenty feet, at which the limestone was reduced to a breadth of four feet. In the northeast part of this open working, a shaft, designated as No. 5, was then sunk down the incline of the limestone, (which here dips at from 70° to 80°,) to a depth of ninety-one feet from the surface; where the bed was twenty-four feet in breadth, but poor in copper. At fifty-four feet, however, where it was ten feet wide, it was a conglomerate rich in ore. At a depth of sixty feet a gallery was carried thirty feet to the westward, where the limestone, which was sixteen feet in thickness, was cut off by the overlying shale. At the southwest end of the open working, and about 150 feet from the last shaft, a second one was sunk seventy-five feet on the incline of the bed. For the first twenty-five feet the rock was rich in copper; and by subsequent drifting and stoping, a large quantity of ore was obtained near this shaft, from the upper part of the bed, which had a thickness of from fifteen to twenty feet.

Flowers's Pit.

A little to the south of this last shaft the beds appear to be thrown about

Harvey's Pit.

a hundred feet obliquely to the westward, by one or more dislocations; and the cupriferous limestone next appears in Harvey's Pit, which is an open working about one hundred feet long, fifty-six deep, and eighty feet across the strike. This great breadth at the surface is probably the result of a fold, since it becomes much narrower in descending. This working is now abandoned, and employed as a reservoir for water; although still exhibiting ore at the west end, and also in the middle, at the deepest point. To the southwest of this pit masses of diorite afford evidence of a fold or a dislocation; and beyond this are Williams's and Pike's Pits, now thrown into one by the removal of the barrier of rock which divided them, and both excavated to a depth of sixty-five feet. In the former of these the limestone occupies a breadth of from 135 to 150 feet, corresponding to a vertical thickness of about seventy-five feet. This great breadth is ascribed by Mr. Macfarlane to a folding in the strata. Great quantities of a rich copper conglomerate were found in the upper part of this pit; but at a depth of forty feet, the ore occurred in more solid masses in the limestone. A little to the west of this open working a shaft was sunk seventy-eight feet, through the upper shale into the limestone beneath; at which depth a drift was carried forty-two feet to the overlying rock, and sixty feet to the underlying rock or foot-wall. This—which was partially cut through, and found to consist of alternating layers of diorite, and of a shale holding copper pyrites—was followed by a gallery for twenty-seven feet. The drift had been carried, not across the strike, but nearly with it. It was however continued for sixty feet farther in the same direction, keeping between the shaly diorite and the cupriferous limestone, and then sixty-three feet farther, ascending the slope of the foot-wall, which dipped to the northwest about 40°. This drift had been carried beneath the cupriferous limestone; and on sinking a shaft in the middle of Pike's Pit, it was met below a deposit of rich ore-bearing rock, which was underlaid by a few feet of barren limestone. The drift near this shaft was then widened, and its roof removed; and the overlying cupriferous limestone, which was thus exposed, has recently yielded large quantities of rich ore.

Pike's Pit.

In preparing the above description, many details are taken from an account of the mine prepared at the end of October, 1862, by Mr. Thomas Macfarlane, the manager of the mine, and published in *The Canadian Naturalist*, vol. vii, page 447. The author has since kindly furnished details of the results of the mine up to the close of the year; from which it appears that during thirteen months, from the 1st of September, 1861, to the 1st of October, 1862, the total amount of ore sold was 2336 tons of twenty-one hundred-weights or 2352 pounds each; the average copper content of the ore being 12·0 per cent. For the month of October, 1862, the produce was 397 tons, of 15·2 per cent.; for November, 337 tons, of 12·5; and for December, 357 tons, of 13·2 per cent. Of this last, 88

Produce of mine.

tons averaged 22·2 per cent., 124 tons 13·0, 35 tons 10·6, and 110 tons 7·1 per cent. of copper. The whole amount of ore raised from this mine from its opening in 1859 to the close of 1861, including a portion of the above period, is stated to have been nearly 6000 tons, averaging 17·0 per cent. of copper. During the thirteen months, according to Mr. Macfarlane, the average produce for the cubic fathom was 1·6 tons of ore, of 12·0 per cent.; and the average cost of mining and bringing to the surface $11·28 the fathom, or $7·03 the ton of ore. It is however to be borne in mind that these figures are chiefly deduced from the results obtained by quarrying out in open cuttings the productive parts of the cupriferous bed; and that no allowance is made for exploration or work in unproductive portions, with a view to the future of the mine. Except in the drift already mentioned, but very little work of this kind has been done; and the whole cost of such explorations is estimated by Mr. Macfarlane at about $1·50 for each ton of ore obtained; so that this being added to the estimate already given, the cost was $8·50 for the ton of 12·0 per cent. ore.

The ores raised from this mine are chiefly, as before stated, vitreous and variegated sulphurets. The following analyses by Mr. Macfarlane will serve to give an idea of the ore and its gangue. The first three are dressed ores of different qualities; the fourth is an analysis of the material obtained in drilling a large mass of the copper conglomerate; while the fifth is the cement of a breccia, which enclosed angular fragments of limestone. These fragments contained no copper, but yielded carbonate of lime 73·20, carbonate of magnesia 15·50, alumina and oxyd of iron 2·75, silica 8·25; = 99·70. Assays of ores.

	I.	II.	III.	IV.	V.
Copper,	24·75	13·07	9·95	34·20	37·20
Iron,	5·81	4·06	3·36	7·01	7·31
Sulphur (by difference),	11·22	12·88	7·17	16·33	15·89
Carbonate of lime,	33·10	53·07	53·10	4·64	·95
" magnesia,	.....	traces	2·10	.....	38·65
Alumina,	.....	.....	.....	·84	.....
Silica,	25.12	16·92	24·32	36·98	.....
	100·00	100·00	100·00	100·00	100·00

From the workings at Acton, the outcrop of the limestone is traced, with a very sinuous course, to Wickham Mine. The sulphurets of copper have been found in a great number of places in the intermediate distance, and they are rarely absent from the limestone. Trials have been made at some of these points on the thirty-second and three succeeding lots of the fifth range of Acton. The quantity of ore obtained was however small; which may be due to the fact that the openings have been made near the base of the limestone band; for it is the summit of this which, both at Acton Vale and Upton, appears to be most productive of copper ore. At the Wickham

Wickham Mine. Mine, which is on the fifteenth lot of the tenth range of the township of that name, the yellow, variegated, and vitreous sulphurets occur disseminated in a bed of limestone. The ores are however more abundant in what appear to be veins, running through the rock in a northeast direction, with a high inclination. The working here has not yet been sufficient to determine the thickness of the bed, nor the extent of the deposit; but from a shaft, which was sunk to a depth of thirty feet, about four tons of ore of thirty per cent. were obtained.

It has already been mentioned that to the southeast of that portion of the synclinal which holds the copper of Upton, Acton, and Wickham, there exists a subordinate fold, which extends from Durham, through Roxton and Ely. On the twenty-first lot of the seventh range of Durham, the copper-bearing limestone, underlaid by a black shale, is exposed on what appears to be the southeast side of this synclinal; and it is intersected by several veins, which contain copper pyrites in a gangue of calc-spar, mixed with a little quartz, and fragments of the wall-rock. These veins have a general northeastward bearing; and trial shafts have been sunk upon three of them, whose breadths vary from six to thirty inches. On the most northwesterly of these, an excavation reached the underlying black shale at a depth of twelve feet. Eighteen feet to the southeast, in a second shaft, the black shale was found at a depth of thirty-six feet; and at the third, twenty-four feet farther in the same direction, a shaft of twenty-four feet has been sunk without reaching the shale. In this last, the vein has an underlie to the southeastward of about a foot in a fathom; and in a breadth of from six to twelve inches, it shows good masses of yellow copper ore.

Durham.

Roxton. Farther to the southwest, on the twenty-third lot of the third range of Roxton, the limestone appears in a nearly vertical position, with shales both above and below, and having a breadth of about 100 yards. Near the summit of the band, and also in contact with the overlying shale, rich specimens of variegated ore were found disseminated in the limestone, an associated with calc-spar in irregular veins. A considerable mass of the rock has been excavated, but it is difficult to ascertain the amount of ore obtained.

Wendover. In the continuation of the Farnham and Lauzon synclinal to the northeast of the St. Francis, the diorite of the series is found developed to a great extent along the river, opposite Drummondville. The rock has here a breadth of about half a mile, and dips to the southeast at a moderate but variable angle. Besides the varieties of it described on page 243, some portions have a dark maroon or purplish color; and are interstratified with shaly layers, into which the more compact diorite passes by insensible degrees. In the lower part of the section, these slates sometimes contain concretionary or nodular masses, somewhat resembling those of the shale at St. Joseph described on p. 255, but smaller. To these succeed black shales containing graptolites, underlaid by a band of about ten feet of diorite, and by a second layer of graptolitic shales, with two undetermined bivalve shells. Much of the diorite is broken and shattered, as if by numerous small faults; and the surfaces exhibit what is called slickensides, the result of the movement of the parts on one another. This diorite is supposed to correspond with those of Upton and Acton, from which many beds of it cannot be distinguished; but the cupriferous limestone which there accompanies it, seems to be wanting, and it is the diorite which holds copper. In this exposure, on the first lot of the first range of Wendover, six or more ore-bearing veins or courses are met with in a breadth of about 350 yards. They have a width of from three to twelve inches, and in some cases consist of little more than shattered fragments of the wall-rock, cemented by copper pyrites. In other cases the interstices are filled up with calc-spar holding yellow, variegated, and vitreous copper ores. Several small excavations have here been made upon these veins, and good specimens of ore obtained. The locality appears to deserve a more effectual trial than has yet been given to it. Diorite.

In the continuation of the synclinal to the northeast, the rocks are in many parts concealed by the overlying drift. On the fourteenth and fifteenth lots of the eighth range of Somerset, however, a band of diorite is met with resting upon the limestone conglomerate; which is here ten feet in thickness, and contains copper pyrites. In the adjoining township of Nelson, on the eighth lot of the eleventh range, copper has lately been discovered, and explorations have been commenced in rocks said to resemble those found farther to the northeast in the parish of St. Flavien. The Black River mine which is situated in this parish, is about five leagues west of the Chaudière River, and two leagues south of the St. Lawrence. Here is a band of dioritic rocks, similar in many respects to that of Wendover, and about a quarter of a mile in breadth, dipping to the northwest at a moderate angle. As this is supposed to be on the northwest side of the synclinal, the inclination of the strata would here be the result of an overturn. The band has been traced for two miles on the strike, and is overlaid by red slates. Much of this band is a fine-grained greenish-grey amygdaloid, holding numerous small spheroidal masses of calc-spar, with which the mass of the rock in these portions seems also to be penetrated. Some portions of the strata are reddish-brown; and resemble an indurated and altered argillite, being slightly or not at all amygdaloidal, and made up of reniform masses from a few inches to a foot or more in diameter. Somerset. Nelson. St. Flavien.

On the northwest side of the band the diorites are seen interstratified both with red slates and limestone. Beds of the latter a few feet in thickness are also met with at what appears to be the base of the series. These limestones are often conglomerate, enclosing fragments or rounded masses of diorite. In one portion angular fragments of a fine-grained diorite, often reddish, are imbedded in a finely granular reddish limestone base. Another portion near the southeast side of this band consists of both angular and rounded masses of diorite, often amygdaloidal, and sometimes two feet in diameter; the spaces between which are lined with a layer of columnar calc-spar, within which crystalline quartz fills the interstices. These minerals often enclose small portions of copper pyrites; and of a black carbonaceous matter, or indurated bitumen, which is also common in quartz veins here. The mode in which this latter substance occurs at St. Flavien, has been detailed on page 525. In other cases, the whole of the interstices in the breccia or conglomerate are filled with lamellar calc-spar; in which small grains and filaments of native copper, and stains of the green carbonate, are disseminated.

Black River Mine.

This great mass of rocks is cut by veins holding copper ore, of which more than a dozen have been observed. Some of these are filled with a breccia of the wall-rock, in which the interstices contain yellow and variegated sulphurets of copper. In other veins these same ores occur in a gangue chiefly of quartz; and in others still, with calc-spar. This calc-spar is sometimes lamellar and cleavable, and at other times drusy; holding, besides the sulphurets of copper, little masses of fibrous malachite, and small crystals of the blue carbonate. The carbonaceous matter already mentioned is frequently associated with these ores, and sometimes fills an inch or two of the veins. The dimensions and directions of these veins are very variable; the underlie of some being nearly south, or to the east of south, at high angles; while others have a northwest; and others still, a northeast underlie, or are nearly vertical. Some of the veins are from three to six inches in breadth; while others attain two feet or more. Striæ, produced by the sliding of the surfaces, are occasionally found on their walls. Small excavations have been made upon several of these veins, and the portions of rich ore which have been obtained are such as give considerable promise for the future. The resemblance between these amygdaloidal diorites, with quartz, calc-spar, and native copper, and some of the Upper copper-bearing rocks of Lake Superior, is worthy of notice.

In the continuation of this synclinal to the northeast, small portions of copper are observed in several places. Thus on the shore of the St. Lawrence, a little below St. Nicholas church, the green carbonate occurs in red slate, and again in the same rock a mile above Point Levis. About ten miles from the St. Lawrence copper pyrites occurs on the Chaudière, at the Narrows, in a calcareous sandstone; and the same ore is found in a red limestone on the Etchemin, four miles from its mouth. On the same

St. Henry.

river, a little below St. Henry, small portions of native copper occur in red shale; and the metal has been found in a similar rock at Point Levis. On the north side of the St. Lawrence copper pyrites is found in red shale and sandstone, a mile below Cape Rouge; and at Quebec in a cutting made

for the aqueduct at Coteau Ste. Geneviève, vitreous copper ore was found Quebec.
associated with a limestone conglomerate. The small portions of copper which occur in the places just mentioned are not of economic importance, but are interesting as showing the persistence with which the metal accompanies the rocks of this portion of the Quebec group.

In the second synclinal, which extends from St. Armand to St. Mary on the Chaudière River, copper ores are found in small quantities in various localities in Sutton and Brome. The iron slates of this region (page Sutton.
679) often contain a little disseminated copper pyrites, or are stained with the green carbonate; which also sometimes occurs in the dolomites associated with these specular schists. On the eighth lot of the tenth range of Sutton, on the eastern side of the synclinal, copper ore is found in larger quantity, and mining operations have been commenced in a band of fine micaceous or nacreous slates; which run in a northward direction, and dip at a high angle to the westward, or are nearly vertical. These strata are exposed for 500 feet, and may be traced for half a mile along the strike, running parallel with a band of dolomite, which is seen about half a mile to the eastward, across the strike. Nodules of magnesian limestone are however disseminated in the slates immediately to the east of the portions which hold the copper ores. These, which consist of the yellow, variegated, and vitreous sulphurets, are disseminated in grains, or in small thin lenticular masses. The proportion in which the ores occur is variable. The bed in which the principal excavations have been made is said to vary from six inches to nearly three feet; and about eight feet to the east of this another cupriferous bed, of six inches in width, has been observed. The copper may however be disseminated through a greater breadth than these measures indicate. In one excavation made here, the ore appeared to be more or less diffused through a breadth of four and a half feet; and the assay of a sample from this cutting, gave four and a half per cent. of copper as the average from this thickness of rock. A layer of fine-grained blackish slate, an inch in thickness, from this place, which seemed to owe a portion of its color to vitreous ore, so finely divided as to be scarcely apparent to the eye, yielded on assay ten per cent. of copper. A shaft of ten fathoms has been sunk on the incline of the bed, and a small quantity of ore extracted. Small quartz veins, holding variegated copper ore, are met with cutting these cupriferous slates.

To the northward, the continuation of the synclinal shows copper ore in Shefford.
Shefford, and in Stukley. Good specimens of vitreous copper in a gangue of quartz and calc-spar, cementing a brecciated vein of fine micaceous schist, are said to come from the land of Major Wood, a little to the east of Frost Village in Shefford. In Stukley, on the seventh and eighth lots both of the first and second ranges, copper pyrites is described as occurring in a band of limestone, interstratified with slates. An excavation in

Stukley. one place, to a depth of ten feet, showed promising quantities of the ore, which has also been observed on the second lot of the fourth range. From the sixth to the eleventh range of the township, a belt of chloritic slates, having a dip to the northwest of from 30° to 60°, and including quartzose and limestone bands, is marked in a great many localities by the presence of copper ores. Certain beds in these slates present segregated veins, sometimes cutting the strata, but more frequently running with them, in irregular masses or bunches. The veins consist of quartz, with bitter spar, calc-spar, and chlorite, often containing also feldspar and epidote, and carrying small quantities of vitreous and variegated copper ores in strings and grains, sometimes with specular iron. On the ninth and tenth lots of the sixth range, two excavations have been made, one fifteen feet long, and thirty feet deep on the slope of the bed; which is to the northwest, at an angle of forty-five degrees. From these pits, more than 700 tons of rock were raised, which gave a few barrels of marketable ore, but too little to pay the expense of working. On the eighth lot of the seventh range, copper ore occurs in two bands of dolomite, dipping as before to the northwest: one of these is about thirty feet wide. The second, which is greenish and chloritic, holds variegated and vitreous ores in larger quantities than most of the localities observed in this vicinity. Two bands of dolomite, probably the same, are also described as occurring on the eighth range, both of which hold vitreous copper ore. Several small pits have been sunk upon these, with encouraging results. On the ninth lot of this range, a band of the chloritic slate contains small quantities of variegated and vitreous ores in a gangue of quartz, with feldspar and bitter spar. Copper has been noticed under similar conditions in chloritic slates on the second, fifth, and eighth lots of the ninth range, and the fourth, fifth, sixth, and seventh of the tenth. On the last-named lot the copper ore is found with specular iron, in a bed of hard chloritic slate, through a breadth of two feet, in which quartz and spars predominate. A pit has been sunk here to a depth of twenty-two feet. On the fifth lot of the eleventh range of Stukley, there is a band of soft purple slate, barred with black, and marked by films of a greenish chlorite-like mineral. It dips northwest $< 65°$, and in its upper portion holds strings of quartz and calc-spar, with a little copper ore.

Melbourne. To the northeast of Stukley, the copper-bearing strata of the second synclinal are continued across Ely, where they are concealed, for the most part, by the superficial deposits. They however re-appear in Melbourne, where the chloritic and micaceous or nacreous slates are traced across the northwestern portion of the first six ranges, and are found to contain disseminated sulphurets of copper in a great number of places, often with epidote and specular iron. At the Coldspring Mine, on the sixth lot of the second range of Melbourne, the strata dip to the northwestward at an angle of about forty-five degrees, and exhibit in a breadth of two hundred feet several parallel bands, in which the quartzose mica-slate is colored green by carbonate of copper, and contains portions of the vitreous and variegated ores disseminated in grains and lenticular masses. A shaft has been sunk here, which intersects one of the beds at a depth of six fathoms, and several trenches have been made across the beds. A vein yielding rich specimens of vitreous copper is also described as here cutting the strata at a small angle. Some of the beds of slate just noticed, like those of Sutton, contain sulphuret of copper in a state of minute division. Such a band impregnated with the vitreous ore, gave, according to Mr. Robb's assay, seven per cent. of copper. Coldspring Mine.

On the second lot of the fourth range, is what is called the Balrath Mine. Here the cupriferous strata include a vein from two to four feet wide, which is described as conformable to the stratification, and as consisting of quartz and calc-spar, carrying in certain portions considerable quantities of variegated copper ore. A trench twenty feet long and ten feet deep was first dug on the strike of this vein, and a shaft then sunk to about fifty feet, from which about a ton of good ore was obtained. Four other smaller openings parallel to this also afforded indications of copper. On the second lot of the sixth range, a shaft was sunk at a little distance from a copper-bearing bed, intersecting it at a depth of fifty feet, where the quantity of the ore was found to augment. Balrath Mine.

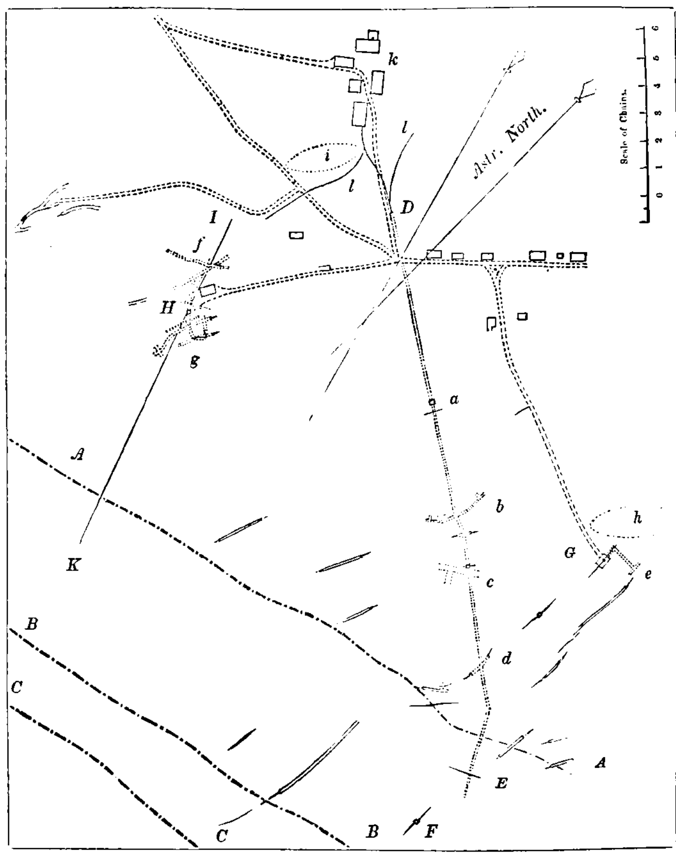
Beyond the St. Francis, the cupriferous band is continued in the township of Cleveland. On the twenty-sixth lot of the thirteenth range of this township, variegated and vitreous copper ores are found disseminated in a bed of chloritic rock twelve inches in thickness, which dips to the northwest at a high angle. A shaft has been sunk upon this to a depth of about twenty feet. Sixty feet to the eastward of this is a cupriferous bed of three feet, and ninety feet to the west another of five feet in thickness. In these the same ores are more sparingly disseminated in a chloritic rock. On the twenty-fifth lot of the twelfth range, is what is known as the St. Francis Mine. Here, a vein slightly oblique to the stratification is found traversing chloritic beds, which are associated with an argillite holding nodules of quartz and orthoclase feldspar. These rocks are described on page 606. The vein, which is of quartz, has been traced in a north-east direction about ninety fathoms, with an average thickness of three feet. Five or six small excavations, which have been made along its outcrop, exhibit the variegated and vitreous ores of copper, mixed with yellow sulphuret. In the continuation of the synclinal through Shipton and Tingwick, indications of copper have as yet been observed in but few places; but in Chester the chloritic slates on the eleventh lot of the tenth range contain small portions of variegated and yellow copper ores in quartz veins. The second lot of the ninth, and the eighth lot of the seventh range have also afforded small Cleveland. St. Francis Mine.

Chester. quantities of copper; and the vitreous ore is said to be found in chloritic slates on the sixth and ninth lots of the fourth range. On the eighth lot of the fifth range, these slates hold a vein of quartz about two feet in width, which appears to run with the strike, and contains masses of the vitreous copper ore, with green carbonate. In the adjacent township Halifax. of Halifax, copper ores are met with in the chloritic and nacreous slates, which, as before, dip to the northwest at a high angle, and are associated with dolomite; in which rock, a vein of quartz holding copper pyrites is found on the sixth lot of the seventh range. Variegated ore is also reported as existing on the fourth and sixth lots of the ninth range, and on the sixth lot of the eleventh range. The Halifax Copper-Mining Company has lately been established to work a quartz vein, which is described as being from eight inches to three feet wide, and as containing promising quantities of vitreous ore, with copper pyrites, and portions of green carbonate and red oxyd of copper; the latter two occurring at the surface of the vein. This synclinal, with its copper-bearing Ireland. strata, is traced from Halifax, through contiguous parts of Ireland and of Inverness, into Leeds. On the fourth lot of the eleventh range of Ireland, variegated ore is found; and on the ninth lot of the ninth range, copper pyrites occurs in dolomite. It is also met with in similar conditions on the second lot of the fourth range of Inverness. On the fourth lot of the second range, variegated copper ore occurs in a quartz vein two feet wide in nacreous slates. This locality was, in 1847, recommended by the Survey for a crop trial.

Leeds. In Leeds the copper-bearing rocks are exposed in a great number of places, and have been more carefully examined than in any other locality Harvey Hill Mine. along this synclinal. The explorations at the Harvey-Hill Mine, on the seventeenth lot of the fifteenth range, now the property of the English and Canadian Mining Company, are the most extensive which have as yet been made in the Eastern Townships. The shafts, and the long adit which has been opened, afford an opportunity not elsewhere presented for studying the structure of this mining region, and it is proposed therefore to give a detailed description of this mine. The accompanying plan and sections are reduced from drawings furnished to the Survey, on a scale of one inch to a chain, by Mr. Herbert Williams, the skilful director of the Harvey-Hill Mine; who has also kindly given many details to complete the description. The copper ores at this locality occur both in courses or veins, and in beds. The strata are here, for the most part, finely micaceous slates, which, from their unctuosity, are often called talcose, but are generally not magnesian. A bed of steatite is however met with, and dark bands, approaching to argillite, occur in some parts, while others are whitish or light grey in color, and contain a large amount of chloritoid disseminated. The dip of the strata appears to be from 25° to 80° W. of N.; with an average inclination of from fifteen to thirty degrees. The courses are really irregular and interrupted veins, which do not coincide with the strata either in dip or strike. The bearings of eight of them are from north, to N. 20° E., while others run nearly eastward. Their underlie is generally to the westward, at from fifty to nearly ninety degrees. These veins, which appear to have filled up fissures in the slates, are more or less lenticular in shape. Some of them have been traced for as much as 100 fathoms on the surface, and are occasionally six or seven feet wide in the thickest part, thinning out however both horizontally and vertically. Veins.

These veins have a gangue of quartz, occasionally mixed with calc-spar, pearl-spar and chlorite, and contain rich ores of copper; some of them yielding the variegated and vitreous species, and others, copper pyrites. These are sometimes so abundant that as much as two tons of twenty per cent. ore have been obtained from a fathom. Within an area of about thirty acres, open cuttings have been made upon as many as fifteen distinct courses, and shafts have been sunk on two others. Notwithstanding the richness of portions of these veins, the ore is disseminated in them in such an irregular and uncertain manner, that they are considered secondary in importance to the interstratified beds, in which the sulphurets of copper are disseminated in the slate rock. The first of these beds has a thickness of from two to six feet. Twenty fathoms below it, occurs a bed of three inches, followed, in descending, by fifteen feet of barren slate. This separates it from another ore-bearing bed of six inches, which rests upon a stratum of soapstone or steatite, six feet in thickness. In the plans and descriptions here given, the stratum of steatite, with the two layers of copper-bearing rock, and the intervening fifteen feet, will be represented as a single band, and designated as the second. This band, characterized by the bed of steatite, can be traced for a distance of two miles along the outcrop, but is lost sight of to the eastward of Fremont's shaft. An adit has been carried horizontally into the side of the hill for a distance of 248 fathoms, intersecting in its course the upper bed. The second bed, however, was not seen in the adit, and is perhaps displaced by some fault in the strata. Near the place where it might have been looked for, a quartz course occurs. Several of these courses were met in the adit, but they appear to have no connection with those at the surface, and, according to Mr. Williams, thin out both vertically and horizontally. At about twenty fathoms from the extremity of the adit, after traversing about twelve fathoms of soft, dark bluish slate, a light grey band was met with, holding chloritoid, and a little copper pyrites. A rock similar to the last also occurs at the end of the adit, and contains, besides a little disseminated ore, some quartz courses holding copper pyrites. This band of greyish chloritoid slate is marked C in the plans. The strata in this part of the adit appear much disturbed; and the dip varies, being in some places from 10° to 14°, and in others from 35° to 40°. Copper beds. Upper bed. Second bed. Third bed.

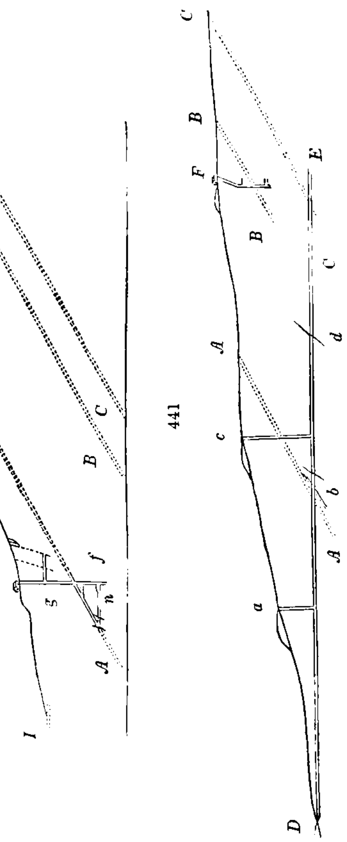
439.—PLAN OF HARVEY-HILL COPPER MINE, LEEDS.



- - — - Outcrop of copper beds.
- —— Ditto of quartz courses.
- ═══ Open cuttings on ditto.
- ::::::: Under-ground workings.
- = = = Roads.
- *A A*, Upper copper bed.
- *B B*, Second copper bed.
- *C C*, Lowest copper bed.
- *D E*, Morrison's adit; line of section No. 2.
- *a*, 1st shaft in adit, with quartz course.
- *b*, Sewell's level, on a lode.
- *c*, 2nd shaft in adit, with bed *A*.
- *d*, Level on a quartz course.
- *F*, Fremont's shaft.
- *G*, Harvey-Hill shaft.
- *e*, 10-fathom cross-cut, and level.
- *H*, Kent's shaft, with level on bed *A*.
- *f*, 30-fathom levels on bed *A*.
- *g*, 10-fathom levels.
- *I K*, Line of section No. 1.
- *h*, *i*, Reservoirs. *k*, Dressing floors.
- *l l*, Lines of tramways.

The interstratified beds contain the yellow and variegated ores, the latter generally predominating. These sulphurets are disseminated through the slate in small masses, often of a lenticular form, running with the bedding. They are generally thin and small, but sometimes attain from one half to three fourths of an inch in thickness; and occasionally present in **The ores.**

440, 441.—SECTIONS AT THE HARVEY-HILL MINE.



440. Section 1.—*I*, Level of Morrison's adit.—*H*, Kent's shaft, with three cross-cuts.—*A A*, Upper copper bed.—*B B*, Second copper bed.—*C C*, Lowest bed.—*f*, 30-fathom cross-cut.—*g*, 10-fathom cross-cut.—*n r*, Quartz courses or veins.

441. Section 2.—*D*, Entrance to the adit.—*a*, First shaft.—*c*, Second shaft.—*A A*, Upper copper bed.—*b*, Sewell's lode, a quartz course.—*d*, Another quartz course.—*F*, Fremont's shaft.—*B B*, Second copper bed.—*C C*, Lowest bed.—*E*, Extremity of adit.

section, a length of six or even twelve inches. Besides plates and lenticular masses, which interlock, and overlap one another, numerous small grains of ore are scattered through the beds, and the average amount of copper in the layer may be stated at from three and a half to five per cent. The copper-bearing beds are sometimes light grey and quartzose, and have at other times a chloritic aspect.

In the second shaft of Morrison's adit, the upper copper-bearing bed was met with at a depth of fifteen fathoms. Immediately beneath it was found a quartz course, which contained some very rich copper ore; while the bed itself at this point held scarcely a trace of copper, and could only be distinguished from the adjacent slate by its lighter color and quartzose nature. Kent's shaft. In sinking Kent's shaft, which is about 170 fathoms to the westward, the same bed is met with at a depth of about twenty fathoms. It has also been intersected by two levels or cross-cuts from the shaft, the lower at thirty fathoms, and followed upwards for a distance of over twenty fathoms on the incline. The working of the bed is now being continued up toward the shaft, as well as east and west from the thirty-fathom level; where it has been wrought for about twenty-five fathoms on its strike, and for ten fathoms in the level above. In the early part of 1862, ten superficial fathoms of the rock from this upper level were broken, weighed, and sampled, and were found to average 258 hundred-weights of ore yielding three and a half per cent. of copper (equal to over 1000 pounds of metal) to the fathom of ground. The ore now removed from the working at thirty fathoms averages about five per cent. of copper. In driving the lower cross-cut, a lenticular quartz course was met with, from which there were taken over fifty tons of rich ore, yielding forty-three per cent. It thinned out as it approached the interstratified bed; and on working this on the incline, it was found to be greatly impoverished for some distance on either side of its contact with the quartz course. In driving east on the bed, from the thirty-fathom level, another lenticular quartz course is met with, running nearly with the dip of the bed, which last is almost destitute of copper on both sides. The course, however, which is being followed, and has a breadth of from eighteen to twenty-four inches, yields about a ton and a half of forty per cent. ore to the fathom. This, with the other two instances already mentioned, seems to show that these veins or courses have been filled with ore derived from the bed. In working this bed, masses of quartz are occasionally met with imbedded in it. These, which are probably in some cases courses running with the strata, and in others small lenticular beds, vary from a few inches to six or seven feet in length, and from a quarter of an inch to a foot or two in thickness. They contain, on an average, from seven to eight per cent. of copper; while the adjacent slate, for a thickness of five or six feet, does not contain more than five per cent. The various workings in Kent's shaft may be said to have tested the bed over an area of over 600 square fathoms; while the extension of this same bed to the adit, a distance of 170 fathoms, and the fact that it has been traced along its outcrop for more than 500 fathoms, show that much may be expected from working this copper-bearing bed.

Molybdenite. In some courses in this working, a considerable quantity of sulphuret of molybdenum is found, with a little copper ore, in a gangue of quartz and bitter spar. Not unfrequently, these courses hold large masses of the copper ores, which are sometimes perfectly pure and homogeneous, and at other times enclose cleaveable masses of bitter-spar, or of limpid transparent quartz, giving to the ore a porphyritic aspect. This quartz, on examination, is found to be in regular prismatic crystals, which however have their angles rounded. In one case, a mass of compact variegated copper ore was penetrated by several terminated prisms of quartz, from one fourth to one half an inch in diameter. All the angles of these were much rounded, and the planes of the crystals, which were in close contact with the ore, were concave, and had lost their polish; retaining only a somewhat greasy lustre, precisely like crystals which have been exposed to the action of a solvent liquid. A thin shining green layer, apparently of a silicate of copper, covers the surfaces of the ore in contact with the crystals. Similar specimens of quartz have been found in the vitreous copper ore of this locality, and also at the Ham Mine. Quartz crystals.

Fremont's shaft was sunk upon a quartz vein, which had an underlie of 75° to the eastward. After following this for forty-five feet, the underlie changed to the westward, still with the same angle; but the shaft being continued vertically for seventy-five feet more, the second copper bed, with its underlying stratum of steatite, was met. The layer in contact with the steatite was excavated for five fathoms on the incline, in the course of which the vein from the surface was again met with. At the bottom of the incline, a level was driven in the bed for about five fathoms; and the copper ore being continuous throughout these distances, its presence may be said to be shown over about twenty-five square fathoms of the bed. In some parts of this working, the copper ore is found in the steatite; a layer of which, several inches in thickness, sometimes becomes a highly crystalline green talc, holding bitter spar, and rich in disseminated sulphurets of copper. The shaft at G was sunk upon a quartz course, which abounded in vitreous ore. In a cross-cut from this shaft, at a depth of ten fathoms, a second quartz course was met with. Fremont's shaft.

The following quantities of ore, averaging about thirty-five per cent., have within the last five years been shipped from this mine to England. The fractions of tons are here disregarded. In 1858, 10 tons; in 1859, 43 tons; in 1860, 104 tons; in 1861, 70 tons; and in 1862, 95 tons; equalling in all 322 tons of ore. In addition to this, there was at the surface, at the close of 1862, about 1000 tons of poor material, supposed to contain about two and a half per cent. of copper: besides 500 tons of material raised from the upper copper bed, and containing from four to five per cent. of copper.

Besides the copper-bearing beds whose course has just been described, quartz courses holding the various sulphurets of copper have been observed on a great number of lots from the eighth to the eighteenth of the ranges from ten to fifteen, inclusive. In the western part of the township, copper pyrites occurs in dolomite on the fourth lot of the fourth range. On the fifteenth lot of the fourteenth range, a shaft was sunk by the predecessors of the present Mining Company, on the land of Mr. Nutbrown, on a remarkable vein, which cuts a band of steatite, and contains vitreous copper, specular iron, and native gold. This vein has already been noticed on pages 516 and 257. Farther to the northeastward, the copper-bearing slates, with their quartz courses, are continued into the rear of the seigniory of St. Giles; where the Chaudière Mining Company has lately been formed for working several quartz veins, which are found on a portion of the seigniory known as the Handkerchief. According to a report of Mr. Wm. Williams, made in September 1862, eight well-defined quartz veins are here exposed, traversing the slates, in a trench cut at right angles to them, in a breadth of 1100 feet. Two of these are three feet wide, and have been traced 1200 and 1500 feet. All of the veins contain, in greater or less abundance, the same ores of copper as have been described at the Harvey-Hill Mine. A little farther, on the first three lots of the St. Margaret range of the same seigniory, openings have been made upon several quartz veins, which run in a northeast direction, and are from one to two feet in breadth. They contain portions of vitreous and variegated copper ores, occasionally with green carbonate, and with specular iron, and are more or less stained and impregnated with earthy oxyd of manganese. In some of the veins, crystals of quartz occur, in the interstices of which is found a black carbonaceous matter, like that already described at St. Flavien. The rock adjoining the veins, is chloritic slate, in which there are said to be two interstratified quartzose beds, of about six feet each, marked by chlorite and manganese, and holding small portions of variegated and vitreous copper ores.

ative old. *haudière line* *St. Margaret.*

Beyond this, the rocks of the synclinal are traced across the Chaudière River, where, in the front of the third concession of St. Mary, and north of east from the church, red and green nacreous slates are interstratified with beds of red limestone. These, which are much disturbed and broken, are traversed by little veins of quartz and calc-spar, holding small portions of yellow and variegated copper ores, with green carbonate. Fissures are here filled with an impure earthy oxyd of manganese; and patches both of specular iron and of jasper are found in the limestone.

St. Mary.

In the description of the second synclinal, it has been stated that what is regarded as a division or spur of this passes down to the east of Sutton Mountain. Here its eastern outcrop is seen on the western side of the river Missisquoi, as a band of slates, sometimes chloritic, with serpentine and steatite, and occasionally with small portions of copper ore. To the east of the Missisquoi these same strata are repeated on the eastern side of the anticlinal axis, which separates the second from the third synclinal.

Potton.

The western outcrop of this latter, marked by the same rocks, is traced northward through the eastern parts of Potton, Bolton, and Stukley, into Orford; and thence, through Brompton, to the southeast parts of Melbourne, Cleveland, and Shipton. The copper ores already described in the northwestern parts of the last three townships, belong, like those of the northern part of Ireland, to the second synclinal, and have been already noticed. The outcrop of the third is continued through Ham and Wolfestown; and farther on, there is a great development of the rocks of this series, which may be regarded as a continuation of the third synclinal, and consist of dolomites and serpentine, with steatite, chloritic, and epidotic rocks. These are traced to the northeast, and include large portions of the townships of Garthby, Coleraine, Ireland, Thetford, and Broughton, the northwestern parts of Adstock and Tring, and the contiguous portions of the seigniories of St. Joseph and Vaudreuil; beyond which the rocks of this synclinal are traced into Frampton, Cranbourne, Standon, and Buckland. This distribution of these strata is important, inasmuch as copper and other valuable minerals will probably be discovered in many parts of their course. Vitreous and variegated ores are found in quartz veins on the twelfth and thirteenth lots of the fifth and sixth ranges of Broughton; and in St. Joseph, a mile west of the Chaudière River, and opposite to the road above the church, leading to Frampton, vitreous copper ore occurs with quartz, chlorite, and earthy oxyd of manganese, filling small fissures in red and green shales, which are associated with red limestone. On the east side of the river, the red limestone in the vicinity of the peculiar concretionary argillite described on page 255, contains a little green carbonate of copper.

Third synclinal.

St. Joseph.

The principal discoveries of copper in this synclinal, have, up to the present time, been in its southwestern portion, and in the townships of Ascot, Ham, and Garthby. Along its western margin however, on the fourteenth lot of the tenth range of Potton, small quantities of copper pyrites occur in a quartzose rock, on the north side of the Owl's Head Mountain; and on the twenty-eighth lot of the eighth range of Stukley, the same ore is met with in a band of limestone intermixed with chloritic slates. Near to this, in Orford, on the ninth lot of the eighteenth range (according to the Crown Land survey), a quartzose chloritic rock near the band of serpentine, contains a small amount of copper pyrites. The chloritic slates in the vicinity often weather black from the presence of manganese. On the ninth lot of the road range A (Land Company's survey), and near the junction of the serpentine with a diallagic diorite, six quartz veins occur in the latter rock, within a breadth of twenty-five feet. Some of these are ten inches wide, and they all contain portions of yellow copper ore, which is associated with a greenish serpentine-like material. These veins are nearly vertical, but seem to converge towards the south, and also in descending.

Orford.

The eastern side of the third synclinal is traced northeastward in a

Ascot Mine.

narrow belt between the two overlying portions of unconformable newer rocks, through Stanstead and Hatley, into Ascot. Here, in the vicinity of Sherbrooke, the micaceous and chloritic slates contain copper ores in several places. On the eighth lot of the eighth range, at Haskell Hill, is what is now known as the Ascot mine. The ore-bearing bed, which is about five feet in thickness, is an impure limestone, associated with chloritic schists. The dip of the strata at the mine is northward, at an angle of 72°, and a shaft has been sunk forty-three feet on the incline. From this a drift has been carried along the ore-bed, about fifty feet to the west and thirty-five feet to the east. A transverse cutting was made from the bottom of the shaft twenty-five feet to the northward, the rock containing copper ore throughout, which may indicate a thickening of the bed. At the end of this distance the copper-bearing bed had a southward dip at an angle of 75°; showing apparently an upward turn towards the surface, on the north side of a small synclinal fold. The bed has been traced for some distance on each side of the shaft. A little to the southeastward of this shaft, another has been sunk for a few feet on a bed of ore, which dips southward at an angle of about 45°, and appears to be a repetition of the previous bed on the southern side of a small anticlinal. The ore of this locality consists of copper pyrites, which is disseminated in small strings and grains through a mixture of limestone and chlorite. Considerable quantities of the rock sent to market without dressing yielded eight per cent. of copper.

On the ninth range of Ascot, and on the tenth lot, near the line of the eleventh, there is a considerable breadth of fine white micaceous or nacreous slates, with which is interstratified a bed of greenish and greyish quartzose mica schist. This is in parts chloritic or talcose, and contains large quantities of a mixture of iron pyrites, with yellow copper ore, the latter being irregularly disturbed. A few tons of the rock having been removed from the bed by blasting, selected portions of this gave, when dressed, one half their weight of ore, which contained one third of silicious matters, and 7·3 per cent. of copper, the remainder being iron and sulphur. The breadth of this bed, which has an eastward dip of about thirty degrees, is not far from six feet, and it is estimated that it will yield two tons of dressed ore, similar to the above, to the fathom. A great bed of the same ores is found on the sixth lot of the ninth range; and copper pyrites also occurs, with galena, on the ninth lot of the same range.

On the seventeenth lot of the seventh range, on the road between Sherbrooke and Lennoxville, a vein or bed of white quartz is found running with the stratification, nearly north and south, and having a dip of 65° to the eastward. The associated rocks are micaceous and chloritic slates. The bed, which was recommended for a crop trial in 1847, is marked at the surface with gossan, and contains disseminated copper pyrites. A portion of this, separated by washing, was found to contain 30·3 per cent.

of copper, with minute quantities of both gold and silver (page 517). On the thirteenth lot of the same range, in a continuation of this deposit, copper pyrites like the last is disseminated through thirty feet of chloritic rock. Copper pyrites also occurs in veins of quartz, in several places on the ninteenth and twentieth lots of the sixth range of Ascot.

On the twenty-eighth lot of the fourth range of Ham, and near the line of Wolfestown, copper ore occurs in a dolomite; which rests upon chloritic schists, and is overlaid by black glossy slates. The general course of the beds in the vicinity is nearly north and south, with an eastward dip; but near the mine, a turn in the stratification gives them an east and west direction, with a southward dip of forty-five degrees. The thickness of the dolomite band is about 100 feet. It is somewhat slaty in structure, and towards the summit becomes interstratified with thin layers of micaceous and quartzose schists. In the upper thirty feet of the limestone, yellow and variegated sulphurets of copper are disseminated in nodules and lenticular masses, which have often an extent of several inches, with a thickness of an inch or more. Quartz veins are also found cutting the beds, and contain rich specimens of the yellow and variegated ores; while in some cases, small veins are entirely filled with the vitreous sulphuret. Excavations have been made here which show the continuation of the ore-bearing stratum for a distance of about 500 feet, and have yielded several tons of rich ore. The north branch of the Nicolet River falls over the band of dolomite at this place, furnishing an available water-power, and the deposit may not improbably prove to be of considerable importance. Copper ore is also found on the twenty-second lot of the seventh range of Ham, in quartz veins cutting micaceous slates. Ham Mine

In the township of Garthby, on the twenty-second lot of the first range, north, a large mass of iron and copper pyrites is found subordinate to the stratification of the enclosing rock, which is a calcareous serpentine, dipping to the southeast at an angle of 50°. The extent of the deposit has not yet been determined; but there appears to be a breadth of about twenty feet in which the two ores occur, more or less intermingled with rock. Large masses of the mineral consist of a fine-grained iron pyrites, without any copper, while in other portions there is such an admixture of copper pyrites as to afford eight per cent. of the metal. The iron pyrites of this locality, when exposed to the air, is slowly oxydized, and falls to pieces from the formation of sulphate of iron; for the manufacture of which it might be used with advantage. Garthby.

The rocks of the Quebec group, from the vicinity of Quebec to the extremity of Gaspé, have been studied chiefly along the coast, where copper ore has as yet been found in one place only. At the mouth of the Great Capucin River, four miles above Cape Chatte, small portions of copper pyrites are observed in a vein of quartz in red shale. The Shickshock

Gaspé. Mountains are composed of the chloritic and epidotic rocks of the Quebec group, with serpentines containing chrome and nickel; and similar rocks occur near Gaspé Bay, where a hill has received the name of Mount Serpentine. In the vicinity of this, and about six miles from the head of Gaspé Bay, good specimens of copper pyrites are said to have been obtained. The same probabilities of deposits of copper exist throughout this eastern region as in the townships farther to the southwest.

In this connection, it may be mentioned that the shales and limestones of the Gaspé series at Port Daniel (page 443), contain in their lower portion, small quantities of copper. This occurs both in the form of stains of green carbonate, and of small nodules of vitreous copper ore, which, with others of iron pyrites, are found in the shales. These Devonian rocks are here cut by a small vein of heavy spar, containing a little copper pyrites, with malachite. This mode of occurrence of copper ore recalls a similar locality in the Carboniferous rocks of Bathurst, noticed on page 451.

Barford. It has already been stated that veins of copper ore exist in the altered rocks of the Upper Silurian and Devonian age, which overlie the strata of the Quebec group to the southeast. On the third and fourth lots of the sixth range of Barford, the fine-grained argillaceous and micaceous slates of the region dip to the northwest at an angle of about forty degrees, and are traversed by several quartz veins, which have an underlie to the southward at a high angle. In three of these veins, copper ore has been observed; and two of them have been opened by small excavations, and have been traced considerable distances. They are about three feet in breadth, and very well defined. The gangue is quartz, often translucent and somewhat brownish. It is associated with a white mica, in large foliated masses, and with white or greenish-white crystalline apatite. The metallic contents of the vein are copper pyrites, magnetic iron pyrites, molybdenite, and spathic iron, besides which small portions of dendritic native copper have been found in the joints of the quartz. The quantity of copper ore met with thus far in the workings is said to be encouraging, and the locality is well worthy of being proved. The strata in which these veins occur are geologically distinct from those of the Quebec group, and their investigation may lead to important results in connection with the economic mineralogy of these upper rocks; whose age is supposed to be the same with those which contain the copper and tin of Devonshire and of Cornwall. It may here be remarked that the small quantities of tin ore which have been found in New Hampshire, and in Maine, are supposed to belong to these same upper rocks, of which they are a continuation.

The evidence which has been presented in the descriptions of the copper deposits of the Quebec group, appears to show that the metal, like the iron, manganese, nickel, and chrome which so often accompany it throughout these rocks, was held in solution by the waters from which the sediments of the period were deposited. By the agency probably of organic matters (page 574), it was reduced to the condition of a sulphuret, and precipitated with the sediments, either in a finely divided state, or more frequently in small nodules or patches; which became interstratified with the limestones, the slates, the diorites, and other rocks of the series. A subsequent action, probably contemporaneous with that which has metamorphosed and crystallized the rocks over a great part of their extent, dissolved out portions of the copper sulphurets from these beds; and in certain cases deposited them, with quartz and various spars, in the fissures of the rocks; giving rise to the veins or courses which have been described. Origin of copper deposits.

There appear to be, in this region, no facts to sustain the ancient notion of the connection of metalliferous deposits with eruptive rocks; which are absent from great portions of the district. The diorites and serpentines of the Quebec group have already been shown to be rocks of sedimentary origin; and the same may be said of the amygdaloids, which are evidently altered argillites. The frequent similarity of these rocks, and of their associated minerals, to the cupriferous strata of the same age on Lake Superior, has already been alluded to as a reason for supposing that the copper of the latter region is in no way connected with the intrusive rocks which there accompany it (page 699).

The copper deposits of the Eastern Townships are unlike those of Cornwall and of Lake Huron, in which the metal has been concentrated in well-defined lodes. They are however very similar in their structure and mode of occurrence to those of the same age in Norway and Sweden. The analogous copper ores in the Permian slates of Mansfeld and Hesse, and those of both sides of the Ural Mountains, are in like manner disseminated in beds, and not in veins. Copper-bearing beds similar to those of Canada, are also wrought in schistose rocks of the Quebec group, in Maryland, in Tennessee, and in other parts of the United States.

With regard to the working of the copper deposits of Eastern Canada, but little has yet been done. The Acton mine has afforded large quantities of rich ores quarried from open cuttings; and profitable workings, on a smaller scale, have been undertaken at Ascot. In Leeds, the English and Canadian Mining Company has expended considerable sums in systematic mining operations, which, although they have not yet been remunerative, have proved the extent and richness of the copper beds in that vicinity to be such as to give hopes of profit for the future. In numerous other localities, as in Upton, Wickham, Durham, St. Flavien, Sutton, Melbourne, Halifax, and Ham, the explorations which have been made by various parties have shown the existence of considerable quantities of copper ore. In many of these localities it occurs in peculiar conditions, namely as a variegated or vitreous sulphuret, rich in copper, and sparingly disseminated through a quartzose or argillaceous rock. Such ores Mining.

Metallurgy. demand a particular metallurgical treatment. The loss by dressing is considerable; and in order to separate the copper from the gangue by smelting, they require an addition of ores rich in sulphur; such as those from Clarke's mine in Ascot, or from Garthby. The ore of the Ascot mine, with its copper pyrites and calcareous gangue, would also be an advantageous admixture. It is much to be desired that some one of the various methods which have been proposed for removing the copper in a soluble form, could be applied to these ores. In one of these processes, the calcined or roasted ores are exposed to the combined action of air, watery vapor, and the sulphurous acid evolved from the roasting of other portions of the same or of other sulphurets. The sulphuric acid thus formed dissolves the oxyd of copper from the calcined ore, converting it into sulphate of copper. This process is adopted at Linz, in Rhenish Germany, for pyritous ores which are mixed with a great deal of quartz. In Norway, iron pyrites containing three per cent. of copper, or less, is partially roasted at a low heat, by which the copper, and a part of the iron, are converted into soluble sulphates. Still another process is based upon calcining, in a current of air, the pyritous ores (which, if very poor in copper, are previously deprived, by roasting, of a part of their sulphur) with a mixture of common salt, and thus converting the copper into a chlorid, which is soluble in water. From the soluble copper salts obtained by these various processes, the metal is afterwards precipitated, generally by iron, which separates it in the metallic state. In applying any of these methods to the vitreous and variegated ores of Canada, however, the quantity of sulphur present would be insufficient to convert the whole of the copper into sulphate or chlorid; and it would be necessary to make use, as in smelting them, of some poorer and more sulphurous ore.

Humid process.

It can hardly be doubted, that, when the copper deposits of Eastern Canada are thoroughly explored, and proper means of working them and of smelting their ores are adopted, they will become a source of great wealth, and furnish employment to a large population. The same may be said of the copper deposits along the north shores of Lakes Superior and Huron,—although these have the disadvantage of being farther removed from the great markets. As the mining industry of that region becomes developed, the sulphuretted ores which abound there, and which, unlike the native copper of Michigan, require a lengthened metallurgical treatment, will be smelted where fuel is most accessible. Chicago and Cleveland, which are not far from great deposits of coal, will be favorable positions; while the coal-field of Michigan, which comes upon Lake Huron in Saginaw Bay, may probably make that vicinity the site of copper-smelting works. Ores which contain a small proportion of copper, and which cannot by dressing, or by a partial smelting, be advantageously raised to a high percentage, must be reduced near the mines, by some process like those already indicated;

but the quantity of fuel required by the present mode of treatment, is such that the richer ores will still be carried to the vicinity of coal. It may therefore be anticipated that those from Eastern Canada will eventually find their way to the coal mines of the Lower Provinces.

NICKEL.

The principal facts with regard to the distribution of nickel have been given on pages 505–507, and it now remains to notice those localities which may prove to be available sources of this valuable metal. The arsenical ore already described as occurring on Michipicoten Island, has been shown to be an intimate mixture of the arseniurets of copper and nickel; different portions of the same mass containing from seventeen to thirty-six per cent. of nickel. These results have been confirmed by Prof. Whitney; who, on visiting the locality, found this ore in the form of nodules, having a concentric structure, and imbedded in coarsely crystalline calc-spar. These, according to him, were irregularly distributed in the trappean rock, and did not form a regular vein. He found in two specimens, respectively thirty-one and thirty-three per cent. of nickel. Of the second nickel ore from the same locality, already described as a greenish earthy silicate of nickel, and yielding about twenty-four per cent. of nickel, little is known, except that the specimens brought from the mine were filled with small grains of native copper and of native silver; and that large quantities of the green earthy material were said to have been crushed and washed to obtain these metals, the valuable ore of nickel being lost in the process. The analysis of a specimen, from which the native metals had not been separated, gave for one hundred parts: silver 2·35, copper 18·51, and oxyd of nickel 20·85. At the present price of the latter metal, it would be worth nearly as much as the accompanying silver. Michipicoten

The nickel ore from the Wallace Mine on Lake Huron has already been noticed as a steel-grey pyritous ore, whose mineralogical composition is uncertain. A mass, weighing forty-five ounces, which was regarded as an average sample, was reduced to powder, and gave iron 24·78, nickel 8·26, arsenic (mean of two determinations) 3·57, sulphur 22·63, copper 0.06; = 59.30: besides silica 28·40, carbonate of lime 4·00, magnesia 4·40, alumina 3·21; = 99·31. Taking the 59·3 per cent. to represent the metalliferous portion, this evidently contains 13·93 per cent. of nickel, and 6·02 per cent. of arsenic; the remainder being chiefly sulphur and iron. From the small proportion of arsenic, the nickel must, in part at least, be present in the state of sulphuret; a fact which is indeed made evident by the formation of sulphate of nickel by the spontaneous oxydation of the ore. The nickel from this source contained about three parts in a thousand of cobalt. Wallace Mine.

The general diffusion of nickel throughout the magnesian rocks of the Quebec group has been already noticed. It has however never yet been met with in any considerable quantities in these rocks, although workable deposits of its ores may reasonably be looked for in some parts of their distribution (page 709). On the sixth lot of the twelfth range of Orford, the sulphuret of nickel, millerite, is met with in small grains and crystals, disseminated through a mixture of green chrome-garnet with calc-spar, and through the adjacent rock. This ore has a brass-yellow color, is soft, and somewhat resembles copper pyrites: it contains sixty per cent. of nickel. Explorations were made at this place a year or two since, in the hope of obtaining copper, which was supposed to be indicated by the brilliant green of the garnet; and lead, small quantities of which are found in the vicinity. The ore of nickel is sparingly disseminated in small grains through the garnet and calcareous spar; and the masses submitted to analysis did not yield more than one per cent. of nickel. It is perhaps doubtful whether this small quantity could be extracted with profit; but the high price of nickel will allow very poor ores to be wrought to advantage, and the deposits at Michipicoten, and at the Wallace mine, yield an ore of such richness as to be worthy of farther and careful explorations. The wholesale price of commercial nickel, containing ninety-six per cent. of pure metal, was, in the commencement of 1861, quoted at from $1·15 to $1·20 the pound; but it is said to have since augmented in value. The increasing demand for it in the manufacture of German silver and of similar alloys, and its use in the coinage of the United States, of Switzerland, and of Belgium, explain its rise in price. The alloy used in the Belgian mint consists of three parts of copper to one of nickel.

Orford.

SILVER.

Native silver.

But little can be added to the facts already detailed in previous pages with regard to the occurrence and distribution of this precious metal in Canada. On page 517 will be found notices of the native silver which is sometimes associated with the native copper in Lake Superior. It has there already been pointed out that the copper ores of the Quebec group at Upton, Acton, and Ascot have afforded small portions of silver. Filaments of native silver have been observed at the Acton mine. As yet however the quantity of silver found with these ores has not been sufficient to be advantageously separated by the ordinary metallurgical processes. The deposit of native silver found with copper ores at Prince's Mine, is noticed on pages 517 and 708.

The argentiferous galena from Black River on Lake Superior, and that from Mamainse, which gives thirty ounces of silver to the ton of lead, are noticed on page 690. The lead ores which are associated, in the form of interstratified masses, with the ores of copper of the Quebec group, as seen from the assays of the galena from Upton and Acton, contain but two or three ounces of silver to the ton; a quantity which is not worth the cost of extracting. It is otherwise however with the galena which occurs in quartz veins cutting the upper slates of this region (page 691). That found with auriferous pyrites in Vaudreuil on the Chaudière, gave thirty-seven ounces of silver to the ton of lead; and that from Moulton Hill in Ascot, sixty-five ounces. A decomposing pyrites from the latter locality yields a little gold. Small quantities of gold and silver are also found with copper ore in the rocks of the Quebec group in Ascot (page 517). Argentiferous galena occurs in a quartz vein in St. Armand, and at the Owl's Head Mountain in Potton. Silver-lead.

It is well known that with the present improved processes so small a quantity as four ounces of silver may be profitably extracted from a ton of lead. The lead ores of the Laurentian rocks, with the exception of that from Lake Superior just mentioned, do not however appear to contain more than three or four ounces of silver to the ton (page 518).

GOLD.

The principal facts known with regard to the geological distribution of gold in Canada will be found on pages 518–520. Mention is there made of a quartz vein at St. Francis, on the Chaudière; where small grains of native gold have been found imbedded in quartz, together with argentiferous galena, and sulphurets of zinc and iron, both containing gold, and with arsenical pyrites. Since writing the above pages, much larger specimens of gold have been found in quartz, about one hundred yards from the locality just mentioned. It is probable that this, and similar quartz veins, may be wrought with profit; but the gold hitherto obtained from this region has been from the superficial deposits of clay, sand, and gravel, which abound there, and appear to be derived from the breaking up of the rocks that contain the gold-bearing veins. These deposits probably belong, in part to the ancient glacial drift, or boulder formation, and in part to newer stratified clays and gravels, which consist of the materials of this, modified and arranged by the subsequent action of water. On the Magog River, above Sherbrooke, particles of gold occur in a hard-bound gravel, 156 feet above the level of the St. Francis, near by. On the Famine River, there is met with an extensive deposit of clay, everywhere overlaid by sand and gravel. Along the banks of the river, a stratum of the oxyds of iron and manganese, in some parts six or eight inches thick, is seen near the top of the gravel, filling interstices among pebbles of the rocks of the region. Gold is found in this overlying gravel, as well as in the clay beneath; both of which deposits appear to belong to the modified drift. It is met with in similar conditions throughout the banks of stratified material on the Metgermet, which attain a height of fifty feet above the bed of the river. Gold also occurs still more abundantly in the recent alluvions, found in the beds and along the flats of the streams which traverse this region, and in

Gold in veins.

Gold-bearing drift.

time of floods wash down the clay and sand from their banks, depositing the heavier portions along their course. In this way the gold is often caught in the fissures of the clay slates, which frequently form the underlying rock, and are rich in alluvial gold.

Distribution. The auriferous drift of Eastern Canada is spread over a wide area on the south side of the St. Lawrence, including the hill country belonging to the Notre Dame range, and extending thence south and east to the boundary of the province. These wide limits are assigned, inasmuch as although gold has not been everywhere found in this region, the same mineralogical characters are met with throughout; and, in its continuation southward, in Plymouth and elsewhere in Vermont, considerable quantities of gold have been obtained from the alluvial deposits. In Canada, gold has been found on the St. Francis River from the vicinity of Melbourne to Sherbrooke, in the townships of Westbury, Weedon, and Dudswell, and on Lake St. Francis. It has also been found on the Etchemin, and on the Chaudière and nearly all its tributaries, from the seigniory of St. Mary to the frontier of the state of Maine; including the Bras, the Guillaume, the Rivière des Plantes, the Famine, the Du Loup, and the Metgermet. Several attempts have been made to work these alluvial deposits for gold, in the seigniories of Vaudreuil, Aubert-Gallion, and Aubert de l'Isle, but they have been successively abandoned, and it is difficult to obtain authentic accounts of the result of the various workings, although it is known that very considerable quantities of gold were extracted. The country people still, from time to time, attempt the washing of the gravel, generally with the aid of a pan, and are occasionally rewarded by the discovery of a nugget of considerable value. In the years 1851 and 1852, an experiment of this kind, on a considerable scale, was tried by the Canada Gold Mining Company, in the last named seigniory, on the Rivière du Loup, near its junction with the Chaudière. The system adopted for the separation of the gold from the gravel was similar to that used in Cornwall in washing for alluvial tin, and the water for the purpose was obtained from a small stream adjoining. Great difficulties were however met with, from a deficient supply of water during the summer months. The gravel from about three eighths of an acre, with an average thickness of two feet, was washed during the summer of 1851, and yielded 2,107 pennyweights of gold; of which 160 were in the form of fine dust, mingled with about a ton of black iron-sand, the heavy residue of the washings. There were several pieces of gold weighing over an ounce. The value of this gold was $1,826, and the whole expenditure connected with the working $1,643; leaving a profit of $182. In this account is, however, included $500 lost by a flood, which swept away an unfinished dam; so that the real difference between the amount of the wages and the value of the gold obtained should be stated at $682. The average price of the labor employed was sixty cents a day.

Rivière du Loup.

Gold washings.

In 1852, about five eighths of an acre of gravel were washed at this place, and the total amount of gold obtained was 2,880 pennyweights, valued at $2,496. Of this, 307 pennyweights were in the form of fine dust mixed with the iron-sand. A portion was also found in nuggets or rounded masses of considerable size. Nine of these weighed together 468 pennyweights, the largest being about 127, and the smallest about 11 pennyweights. Portions both of native platinum and of iridosmine were obtained in the washing, but the quantity of these was too small to be of any importance. The washing season lasted from the twenty-fourth of May to the thirtieth of October, and the sum expended for labor was $1,888, leaving a profit of $608. A part of this expenditure was, however, for the construction of wooden conductors for bringing the water a distance of about 900 feet from the small stream. As this work would be available for several years to come, a proper allowance made for it would leave a profit in the year's labor of about $680. It thus appears that from an acre of the gravel, with an average thickness of two feet, there were taken $4,323 of gold; while the expenses of labor, after deducting, as above, all which was not directly employed in extracting gold, were $2,957, leaving a profit of $1,366. The result of a week's working at this place, under the inspection of a member of the Geological Survey, in 1852, showed a yield of 143 pennyweights of gold, valued at $124; while the amount paid for wages to the miners during that time was $60. In a previous trial on the Touffe des Pins, a small tributary of the Chaudière, sixty bushels of the gravel from the bed of the stream were washed in a day, by means of a rocker, or kind of shaking table, and yielded 440 grains of gold, or about seven and one third grains to the bushel. The gold of this region is, as usual, alloyed with a portion of silver. The fineness of the gold-dust was 871 thousandths. Another sample of gold, in thin scales, gave 892, and small masses 864; while a nugget from Vaudreuil yielded 867 thousandths of gold. **Platinum.**

The composition of the heavy black sand, which is obtained in the washing of the gravel, has been noticed on page 520. It is a mixture of magnetic oxyd and peroxyd of iron, with chromic and titanic iron ores. Rolled masses of these ores, sometimes several pounds in weight, are also met with in the gravel. Small crystals of rutile were obtained in the washings; and grains of red and pink sand, chiefly composed of grains of garnets, but including a few minute crystals having the form of zircon. The gold was not unfrequently incrusted with an earthy coating of black oxyd of manganese; and some specimens were white on the surface, from a coating of mercury; which is, however, at once driven off by heat, leaving the gold of its natural color. A single well-worn and rounded mass of native copper, several ounces in weight, was found in the gravel in this region; and in the washings at the Rivière du Loup, were large quantities of leaden shot of various sizes, probably scattered by sportsmen. **Black sand.** **Mercury.** **Copper.**

Although the greater part of the gold at the Rivière du Loup was extracted from the gravel on the alluvial flats by the river side, a portion was obtained by washing the material taken from the banks above. As has been before remarked, the distribution of the gold-bearing drift over the surface of the country took place before the formation of the present water-courses; and the greater richness of the gravel from their beds is to be ascribed to the fact that these rapid streams have subjected the earth to a partial washing, carrying away the lighter materials, and leaving the gold with the heavier matters behind. According to Mr. Blake, it is found in California that the gold in the diluvial deposits, which have not been subsequently disturbed by the streams, is not uniformly distributed, but is accumulated here and there in quantities greater than in other places. During the first deposition of the earth and gravel, the precious metal became accumulated in depressions of the surface rock, constituting what are there called pockets by the miners.

It would appear from the facts here given that the quantity of gold in the valley of the Chaudière is such as would be remunerative to skilled labor, and should encourage the outlay of capital. There is no reason for supposing that the proportion of the precious metal to be found along the St. Francis, the Etchemin, and their various tributaries, is less considerable than that of the Chaudière. What is called the hydraulic method of washing such deposits is adopted on a great scale in California, and to some extent in the states of Georgia and North Carolina. "In this method, the force of a jet of water, with great pressure, is made available, both for excavating and washing the auriferous earth. The water, issuing in a continuous stream, with great force, from a large hose-pipe, like that of a fire-engine, is directed against the base of a bank of earth and gravel, and tears it away. The bank is rapidly undermined, the gravel is loosened, violently rolled together, and cleansed from any adhering particles of gold; while the fine sand and clay are carried off by the water. In this manner hundreds of tons of earth and gravel may be removed, and all the gold which they contain liberated and secured, with greater ease and expedition than ten tons could be excavated and washed in the old way. All the earth and gravel of a deposit is moved, washed, and carried off through long sluices, by the water, leaving the gold behind. Square acres of earth on the hill sides may thus be swept away into the hollows, without the aid of a pick or a shovel in excavation. Water performs all the labor, moving and washing the earth, in one operation; while in excavating by hand, the two processes are of necessity entirely distinct. The value of this method, and the yield of gold by it, as compared with the older one, can hardly be estimated. The water acts constantly, with uniform effect, and can be brought to bear upon almost any point, where it would be difficult for men to work. It is especially effective in a region covered by trees, where the

Hydraulic process.

tangled roots would greatly retard the labor of workmen. In such places, the stream of water washes out the earth from below, and tree after tree falls before the current, any gold which may have adhered to the roots being washed away. With a pressure of sixty feet, and a pipe of from one and a half to two inches aperture, over a thousand bushels of earth can be washed out from a bank in a day. Earth which contains only one twenty-fifth part of a grain of gold, equal to one fifth of a cent in value, to the bushel, may be profitably washed by this method; and any earth or gravel which will pay the expense of washing in the old way, gives enormous profits by the new process. To wash successfully in this way requires a plentiful supply of water, at an elevation of from fifty to ninety feet above the bed-rock, and a rapid slope or descent from the base of the bank of earth to be washed, so that the waste water will run off through the sluices, bearing with it gravel, sand, and the suspended clay." Blake's description.

The above description has been copied from a report on the gold mines of Georgia, by Mr. William P. Blake, who had carefully studied this method of mining in California, and by whose recommendation it has been introduced into the Southern States. He tells us that in the case of a deposit in North Carolina, where ten men were required, for thirty-five days, to dig the earth with pick and shovel, and wash it in sluices; two men, with a single jet of water, would accomplish the same work in a week. The great economy of this method is manifest from the fact that many old deposits in the river beds, the gravel of which had been already washed by hand, have been again washed with profit by the hydraulic method. He tells us that in California the whole art of working the diluvial gold deposits was revolutionized by this new method. The auriferous earth, lying on hills, and at some distance above the level of the water-courses, would, in the ordinary methods, be excavated by hand, and brought to the water; but, by the present system, the water is brought by aqueducts to the gold deposits, and whole square miles, which were before inaccessible, have yielded up their precious metal. It sometimes happens, from the irregular distribution of the gold in the diluvium in California, that the upper portions of a deposit do not contain gold enough to be washed by the ordinary methods; and would thus have to be removed, at a considerable expense, in order to reach the richer portions below. By the hydraulic method, however, the cost of cutting away and excavating is so trifling, that there is scarcely any bank of earth which will not pay the expense of washing down, in order to reach the richer deposits of gold beneath. California.

The aqueducts or canals for the mining districts of California are seldom constructed by the gold workers themselves, but by capitalists, who rent the water to the miners. The cost of one of these canals, carrying the waters of a branch of the Yuba River to Nevada County, was estimated at a million of dollars; and another one, thirty miles in length, Cost of canals.

running to the same district, cost $500,000. The assessed value of these various canals in 1857 was stated to be over four millions of dollars, of which value one half was in the single county of Eldorado. The Bear River and Auburn Canal is sixty miles in length, three feet deep, and four feet wide at the top, and cost in all $1,600,000; notwithstanding which, the water rents were so great that it is stated to have paid a yearly dividend of twenty per cent.; while other similar canals paid from three to five and six per cent., and even more, monthly. The price of the water was fixed at so much the inch, for each day of eight or ten hours. This price was at first about three dollars, but by competition it has now been greatly reduced.

From these statements, it will be seen that the great riches which have of late years been drawn from the gold mines of California, have not been obtained without the expenditure of large amounts of money and engineering skill. This last is especially exhibited in the construction of these great canals, and the application of the hydraulic method to the washing of auriferous deposits, which were unavailable by the ordinary modes of working, on account of their distance from water-courses, or by reason of the small quantity of gold which they contain.

In order to judge of the applicability of this method of washing to our own auriferous deposits, a simple calculation based upon the experiments upon the Rivière du Loup will be of use. It has been shown that the washing of the ground over an area of one acre, and with an average depth of two feet, equal to 87,120 cubic feet, gave, in round numbers, about 5000 pennyweights of gold, or one and thirty-eight hundredths grains to the cubic foot; which is equal to one and three-quarters grains of gold to the bushel. Now, according to Mr. Blake, earth containing one forty-fourth part of this amount, or one twenty-fifth of a grain of gold, can be profitably washed by the hydraulic method; while the labor of two men, with a proper jet of water, suffices to wash one thousand bushels in a day; which, in a deposit like that of Rivière du Loup, would contain about seventy-three pennyweights of gold. It is probable however that a certain portion of the finer gold dust, which is collected in the ordinary process, would be lost in working on the larger scale. It has already been shown that the gold in Canada is not confined to the gravel of the river channels, and the alluvial flats; but is found on the Metgermet and St. Francis Rivers, at from fifty to a hundred and fifty feet above their beds; and although its proportion were to be many times less than in the gravel of the Rivière du Loup, these thick deposits, which extend over great areas, might be profitably worked by the hydraulic method. The fall in most of the tributaries of the Chaudière and of the St. Francis, throughout the auriferous region, is such that it would not be difficult to secure a supply of water with a sufficient head, without a very great expenditure in the construction of canals; and it may reasonably be expected that before long the deposits of gold-bearing earth, which are so widely spread over south-eastern Canada, will be made economically available.

Lake Superior. It has been already mentioned on page 517, that the native silver from Prince's Mine on Lake Superior contains small portions of gold. The parallelism in age and mineral contents between the Upper copper-bearing rocks of this region, and the Quebec group of Eastern Canada, makes it not improbable that gold may one day be added to the list of the mineral riches of Lake Superior. The gold of Eastern Canada appears not however to be confined to the rocks of the Quebec group. Although it occurs in these with the copper ores of Ascot and Leeds, and in the garnet-rock of Vaudreuil, it is also found with mispickel and argentiferous galena in veins of quartz which traverse the upper slates.

Nova Scotia. The gold of Nova Scotia occurs with pyrites, mispickel, and native copper, in quartz veins, which traverse a great belt of schistose rocks along the Atlantic coast. These rocks, which were described by Dr. Dawson in his *Acadian Geology*, and were by him regarded as altered palæozoic strata, perhaps of Lower Silurian age, consist of gneiss with argillites and mica-schists holding staurotide, interstratified with quartzites, and penetrated by granite. In the general absence of anything like the magnesian strata of Eastern Canada, and in its other lithological characters, this series appears distinct from the Quebec group. The age of these rocks is thus uncertain. At Cape Canseau, dark colored argillites holding crystals of chiastolite are met with; and the chiastolite of Eastern Canada belongs to the upper slates, which are also gold-bearing. In Nova Scotia, although the gold occurs throughout this coast series, it is also said to be found at Cape Porcupine in rocks of the same age as these upper slates. This probable identification of a part of the gold formation of Nova Scotia with the altered Upper Silurian and Devonian strata of Eastern Canada, gives an additional economic interest to these rocks, whose metalliferous character has already been insisted upon, on pages 711 and 734. Besides forming the southeastern limit of the Quebec group from Stanstead to Gaspé they occupy a considerable area in the third synclinal, extending from Lake Memphremagog northward into Ham and Stoke (page 718).

II. MINERALS USED IN CERTAIN CHEMICAL MANUFACTURES.

Under this head it is proposed to notice several substances which could not be considered in the previous class, and which are employed in certain chemical processes, or require peculiar chemical treatment to render them available. The present class will include iron pyrites, and the ores of chrome, cobalt, manganese, titanium, and molybdenum; together with the native carbonate of magnesia, which may be used for the preparation of magnesia and of its salts.

IRON PYRITES.

Of the three species which are mentioned under this head on page 513, only one is of economic importance,—the common cubic pyrites or bisulphuret of iron. This mineral, when in a state of purity, consists of 46·7 parts of iron, and 53·3 of sulphur in 100·0 parts. It is never resorted to as an ore of iron, but is extensively employed as a source of sulphur, and for the manufacture of copperas, which is a sulphate of iron. When iron pyrites is exposed to an intense heat, in proper vessels, it gives off one half of its sulphur, which, by proper arrangements, may be collected in the form of commercial sulphur, or brimstone. The temperature required to obtain this result is, however, very elevated; and in practice it is found convenient to distil at a less heat, by which means only thirteen or fourteen per cent. of sulphur are obtained from the pyrites. This process is, however, but seldom resorted to at present; and as the great use of sulphur in the arts is in the fabrication of sulphuric acid, it is found more advantageous to calcine the iron pyrites in furnaces of a peculiar construction. By this means, almost the whole of the sulphur is expelled in the form of sulphurous acid, which is conducted at once to the leaden chambers employed in the fabrication of sulphuric acid. Formerly large quantities of sulphur were imported from Sicily for this manufacture; but within the last few years it has been almost entirely replaced by pyrites, which is brought in large quantities from Spain and Portugal, and also from Belgium and Ireland. In a recent note on the statistics of the alkali manufacture in the United Kingdom, it is stated that the consumption of pyrites for the year 1862 reached 264,000 tons. The value of good iron pyrites in England is said to be a little over ten dollars the ton; but the pyrites imported from Spain and Portugal, contains a small but variable amount of copper, which is extracted from the calcined residue, and thus adds very much to the value of the mineral. Formerly, from eight to ten per cent. of sulphur remained behind in the calcined pyrites, and was lost; but by recent improvements this loss is reduced to two per cent.

Sulphuret of iron.

Its uses.

Sulphuric acid.

In order to give some idea of the great importance of iron pyrites and of its products, in a manufacturing point of view, it must be said that sulphuric acid, which is now for the most part manufactured from pyrites, is the agent used for decomposing common salt for the manufacture of soda; in its various forms of soda-ash, carbonate of soda, and caustic soda. From this decomposition is also obtained hydrochloric acid: this is used in the manufacture of chlorine, and of bleaching powder or chlorid of lime, which are indispensable in the bleaching of cotton, linen, and the materials for paper. Besides this, the manufactures of soap and glass, and many other chemical products, are dependent upon the soda thus obtained. The sulphuric acid is also used for the manufacture of nitric acid, of superphosphate of lime, of alum, and many other products; all of which are generally manufactured in the vicinity of sulphuric acid and alkali works. Large quantities both of sulphuric acid and soda are now consumed in the refining and de-odorizing of petroleum and of coal oil.

The value of the products of the alkali manufacture in Great Britain during the last year is stated at £2,500,000. Of this about £1,000,000 was manufactured in South Lancashire; where 3,110 tons of sulphuric acid are consumed weekly for the decomposition of 2,600 tons of salt. Besides this, 700 tons of the acid are employed for other purposes, making a weekly total of 3,810 tons of sulphuric acid manufactured in that district alone: the greater part of this is from pyrites. These details are taken from a report on the chemical manufactures of South Lancashire made to the British Association in September, 1861, by Messrs. Schunck, Roscoe, and Smith, and serve to show the immense importance, to a manufacturing country, of an abundant source of sulphur. The time will come, sooner or later, when our increasing industry will be sufficient to warrant the establishment in Canada of manufactures of chemical products; and should the present processes still continue to be employed, the deposits of iron pyrites will then become available.

Iron pyrites is also employed in another important manufacture: that of sulphate of iron or copperas, which is very extensively used in dyeing and in other chemical processes. According to the report cited above, eighty tons of this salt were in 1861 manufactured weekly in South Lancashire. For half a century the American market has been to a large extent supplied by the copperas which is manufactured from a bed of iron pyrites in Stafford, Vermont. The process of manufacture is very simple. The pyrites, which in some cases is subjected to a preliminary roasting, is broken into small pieces, and placed in heaps beneath sheds, and upon water-tight floors. It is then from time to time moistened with water, which favors the oxydation of the mass at the expense of the oxygen of the air. After some time, the pyrites heats, crumbles, and is in great part converted into a soluble sulphate of iron, which is dissolved out by water, and, from the floors below, is led into boilers, in which it is evaporated to such a point, that by cooling, crystals of the sulphate of iron are deposited. Copperas

The most considerable deposit of pyrites known in Canada is one occurring on the nineteenth lot of the second range of Elizabethtown, near Brockville. It probably forms a great interstratified mass in the rocks of the Laurentian system; but the locality has not been sufficiently explored to determine either its extent, or its relations to the strata. According to Mr. Macfarlane, an excavation of fifty by thirty feet has been made in the mass without coming to the limit of it in either direction. The pyrites, which is very pure, and free from earthy admixture, is of two varieties, the one being somewhat porous and dull, with a greenish hue, and the other Elizabethtown.

compact, massive, with a brilliant lustre, and a somewhat conchoidal fracture. Both varieties contain a small proportion of cobalt, which in the latter is equal to five or six thousandths of the oxyd of cobalt, besides traces of copper. These metals might be extracted from the residue left after the calcination of this pyrites for the manufacture of sulphuric acid; and under the head of Cobalt, it is proposed to give some account of the mode of separating this valuable material from the pyrites. It is said that other large deposits of this mineral occur in this vicinity; and localities which have not yet been examined are mentioned on page 513. The great bed of iron and copper pyrites occurring at Garthby (page 733), and another on the sixth lot of the ninth range of Ascot, will also furnish large amounts of iron pyrites. These beds occur in the same formation as the pyrites of Stafford in Vermont, which like them is associated with copper pyrites. Iron pyrites also abounds in the syenitic gneiss near Portage du Fort, particularly on the twenty-first lot of the second range of Clarendon.

Garthby.

CHROMIUM.

Chromic iron ore.

The occurrence of the compounds of chrome, or chromium, in the rocks of Canada, is described on page 504. The chrome used in the arts is always obtained from the substance which is known as chromic iron ore,—or sometimes, incorrectly, chromate of iron. This is a black mineral, somewhat resembling magnetic iron; from which however it is distinguished by the color of its streak and powder, which are dark brown, and by the fact that it is not attracted by the magnet. This ore is composed of the oxyds of chrome and iron; which are however occasionally replaced, in part, by alumina and magnesia; so that its composition is variable. The analyses of different specimens of the pure ore give from forty to over sixty per cent. of the green oxyd, or sesquioxyd of chrome; but inasmuch as the ore is often mingled with a greater or less amount of earthy matter, the proportions of oxyd of chrome in many commercial samples, may fall considerably below the numbers just given.

Chromate of potash.

The compound of chromium chiefly used in the arts is the combination of chromic acid with potash, known as the bichromate of potash, from which are prepared both red and yellow chromates of lead; the latter being the pigment known as chrome-yellow. The green oxyd of chromium is also prepared from this salt, and is used as an indellible green color in painting, and for the preparation of an indestructible green printing-ink. Large quantities of the bichromate of potash are used in dyeing, and in calico-printing; and according to the report above cited, the quantity of this salt manufactured weekly in South Lancashire was, in 1861, fourteen tons. This salt consists of one equivalent or forty-seven parts of potash, and two equivalents or one hundred and two parts of chromic acid. Of this latter, fifty-one parts correspond to thirty-nine parts of the green or sesquioxyd of chrome; and although the metal exists in this latter form in the ores, it is now usual for commercial purposes to give the percentage of chromic acid which these will yield. Thus the chromic iron from Bolton, which gives by analysis 45·9 per cent. of oxyd of chromium, would yield sixty per cent. of chromic acid. Rich ores of this kind are said to be worth in Baltimore, from whence large quantities are shipped, one dollar per ton, for each unit of chromic acid. This agrees closely with the price offered for the chromic iron from Ham, to be noticed below. Samples of two barrels from this locality, sent to Glasgow and to London in 1861, gave from 43·7 to 44·1 per cent. of oxyd of chrome. The mean of these, 43·9, equals 57·4 per cent. of chromic acid, and the prices offered for this ore in London, and in Glasgow, were respectively £11 10s. and £12 sterling the ton.

This valuable mineral is met with in considerable quantities in several localities among the serpentines of Eastern Canada. On the fourth lot of the second range of Ham is found the ore mentioned above. It forms a lenticular bed in the serpentine, having a thickness of about fourteen inches. About ten tons of the ore, of which that sent to England was a sample, were extracted from seven square fathoms in the plane of the bed. Farther to the northeast, on a small island in Breeches Lake in Garthby, there is a considerable amount of chromic iron in disseminated crystals, running in bands through serpentine. It is not however probably in sufficient quantity to be wrought with profit. On the twenty-third lot of the seventh range of Bolton is a bed of chrome ore from one to two feet in thickness, in serpentine. The bed dips eastward, at an angle of about eighty degrees, and the ore appears to occur in detached masses of from fifty pounds to half a ton in weight. The assay of a portion of this ore, as stated above, gave 60·0 per cent. of chromic acid. Chrome ore has also been met with on the twenty-second lot of the sixth range of Melbourne, where lenticular masses of it, from six to nine inches in thickness are found running in beds in serpentine. It is probable that the ore will be met with in many other parts of this region. A boulder of several hundred pounds weight was many years since found near Lake Memphramagog, and was very rich in chrome, yielding not less than 65·0 per cent. of chromic acid. On Mount Albert in Gaspé, which is composed of serpentine, loose masses of chrome ore, sometimes weighing twenty pounds, were traced for half a mile along the strike of the rock, and probably indicate the presence of a bed of the mineral in the vicinity.

Ham.

Bolton.

Melbourne.

Gaspé.

The principal supplies of this ore are now obtained from the states of Pennsylvania and Maryland, and from Norway. The annual consumption for the manufactories of South Lancashire alone, must be equal to about 1000 tons of ore, yielding fifty per cent. of chromic acid. The process of manufacturing the bichromate of potash is one which might, as Mr. Macfarlane has suggested, very well be carried on in this country. It consists simply in calcining the finely ground ore with crude potash, in a proper furnace, exposed to a current of air, by which the chromic oxyd is acidified, and unites with the potash. The resulting mass is lixiviated with water, and the solution, being mixed with a certain amount of sulphuric acid, furnishes by evaporation crystallized bichromate of potash. In the absence of sulphuric acid, a crude neutral chromate of potash might readily be prepared by simple evaporation, and shipped to England, to be there converted into bichromate. The cheapness and facility with which the ore, the potash, and the requisite fuel may be obtained in the Eastern Townships, are such as to offer encouragement for the working of the chrome ores in the country.

COBALT.

This metal is associated in small quantities with the ores of nickel in Canada, as has been noticed on page 506. The only mineral as yet known which can be made available as a source of cobalt is, however, the great deposit of iron pyrites already described as occurring at Elizabethtown; the brilliant compact variety of which yields from 0·5 to 0·6 per cent. of oxyd of cobalt. Mr. Macfarlane has made some experiments on the practicability of extracting profitably this small amount of cobalt from the ore. According to him, 1,000 parts of the finely pulverized pyrites are mixed with 100 parts of sea-salt, and calcined in a muffle, until the perchlorid of iron, at first formed, begins to be decomposed with the evolution of chlorine gas. The matter being then removed, and cooled, gives to water a solution, which, besides unaltered sea-salt and sulphate of soda, contains a trace of perchlorid of iron, with chlorids of cobalt and copper, equal to 6·0 parts of oxyd of cobalt and 1·5 of oxyd of copper. By the careful addition of a solution of carbonate of soda, the iron and copper may be first separated, and the cobalt subsequently thrown down as a carbonate, and converted by calcination into the black oxyd, in which form it is sold in commerce; its price in the English market being from eleven to thirteen shillings, or about three dollars, the pound. It is employed in giving a blue color to glass and porcelain, and in the preparation of the blue pigment known as smalt, and the rare and costly color called Thénard's blue, which is a phosphate of cobalt. Mr. Macfarlane estimates the cost of treating a ton of the cobaltiferous pyrites to be as follows: excavation, \$3·00, roasting 0·25, freight to the factory \$2·50, stamping 0·50, calcining \$6·00, lixiviation, precipitation, etc., \$1·25, freight to market, agency, etc., 0·50; = \$14·00. Supposing that, in the large way, two thirds only of the cobalt are separated, there would be obtained from a ton, eight pounds of the oxyd, which, at \$3.00 the pound, is equal to \$24·00; leaving thus a large margin for profit. (Canadian Naturalist, June, 1862.)

Cobaltiferous pyrites.

In this calculation the sulphur is supposed to be for the most part expelled in the roasting, after which the ore is crushed and mixed with a small proportion of salt, and calcined in a reverberating furnace. In this way the sulphur is entirely lost; but in case this pyrites were used for the manufacture of sulphuric acid, the cobalt could be advantageously extracted from the residue, and in this way the ore might probably be shipped to Liverpool with advantage. Cobalt ores are now rare, and much sought after, so that an abundant supply of any cobaltiferous mineral attracts the attention of the English manufacturers, who applied for, and received for trial, a portion of the large specimen of this pyrites which was sent to the International Exhibition of 1862. It will be recollected that cobaltiferous pyrites has been described as occurring with the copper ores of Escott, and also in D'Aillebout; so that it is not improbable that other and more abundant sources of cobalt may be found among the minerals of the Laurentian rocks. Cobalt.

MANGANESE.

The few localities in which the peroxyd of manganese has been met with in Canada, are noticed on page 507. It has not as yet been found in sufficient purity or abundance to be of economical importance; but is mentioned in this chapter to call attention to the importance of the native oxyds of manganese, and to the fact that valuable mines of them have been found in the adjoining state of Vermont, in the continuation of the rocks of the Eastern Townships, so that it is not unreasonable to expect that similar deposits of manganese may be met with in that part of the province. Large amounts of the oxyd have been raised in Brandon and Chittenden, Vermont, and shipped to England; where great quantities of it are consumed, chiefly in the manufacture of chlorine for bleaching purposes. Manganese, in different forms, is also used to some extent in dyeing and in calico-printing, and in the coloring of glass and earthen ware. The supply of manganese is in great part obtained from Germany; and for the year 1862, it is said to have equalled 33,000 tons for Great Britain alone. Manganese.

At Bachewanung Bay, on Lake Superior, near the southwest end of the Upper Canada Mining Company's location, and not far from the shore, is a large vein of manganese ore, running north and south, and from fifty to sixty feet wide. It is described as presenting the aspect of a succession of small knobs, in which, mixed with a reddish trappean rock, are numerous strings of the ore, associated with quartz and calc-spar, and occasionally with octahedral crystals of fluor. The ore, which is massive with small geodes of crystals, is described by Prof. Hadley as manganite, or hydrous sesquioxyd of manganese, which for manufacturing purposes is inferior to the peroxyd. A specimen was found by assay to be equal to sixty per cent. of peroxyd of manganese. Bachewanung Bay.

The following are the localities in which deposits of oxyd of manganese have been met with in Eastern Canada. It is generally in the form of the earthy hydrated peroxyd, commonly known as wad or bog manganese, and appears to have formed under conditions similar to bog iron ore. Like this substance, it includes more or less sand and clay, and it is often mixed with a considerable proportion of peroxyd of iron. On the twenty-second lot of the twelfth range of Bolton, a layer of earthy manganese, from three to six inches in thickness, was observed, resting upon the edges of a mass of clay-slate, and filling up the interstices. Its extent was only a few hundred yards, and the ore contained but twenty-six per cent. of peroxyd of manganese. A deposit of this material was also observed on the twenty-fourth lot of the fourth range of Stanstead, but it did not appear to be more important than the last. On the ninth lot of the tenth range of the same township, the same ore is met with near the surface of a bed of sand, over an area of about two acres, in which it occurs in patches, sometimes two or three yards in diameter, and a foot in thickness. These are made up of irregular nodular masses, which, when washed from the adhering sand, contain thirty-seven per cent. of peroxyd of manganese.

Earthy manganese.

Bolton

Stanstead.

In the township of Tring, near its eastern limit, and along the road leading from Lambton to St. Francis, manganese was observed for a little distance on both sides of the road, and to the north became a foot in thickness. It gave by analysis twenty-five per cent. of peroxyd. The same ore was observed in the seigniory of Aubert-Gallion, for nearly half a mile along the west bank of the Chaudière River, opposite the mouth of the Famine. As in the locality mentioned in Stanstead, it occurs in nodular masses, which in some places form patches of a few feet in breadth, with a thickness of from two to four inches. It contains twenty per cent. of peroxyd. In the seigniory of St. Mary, at the junction of the Frampton road with that between the second and third ranges, manganese was observed over an area of a few yards, with a thickness, in some places, of two feet, and was also found in other places near by. This ore gave thirty per cent. of peroxyd. In the seigniory of St. Anne de la Pocatière, a bed of manganese was observed about three fourths of a mile southeast from the church, beneath a cultivated field. Its extent could not well be determined, but it contained thirty-eight per cent. of peroxyd. In the seigniory of Cacouna, at the village of La Plaine, on the land of Mr. Stanislaus Roy, manganese was observed over an area of a few yards, forming a bed four or five inches in thickness, of nodules imbedded in sand. In the neighborhood of Quebec, on the St. Louis road, about four miles from the city, on the land of Mr. Michel Hamel, is a small deposit of earthy manganese, extending over two or three hundred yards, and having in the middle a thickness of twelve inches, but being thinner towards the edges. It has the form of black porous masses imbedded in sand.

St. Mary.

TITANIUM.

Titanium has hitherto received but few applications in the arts; and until within the last few years, during which large quantities of titanic iron ore have been found in the Laurentian rocks of Canada and of Norway, it was comparatively a rare substance. Within two years however, attention has been turned to the probable importance of small portions of titanium in improving the qualities of iron and steel; and Mr. Mushet has obtained several patents for certain modes of using the native ores of titanium and iron, and for obtaining alloys of the two metals. Experiments with the titanic iron ore from Norway, are said to have been undertaken on a considerable scale, for the purpose of determining the value of these new combinations; but as yet, no practical results appear to have grown out of this application of titanium.

Titanium.

A compound was, in 1846, described by Elsner, under the name of ferrocyanid of titanium, as a green paint; and it has recently been again brought into notice as a safe substitute for the poisonous arsenical green color now so much used. In Elsner's process, which is said to be patented in England, titanic acid, prepared by decomposing titanic iron ore by fusion with bisulphate of potash, and by subsequent purification, and separation from iron, is precipitated from its hydrochloric solution by ferrocyanid of potassium at a boiling heat. By this means, a beautiful dark green pigment is obtained; which is however inferior in brilliancy to the arsenical copper green.

Its applications.

In March, 1861, specifications for a patent were deposited in London, by Mr. F. Versmann, for the employment of the compounds of titanium as pigments, or coloring materials. The details of his processes are not known to us. Several finely colored bodies, besides the green ferrocyanid just noticed, have however been obtained from titanium. Thus the action of gaseous ammonia upon titanic acid, heated in a porcelain tube, gives rise to a stable nitrid of titanium of a violet color; and when fused with vitrifiable substances, in presence of metallic tin, titanic acid gives rise, according to Karsten, to a beautiful deep blue enamel. This resembles the smalt which is prepared with the oxyd of cobalt, and it may perhaps be made to replace it. The sulphuret of titanium, prepared by the action of sulphuretted hydrogen upon the bichlorid, is a beautiful bronze or gold-yellow substance, which crystallizes in scales, has a metallic lustre, and resembles the sulphuret of tin, known as mosaic gold. From the cheapness and facility with which titanium and its compounds may now be obtained, it may be presumed that before long this substance will find numerous applications in the arts; in which case the rocks of the Laurentian series in Canada will probably be able to furnish it in inexhaustible quantities.

Vaudreuil. The various localities of titanium in the province have been noticed on page 501. The presence of small portions of this metal in many of the specular schists of the Eastern Townships, is there noticed; and also the existence in Vaudreuil of a bed of iron ore, forty-five feet in width, which is a mixture of about two parts of magnetic iron and one part of titanic iron, or ilmenite, containing forty-eight per cent. of titanic acid. Ilmenite, in a very pure form, is still more abundant in the Laurentian series, where it is sometimes mistaken for an ordinary ore of iron. It closely resembles magnetic iron in its external characters, and in giving a black streak and powder. It is however distinguishable by the fact that it is not attracted by the magnet. The most important mass of it known is that which occurs in the parish of St. Urbain, at Bay St. Paul. Here is a great bed, which has a thickness of ninety feet, and is exposed for a length of three hundred feet. It is however said to have been traced, with perhaps some interruptions, for about a mile. Besides several smaller masses of the ore in the neighborhood, which, like this, are imbedded in an anorthic feldspar rock, a still larger deposit is said to exist in the vicinity, but is perhaps only a continuation of the previous one. The ore, which is generally very free from any earthy admixture, contains 48·6 per cent. of titanic acid. This is also sometimes found in orange-red crystalline grains disseminated through the ore, thus increasing its richness in titanium.

Bay St. Paul.

MOLYBDENUM.

Molybdenum. This rare metal exists in nature for the most part as a sulphuret, known as molybdenite, or in the form of molybdate of lead. The former ore is the more common, but is very seldom met with in any considerable quantity. Notwithstanding its scarcity, it has however found several applications. The combination of molybdic acid with ammonia is used as a reagent for the detection and determination of phosphoric acid, in chemical analysis. A fine blue pigment has also been prepared from molybdenum; and a few years since a German chemist proposed the blue of molybdenum as a substitute for indigo in dyeing silk, cotton, and linen. Experiments to test the applicability of this substance were made by Kurrer, and are reported in Dingler's Polytechnical Journal for 1853; from which it appears that by the use of molybdenum and a salt of tin, blue dyes of every shade, and of remarkable durability, when exposed to sun and air, were readily fixed upon silk. Durable blues, though inferior to those given to silk, are imparted to cotton by the same dye. The molybdates may also be employed in printing, to give what are called topical colors to both silks and cottons. The molybdic acid for this purpose is said to have been manufactured at Prague, from a massive molybdate of lead, which is found in some quantity in Bavaria. It does not appear that these processes

Its uses.

have ever become adopted to any great extent, one cause of which is undoubtedly the rarity and costliness of molybdenum. At the Industrial Exhibition of 1855, Batka, a manufacturing chemist from Prague, presented specimens of an impure molybdate of soda, prepared for dyeing silks, and containing less than one half its weight of molybdic acid. Its price was \$1·20 the pound, while that of the native sulphuret of molybdenum, exhibited by him, which may be made to yield about nine tenths its weight of molybdic acid, was \$3·45 the pound. The small supply of the material, conjoined with the demand for it for the uses of the laboratory, has probably prevented its more general employment.

Manicougan Bay.

On page 504, several localities of molybdenite have been mentioned; but the only one of them, so far as known, which affords any available quantity of the mineral, is that described as occurring in Quetachoo-Manicougan Bay, on the north shore of the Gulf of St. Lawrence; where it occurs disseminated in a bed of quartz six inches thick, in the form of nodules from one to three inches in diameter; and in flakes, which are sometimes twelve inches broad, by one fourth of an inch in thickness. The bed, which is interstratified in a white coarse-grained gneiss, holding garnets and black mica, was traced about fifty yards, with a dip N. 15° E. < 58°, and would probably furnish a considerable quantity of molybdenite. This mineral, which has a specific gravity of about 4·5, has a leaden-grey color, and a metallic lustre. It is soft, and unctuous to the touch, and is often mistaken for plumbago; from which it is distinguished by its much greater weight, by a peculiar greenish hue in the metallic streak which it leaves on white paper, and by the fact that when heated to redness in the open air, it gives off the odor of burning sulphur, and is slowly converted into a yellowish-white substance, which is molybdic acid.

Harvey Hill.

Since writing the previous chapters, sulphuret of molybdenum has been found at Harvey Hill, in Leeds, by Mr. Herbert Williams, the director of the works of the English and Canadian Mining Company at that place. The mineral occurs in some of the short courses or veins of quartz and bitter spar, which intersect the copper-bearing slates of this locality. It forms small masses, generally rounded in their outline, and sometimes an inch or more in diameter. Judging from the specimens sent, the mineral would seem to be abundant. The molybdenite of this locality, instead of being foliated, as is generally the case, is finely granular, with an uneven fracture; it is very soft, and assumes a polish when rubbed with the nail. It is not improbable that some among the numerous localities in which molybdenite has been met with on Lake Superior, may be found to yield considerable quantities of this material.

MAGNESIA.

Magnesia and its salts are extensively used in pharmacy, and the former has been proposed as an ingredient in certain cements. The consumption of magnesia is however limited, and minerals available for its manufacture are found in abundance in most countries. Among these are serpentine, a hydrous silicate, containing about forty per cent. of magnesia, with a portion of iron. In France, this mineral is used for the manufacture of sulphate of magnesia. It is first calcined at a strong red heat, for forty-eight hours in a reverberatory furnace. This expels the water, and renders the iron nearly insoluble. The mineral is then ground to powder, and mingled with a proper quantity of sulphuric acid, which rapidly converts the magnesia into a sulphate, forming a crystalline mass, from which it is dissolved by water; leaving the silica, and most of the iron behind. A little milk of lime is now added to separate any dissolved impurities, and the clear solution being evaporated, deposits pure sulphate of magnesia, or Epsom salt. A small establishment at Remiremont in the Vosges, has long been in operation, and a few years since manufactured annually from twenty to twenty-five tons of the salt from the serpentine of the vicinity. One hundred parts of this, containing forty parts of magnesia, will require about one hundred parts of sulphuric acid, and yield about two hundred and fifty pounds of Epsom salt. As a great portion of the magnesia is consumed in the form of calcined or carbonated magnesia, it is more economical to make use of a process which dispenses with the use of sulphuric acid, which is necessary to decompose the serpentine. Magnesian limestone, or dolomite, is therefore resorted to. This contains, when pure, a little over twenty per cent. of magnesia, in the form of a carbonate, combined with an equivalent of carbonate of lime. When this magnesian limestone is calcined, there is obtained a mixture of caustic lime and magnesia, which is suspended in water, and treated with a current of carbonic acid gas. By this means a very soluble bicarbonate of magnesia is obtained, which may be separated from the less soluble carbonate of lime.

Magnesian salts.

By referring to preceding chapters, it will be seen, that, besides the extensive formations of dolomite, which abound in various parts of the country, serpentine is found in great abundance, forming a rock in various localities, both in the Laurentian and the altered palæozoic strata. The native carbonate however is much better fitted for the preparation of magnesian salts than serpentine or dolomite; since, when calcined, there is obtained, at once, caustic magnesia, without admixture of lime. The occurrence of considerable beds of this rock in Bolton and Sutton has been noticed on pages 457 and 615. When this impure carbonate of magnesia is calcined, there is obtained a mixture of caustic magnesia, with oxyd of iron, and the silicious or feldspathic impurities which the rock contains; and it suffices

Magnesite.

Bolton.

to treat this mixture with a solution of carbonic or sulphuric acid to obtain bicarbonate or sulphate of magnesia. In the latter case, a small amount of oxyd of nickel, which the mineral contains, is taken into solution, but this may be precipitated by a little sulphuret of barium.

A French engineer, Vicat, has within the last few years proposed the use of magnesia, in place of lime, for hydraulic cements which are to be used in constructions exposed to the action of sea-water. For this purpose, according to him, pozzuolana, or calcined clay, is to be mixed with fifteen or twenty per cent. of caustic magnesia, exempt from lime, when a cement will be obtained, which hardens after three or four days, under either fresh or salt water, and soon acquires a great degree of solidity. The cost of obtaining magnesia from its sulphate, prepared from serpentine, or from magnesian limestone, is such as to constitute an objection to its use. By calcining the magnesite of Canada, however, there is obtained a mixture of caustic magnesia, with oxyd of iron and silicious matters. As the latter substances would not probably be in any way prejudicial to the cement, the mixture thus obtained might be used instead of pure magnesia. The magnesite of Bolton, which contains about sixty per cent. of carbonate, would, by calcination, afford a mixture containing forty-three per cent. of caustic magnesia. This carbonate of magnesia, of which the Eastern Townships possess large quantities, is a rare rock in most other regions, so that it is not impossible that the magnesite of Lower Canada may one day become an article of export.

Magnesian mortar.

III. MINERALS USED IN AGRICULTURE.

Under this head are included those substances which may be used as fertilizers for the soil. Of these mineral manures, the only ones found in Canada are phosphate of lime, gypsum, and marl. To these may however be added lime, which is employed as a dressing for certain soils.

PHOSPHATE OF LIME.

Phosphate of lime is used in the arts for the manufacture of phosphoric acid, and of phosphorus, and enters largely into the composition of certain porcelains. It is besides very extensively used as an application to the soil. Phosphates are among the minerals most essential to vegetation, and are removed from the earth in large quantities by growing crops. The importance of a supply of phosphates to the soil is made very evident by the fact that the mineral part of the bones of animals is, for the greater part, phosphate of lime, and up to a recent period furnished a sufficient supply of this material for the demands of commerce. Carefully dried bones, when calcined to whiteness, lose about one third of their weight,

Phosphate of lime.

Bones. which consists of organic matter, and leave a white earthy residue. This contains, on an average, about eighty-six per cent. of phosphate of lime, the remainder being carbonate of lime, with fluorid of calcium and a little magnesia. Burned bones enter to the extent of thirty or forty per cent. into the body of what is called English porcelain, which contains besides, clay, ground feldspar, and flints. The phosphoric acid of the bone-ash is the vitrifiable element of this mixture, and at a high temperature unites the other ingredients into a translucent enamel. The Parian ware is said to be a variety of this same compound, which differs from the true porcelain, into whose composition phosphate of lime does not enter. The bones for this manufacture are in part obtained in Great Britain; and in part from South America, where those of the wild cattle are burned, and in that state exported to England.

By far the greatest consumption of phosphate of lime is, however, for agricultural purposes, for which the amount furnished by bones is altogether inadequate. Recourse is accordingly had to other sources, among which are the so-called Columbian guano, and other similar deposits, which differ from Peruvian guano in the absence of ammoniacal or nitrogenized compounds, and are little more than phosphate of lime, sometimes with a portion of phosphate of alumina or of iron. In many parts, both of England and France, there are also found large quantities of coprolites, which are the exuviæ of animals of former times, and consist for the most part of phosphate of lime. A stratum of clay at the base of the chalk formation in Cambridgeshire furnishes great quantities of these coprolites, which are extracted by washing away the earth by water, and are said to contain about sixty per cent. of phosphate of lime. Nodular masses, which are apparently similar to these coprolites, occur in several parts of the Silurian rocks of Eastern Canada, and have been described on page 461. They do not however contain more than forty per cent. of phosphate of lime; and, being disseminated in hard limestone or sandstone, instead of clay, they could not probably be extracted with advantage, and are of much less importance than the crystalline phosphate of lime, or apatite of the Laurentian rocks, which will presently be described.

Guano.

Coprolites.

The phosphate of lime, whether in the form of bones, coprolites, or apatite, is seldom applied to the soil in its insoluble state, as it is then comparatively unavailable for the nutrition of plants. To render it proper for agricultural purposes, it is converted into a soluble salt, which is known as superphosphate of lime. To render this process intelligible, it should be remarked that in the insoluble mineral or bone phosphate, one equivalent or seventy-one parts of phosphoric acid is united with three equivalents, of twenty-eight parts each, of lime, making the equivalent weight of the ordinary phosphate of lime, one hundred and fifty-five. In order to reduce this to the soluble superphosphate, which contains one

Superphosphate.

equivalent of phosphoric acid and one of lime, it is necessary to remove two thirds of the lime, or two equivalents. This is effected by adding two equivalents, or ninety-eight parts of sulphuric acid (oil of vitriol), which forms with this lime one hundred and thirty-six parts of sulphate. 100·0 parts of ordinary phosphate of lime, therefore, require 63·2 parts of sulphuric acid to convert them into the soluble superphosphate, with one equivalent of base. In this process, however, regard must be had to the foreign matters which accompany the phosphate of lime, and which may also require sulphuric acid for their decomposition. Of these, the principal are fluorid of calcium and carbonate of lime. The former is always present in small quantities in bones, and in still larger amounts in many of the mineral phosphates, and requires, for the decomposition of one hundred parts, one hundred and twenty-five of sulphuric acid. The principal impurity in burned bones is carbonate of lime, which is also mechanically intermixed with many of the mineral phosphates, and requires, for the decomposition of one hundred parts, ninety-eight parts of sulphuric acid. In calculating the value of any material as a source of superphosphate of lime, it is thus necessary to take into account the quantities of fluorid and carbonate present, which take up a portion of sulphuric acid, without giving any valuable product in return. As the greater part of the expense in this process is the cost of the sulphuric acid, the manufacture of the superphosphate of lime is chiefly confined to those districts where sulphuric acid is prepared. In South Lancashire alone, the weekly production of the superphosphate, in 1861, was stated to be from 500 to 600 tons; besides which very large amounts are manufactured in other parts of Great Britain.

Of late years, the increasing demand for phosphates as fertilizers has drawn attention to the use of the crystalline mineral phosphate of lime, or apatite, of which large quantities have been imported from Norway into England; and attention has recently been turned to the abundant supplies of this substance existing in Canada. According to a letter received in September, 1862, from one of the largest manufacturers of superphosphate in England, he, a few years since, imported several thousand tons of apatite from Sweden, and only abandoned its use because the English phosphates of lime could be furnished at lower rates than the Swedish. He writes that the following prices may be expected for phosphate of lime in England: for a mineral containing ninety per cent. of phosphate of lime, about £6 10s. sterling per ton; for one containing eighty per cent., £5 10s.; and for one of seventy per cent., £4 10s. A mineral with a lower per-centage than this would not, it is said, be merchantable. Apatite.

The question is sometimes asked, whether the native phosphates of lime may not be directly applied to the soil as a manure, and thus dispense with the costly process of converting them into superphosphate. Ground bones, Phosphatic manures

which are used with great advantage as a manure, owe a portion of their efficacy to the organic matter which they contain; and which, by its slow decay in the soil, gives rise to ammonia, an important fertilizer. By this process, the phosphate of lime of the bones is at the same time presented to the roots of the plants in a divided state, and doubtless exerts a beneficial action; which, from the slowness with which the substance is dissolved, extends over several years, and is more marked after a year or two than at first. The more dense phosphate of the coprolites, and of the crystalline apatite, is however much less soluble than the phosphate of bones, and slower in its action when applied to the soil. It therefore becomes an object to the agriculturist to apply phosphate in small quantities, and in such a form as will be immediately available to the growing crop. For this purpose, he has recourse to the superphosphate of lime, or to some other soluble phosphate. Peruvian guano owes a great part of its value to the fact that it contains three or four per cent. of phosphoric acid in the form of phosphate of ammonia. When this substance, or the superphosphate of lime, is applied to the soil, it is at first taken into solution by the water there present, and is then decomposed by the compounds of lime and other bases present in the soil; so that it is again converted into an insoluble phosphate, which is produced in a state of very minute division, thus exposing a great amount of surface, and is distributed throughout the soil. To illustrate the extent of subdivision which is attained in this manner, Prof. S. W. Johnson tells us, that, while the particles of ground bones will average perhaps one hundredth of an inch in diameter, those of the phosphate of lime, precipitated from the dissolved superphosphate, are not more than one twenty-thousandth of an inch in diameter; so that one single particle of bone dust, one hundredth of an inch in diameter, would be equal to eight million particles of the precipitated phosphate. This enormous subdivision, which is thus obtained by the use of a soluble superphosphate, renders intelligible the great efficiency of small portions of this substance, when applied as a fertilizer. According to the analyses by Prof. Way, of several of the best specimens of English superphosphate of lime, it appears that they contain on an average about thirteen per cent. of soluble phosphoric acid, and about three per cent. more in the form of insoluble and undecomposed phosphate of lime. The remainder consists of the lime of the superphosphate, together with sulphate of lime and water. Besides these, there is sometimes a portion of animal matter derived from bones, when these are employed, or subsequently added for the purpose of converting the superphosphate into various artificial manures.

Solubility of phosphates

Apatite deposits.

The abundant deposits of apatite in the Laurentian rocks of Canada, have already been noticed on pages 461 and 592. The mineral has been observed in the Laurentian limestones on the Gatineau, and on the seventh lot of the first range of Ross, where it is abundant in crystals disseminated with purple fluor spar in limestone; but the most remarkable deposits of it occur in the townships of Burgess and Elmsley. The mineral has been traced for about a mile on the eighth range of North Elmsley, across the lots twenty-four, twenty-five, and twenty-six, in a direction nearly southwest; and apparently forms an irregular bed in the Laurentian limestone. On the second of these lots, where it has been somewhat quarried, the breadth of the bed seems to be about ten feet, of which three feet are nearly pure crystalline apatite, sea-green in color, and with a small admixture of black mica. Masses of this gave on an average eighty-eight per cent. of phosphate of lime. Ross. Elmsley.

The deposit of apatite just noticed appears to extend southwestwardly, into North Burgess, where it is found in a great many localities. The fourth lot of the eighth range, and the second and seventh lots of the seventh, are localities of the mineral. The first of these has furnished large crystals, thickly disseminated with mica, in a flesh-colored limestone. It has also been found south of Rideau Lake, on the first lot of the fourth range of South Burgess; but it appears to occur in the greatest abundance in the fifth range of North Burgess, where it has been observed in lots four, seven, eight, nine, and ten. Specimens from the latter two lots are massive, crystalline, and very pure. That from the fourth lot is described as presenting eight or ten parallel beds, interstratified with gneiss, and running northeast and southwest. These beds are said to be from eight to twenty-four inches in thickness, and from ten to twenty feet apart. A large block of this mineral was found to resemble closely in aspect that from the two lots mentioned above. It is crystalline, granular, with an uneven fracture, a vitreous lustre, and is translucent, with a greyish hue, which passes into greenish or reddish. It resembles, at first sight, some varieties of quartz rock; from which however it is readily distinguished by its inferior hardness, its greater weight, and by the action of nitric and muriatic acids, which readily dissolve it when in powder, without effervescence. What was regarded as an average specimen from one of the beds, on the fourth lot, gave by analysis: phosphate of lime 91·20, fluorid of calcium 7·60, chlorid of calcium 0·78, insoluble 0·90; = 100·48. When treated with sulphuric acid, it is readily decomposed, and evolves abundance of hydrofluoric acid. This mineral phosphate contains only traces of oxyd of iron; and from its purity, it might perhaps be used instead of bone-ash in the manufacture of English porcelain. Mr. Benj. Hutchins, of Montreal, has recently acquired the most important of these deposits of apatite, in Burgess and Elmsley, and is making preparations to work them, with a view of offering the phosphate of lime of Canada to the English market. Burgess.

GYPSUM.

Gypsum formation.

The existence of gypsum in various geological positions in Canada has already been noticed on page 459. It is only in the Onondaga formation that workable deposits of it are known to occur: and the facts of scientific importance in the history of the gypsum of this formation will be found in the thirteenth chapter, where it has been shown that it is interstratified with peculiar dolomites and dolomitic marls; some of which are farther described on page 625. The outcrop of this gypsiferous formation extends from the Niagara River to the Saugeen on Lake Huron, a distance of about one hundred and fifty miles; but the gypsum mines at present known are all found within about thirty-five miles, on the Grand River, extending from Cayuga to Paris. It is probable however that as the country to the north west of Paris becomes more settled, farther discoveries of gypsum beds will be made in that direction. To the southeast of Cayuga, the overlying drift conceals any beds of gypsum which may be present. All of these deposits seem to be confined to one stratigraphical position, which is probably about the middle of the formation. The gypsum occurs in beds, which thin out in such a manner that they present the form of lenticular masses. These vary in horizontal diameter, from a few yards to a quarter of a mile, and are from three to seven feet in thickness. The strata above them are arched and broken, while those beneath present an undisturbed level floor, the two coming into contact at the edge of the masses. This peculiar structure gives rise to mounds on the surface, which are regarded by the inhabitants of the region as indications of the presence of beds of gypsum below. The probable origin of this structure has been discussed on page 352.

Grand River.

Cayuga.

A large deposit of gypsum, which has been extensively wrought, occurs about three miles below the village of Cayuga, on the left bank of the Grand River, and is supposed to extend over at least sixty acres. The bed, which is five feet in thickness, and very pure, is in some places overlaid by thin beds of dolomite; but in most parts it is covered only by clay and gravel. About five miles above this, which is known as Mr. Brown's plaster-bed, gypsum is met with in Indiana, on the left bank of the river; and about four miles farther up, near York, it occurs on both sides. On the right, near Mount Healy, is a very large bed of gypsum, three or four feet in thickness, which has been extensively wrought. About a mile and a half above York, on the left bank of the Grand River, is a mass of gypsum seven feet in thickness, but divided by layers of dolomite. Occasional masses of gypsum, imbedded in green shales, are met with for two miles farther up the river to Seneca. Twenty miles above, in the township of Brantford, gypsum is again found, extending over several lots, and on both sides of the river. A bed of three feet in thickness is here wrought; and above this place, gypsum is quarried at several places along the river as far as Paris. Near this town, the mass of gypsum is divided into two portions, of four or five feet in thickness, by a bed of four feet of shale. Brantford.

The amount of gypsum annually raised from these various quarries on the Grand River, is about 14,000 tons; which is, for the most part, employed for agricultural purposes, and is consumed in Western Canada. The price of the crude gypsum at the mine is about \$2·00 the ton; but when ground for use, at the mills in the vicinity, it is sold at from \$3·50 to \$4.00. Much of the gypsum is white and pure, and is well fitted for the purposes of cement and stucco. The quality which is used for this purpose sells, when ground, at from \$5·50 to \$7·00 the ton; and when calcined, at about \$10·00 the ton.

Large quantities of gypsum are brought to the Lower Canada market from the Magdalen Islands. Nothing certain is known of the geological relations of this deposit; but it is perhaps, like the extensive beds of gypsum which are wrought in Nova Scotia, of Carboniferous age.

FRESH-WATER MARL.

Under this head may be noticed certain deposits of carbonate of lime, which are found in marshes and shallow lakes; and which generally contain, in greater or less abundance, the shells of several species of freshwater mollusca. Although belonging to the present geological period, this marl is not always of very recent formation; inasmuch as the beds of it are sometimes overlaid by peat, or by a soil supporting a growth of large trees. At other times however the marl covers the bottom of shallow lakes or ponds, and is evidently still in the process of deposition. It appears to be formed by the waters of springs highly charged with lime, which is at first held in solution as bicarbonate, but is deposited when these waters come to the air. It is thus similar in its origin to the deposits of calcareous tufa, which occur in many places where such calcareous springs flow over earth, rocks, and vegetation, instead of falling into lakes or marshes. The presence of carbonate of lime is a necessary condition of the development of shells, and various species of mollusca abound in such waters. These by their remains, which often form a considerable portion of the deposits, give to them the name of shell-marl, which is frequently applied. This substance is white, and earthy in its aspect, and, unless mingled with clay, is a nearly pure carbonate of lime; which, from its finely divided state, is well adapted to serve as a dressing for such soils as are deficient in calcareous matter. When calcined, marl yields a nearly pure and very white lime, well adapted for mortar and for other uses. In many parts of Vermont large quantities of lime are thus manufactured. The marl is moulded into shapes like bricks, which are dried and burned in a kiln. Origin of marl.

The analyses of various marls from Vermont show them to contain from one to four hundredths of carbonate of magnesia, with small but variable amounts of clay, water, and organic matters. When pure, marl may be used as a substitute for prepared chalk or whiting, in cleaning metals, and for similar purposes. In many parts of the country, it is commonly employed by the people for white-washing their buildings. It has also been used for the production of carbonic acid gas for the manufacture of soda-water, and other ærated waters, in place of the pulverized chalk or marble-dust which is generally employed. The fossiliferous limestone of Montreal has sometimes been used for this purpose; but the small amount of bituminous matter which it contains, gives a peculiar odor to the carbonic acid gas obtained from it, which is communicated to the ærated waters.

Marl is met with in a great many localities throughout Canada, and it will be sufficient to mention some of the most important among them. Deposits of this material are abundant in the counties of Bruce and Grey. **Carrick.** One of these, on the twenty-fifth lot of the fifteenth range of Carrick, covers about six acres, and was found to have a depth of twenty-seven inches. It is very pure and white, and is covered with a thin layer of black mould, forming the soil of a meadow. Other deposits, estimated at forty acres in all, occur in the immediate neighborhood. On the sixth lot of the first range of Brant, north of the Durham road, marl occurs in a peaty meadow, beneath a foot of soil. It is two feet in thickness, and extends over seven acres. Another locality in the same township is on the seventieth lot of the first range, south of the same road; where it is seen in the banks of a little stream, near its junction with the Saugeen, and has in some places a thickness of three feet. On the twenty-sixth lot of the first range of Bentinck, a deposit of marl has been traced over eight or ten acres of low ground, which is covered with heavy timber. The marl is very solid and pure, and where examined was found to be four feet in thickness.

In the rear of Kingston, an extensive deposit of marl occurs in the fifeenth and sixteenth lots of the second range of Sheffield; and another on **Brant.** the twelfth lots of the third and fourth ranges of the same township. The former of these has been traced over two hundred acres or more, and has, in the greater part at least, a thickness of ten feet. It is covered by a thin soil, supporting a growth of meadow grass. In the second locality, the marl, whose thickness has not been ascertained, extends over three or four hundred acres of marshy land, which is covered by about four feet of peat. It also forms the bottom of White Lake, in this township. A great portion of the bottom of Loughborough Lake is a thick deposit of marl; and the bottoms of all the lakes, from this to White Lake in Olden, are in greater or less degree composed of the same material. A bed of marl is found at Belleville, but it does not appear to be extensive.

In the township of Yonge, on the thirteenth lot of the eighteenth range, a bed of marl occurs beneath a marsh, and it is said to extend over twenty or twenty-five acres. Its thickness was found to be seven feet, but it is reported to be fifteen feet in some parts of the deposit. Marl has also been found in the bays on the south shore of a lake in Elmsley, where it has a thickness of three or four feet, and extends beneath the waters of the lake. Yonge.

Marl has been observed in many localities along the valley of the Ottawa, and some remarkable deposits of it are found in the lakes near the Bonnechère. In the upper end of Mink Lake, a bed of marl extends out for a quarter of a mile from the shore, where it has a thickness of nine feet, and is covered by two or three feet of water, while nearer the shore the depth of water is less. Several bays in this lake have in like manner bottoms of marl, and a shoal of it occurs in the middle of the lake. In the lower part of White Lake, in the township of MacNab, about seven hundred acres are covered with marl, which was found to have a depth of from five to seven feet, and was covered by not more than two or three feet of water. Both of these lakes might easily be subjected to a partial drainage, by which great quantities of marl would be exposed. Around the shores of Clear Lake, in Sebastopol, there are numerous shallow lakes or ponds, which discharge their waters into this, and contain beds of marl, evidently in the process of deposition. Their waters contain abundance of living fresh-water mollusca, and plants. Marl has also been observed in several small lakes on Calumet Island, and on the twenty-third lot of the first range of Clarendon. Mink Lake. MacNab.

Near Ottawa, marl occurs at New Edinburgh in Gloucester. Here the deposit is evidently of more ancient date than those just described; for it is covered with soil, and supports a growth of large forest trees. The bed of marl has a thickness of about five feet, but its extent is not known. Marl occurs on the eighteenth lot of the fourth range of West Hawkesbury, in a low meadow, which apparently occupies the site of an ancient lake. It is known to cover three or four acres, but is supposed to be much more extensive. At the place which has been excavated, the marl is three and a half feet in thickness, and is covered by four feet of peat. Branches and trunks of trees, in a good state of preservation, are met with in the marl, but not in the overlying peat. This marl has been applied as a manure to the sandy soils of the vicinity, and it is said with very good results. The peat has also been used for a similar purpose. Ottawa.

On the third lot of the first range of Argenteuil, marl is also met with in what appears to be the basin of a former lake, but now filled with peat; beneath about nine feet of which is found a bed of marl, five or six feet deep, and in one place, it is said, thirteen feet. The area of this deposit of peat is about twenty-two acres. On the same lot is another peat bog, which has a length of about half a mile from east to west, with a Argenteuil.

breadth of from one hundred to one hundred and fifty yards. Beneath this, marl was met with, at a depth of twelve feet.

Marl has been observed in Eagle-Nest Lake, on the twenty-second lot of the eighth range of Wentworth; and also in a pond on the fifth lot of the fourth range of Harrington. The quantity in both cases was considerable. In the seigniory of Vaudreuil, at Point à Cavagnol, is a bed of marl which extends over about twenty acres, with a thickness of from twelve to eighteen inches. It has been largely used as a manure on the lands in the vicinity, and with beneficial results.

Montreal. On the island of Montreal, marl is found in several places, underlying the peat along the banks of the river St. Pierre, between Montreal and Lachine. A deposit of very pure white marl also occurs at Thornberry, on the west side of Mount Royal. It is overlaid by peat, and does not appear to be extensive. In the seigniory of St. Hyacinthe, near the foot of Yamaska Mountain, and the junction of the Granby road with that to St. Pie, is a bed of marl about a foot in thickness, extending over about seven acres, and covered by a thin layer of peat. Marl is met with about

St. Armand. a mile southeast of Philipsburgh, on lots 156 and 157 of St. Armand. It appears all around the margin of a small lake, and probably covers between thirty and forty acres. Its thickness in some parts is seven feet. This marl, which, like all the others here mentioned, contains fresh-water shells, rests upon a deposit containing marine shells, probably of post-tertiary age. Marl is also found on the fourth and fifth lots of the tenth and eleventh ranges of Stanstead. It appears at the margin of a pond over an area of about twenty acres, and is said to have a depth of from thirty to forty feet.

Gaspé. In the Bonaventure district, marl is met with a mile or two from the village of New Carlisle. Here, in a valley of about three miles in length, by half a mile in breadth, are four or five small lakes, in the bottoms and around the margins of which is found a layer of pure white marl, from one to six feet in thickness. Marl has been observed in the upper end of Lower Lake Metis; and about five miles below the Matanne River, near the bank of the St. Lawrence, a deposit of the same substance, with a thickness of fifteen inches, has been found to underlie in various places a marsh of between sixty and seventy acres.

Anticosti. In Anticosti, marl exists in most of the small lakes or ponds which have been examined near the coast of the island. One of these at the west end of the island, named Marl Lake, has an area of about ninety acres, and is covered at the bottom with marl, apparently of considerable thickness. The stream which discharges this lake into Indian Cove, carries down a large quantity of the marl to the sea, where it is spread out for a considerable distance over the rocks of the coast. About three miles from Southwest Point, marl was found on the bank of a brook, and was traceable thence for a quarter of a mile, in a bed of a foot in thickness, covered by peat. About half a mile farther inland, it covers the bottom of a lake of two hundred acres; and on the east side of South Point it was observed near the shore, resting on rock, and covered by from four to ten feet of peat.

IV. MINERALS USED AS PIGMENTS.

Under this head will be considered certain matters which are employed as paints. The marls which have just been described are occasionally used in this way, for white-washing walls or wood-work, instead of whiting, and may be mingled with cheap colors. Besides these may be noticed iron ochres, and sulphate of barytes, both of which are extensively used as pigments. Of late years, various substances have been introduced into the arts under the name of stone paints. These often consist of fine shales, or other soft rocks ground to a powder, and, when mingled with oils, constitute a cheap and durable covering for wood-work, which is generally however of some dull and earthy color. In Newburyport, Massachusetts, serpentine, which gives a nearly white powder, is ground, and subsequently impregnated by a peculiar process with various mineral and vegetable colors. By this means, cheap and durable paints of various hues are manufactured. Soapstone, or steatite, is also made use of in a similar manner. Two coats of these materials are said to form a good base for a third of common paint. Both steatite and serpentine fit for the purpose are found in great abundance in many parts of the province. On the thirteenth lot of the ninth range of Stanstead, is a soft and apparently decomposing talcose slate, which exhibits parallel vertical layers of greyish-white and ochre-yellow colors; the latter being due to hydrated peroxyd of iron. This talcose rock has been employed, mixed with oil, for painting houses. A similar material is met with on the seventeenth lot of the thirteenth range of Leeds. Its color is a light ash-grey, and it has been used as a water-color, but it might probably, like the last, be mixed with oil.

Stone paints.

Serpentine.

Steatite.

IRON OCHRES.

These ochres are similar in composition to the ore of iron which has been already described under the name of limonite and bog ore. They differ from it however, in being soft and pulverulent, instead of forming solid masses; and consist of peroxyd of iron, combined with water, and often with a large amount of organic matter,—as will be seen by referring to the descriptions and analyses given on page 511. The color of these ochres is generally some shade of yellowish or reddish brown; but purplish and blackish brown hues are met with. By calcination, the water is removed, and the color of the ochre is changed to a dark red. These substances are extensively used, both in the raw and calcined state, as cheap paints, with oil, and with water.

Ochres.

The most abundant deposits of ochres known in Canada are on the north side of the St. Lawrence, at the foot of the Laurentide hills, where, as has been seen, the most extensive beds of bog iron ore are also met with. A remarkable deposit of ochre is found in the parish of Ste. Anne, Montmorenci, on the land of Mr. E. Caron, about a mile and a half above the mouth of the Ste. Anne River, and covers an area of about four acres, with a depth of from four to seventeen feet. A detailed description of the deposit will be found on page 511. In the superficial portions of the bed are found yellowish and reddish-brown, and brownish-black ochres; all of which are very pure and free from foreign matters. When raised from the deeper parts of the bed, the ochre is of a pale greenish color, but becomes reddish-yellow when exposed to the action of the air. This deposit occurs upon a somewhat sloping ground, and offers great facilities for excavating and draining. No attempt has however as yet made to work it. Iron ochre is said to be found in some abundance on the road to St. Stanislas, at Lake Capabusca, on a tributary of the Batiscan, about seven leagues from Ste. Geneviève.

Ste. Anne.

A great deposit of ochre occurs on the St. Malo range, in the seigniory of the Cap de la Madeleine, about two miles below the parish church, and the same distance from the St. Lawrence. It extends over about 600 acres, and is interstratified with peat, which underlies it, and is in its turn underlaid by shell marl. From an examination of the locality, it would appear that it was originally a lake, in which marl was at first deposited, and which eventually became filled up with peat. Over a part of this surface, ochre was then deposited, and was followed by a second growth of peat; which has been in its turn covered by a more recent deposit of ochre. This succession is shown by a series of borings and excavations made along a line through the middle of the deposit, from southeast to northwest. At fifty paces from the margin, there were found six inches of yellow ochre, followed by the same thickness of peat, and a second bed of six inches of ochre, resting on two feet of peat. Three borings in the next one hundred and twenty paces, showed from one to two feet of ochre, resting upon from four to eight feet of peat. A hundred paces beyond, the ochre was wanting, and nine feet of peat were found to rest upon six inches of marl; while one hundred and sixty paces farther, two feet of ochre, at the surface, were followed by two layers of peat, separated by a second layer of ochre, and underlaid, as before, by marl; the whole section having a thickness of nine feet. Beyond this, the ochre is wanting, and the bed of peat is in some parts twelve feet in thickness. This locality would furnish very large quantities of ochre; and in the parts where it is more or less mingled with the peat, blocks of the mixture, dried and kindled, burn slowly away; the organic matter being destroyed, and leaving the ochre behind, in a calcined state. In the Ste. Marguerite range, ochre is

Cap de la Madeleine.

met with along a distance of several miles. It is however in small patches, seldom more than a few yards in diameter or three or four inches in thickness, and is more or less mixed with sand. In the vicinity of St. Maurice, about a mile and a half below the iron-works, and on the opposite side of the river, a small deposit of ochre has been observed, extending over about two hundred yards, with a thickness of from three to six inches.

In the St. Nicholas range of the seigniory of Pointe du Lac, there is an important ochre bed, which covers about four hundred acres, and has a thickness ranging from six inches to four feet, averaging perhaps eighteen inches. The prevailing colors of the ochre are different shades of red and yellow; but it has in some parts a fine purple tint. All of these however become dark red by calcination. Besides this, a blackish-brown variety is found, which is rarer than the others. This assumes a lighter brown, instead of a red color, when subjected to heat, and probably contains a little manganese. The impurities of these ochres consist of small quantities of sand, and of the roots of plants, which have grown upon the surface, and penetrate the bed to considerable depths. These vegetable impurities are easily got rid of by calcination; but when it is required to preserve the colors unchanged, the ochres are dried and sifted. In 1851, an attempt was made to work these ochres, on a considerable scale, by persons from New York, who erected furnaces for the calcination of the ochres; and are said to have prepared as much as twelve barrels daily, which were sent to New York for sale, and were worth there about five dollars the barrel. Eight different tints were said to have been manufactured from these ochres. The blackish-brown variety, which is rarer than the others, was found to command a considerable price, and was sold by the name of raw sienna; while the same ochre, calcined, was sold as burnt sienna. The enterprise was however, after a while, abandoned. Pointe du Lac.

Farther to the northwest, in the same range, patches of ochre are found in considerable abundance for upwards of a mile; but they are less pure than the deposit just described, and have a thickness of from three to six inches only. Small portions of ochre are in like manner met with on the left bank of the Great Yamachiche River, near the southwest limit of the Augmentation of Caxton. The ranges Ste. Emelie and Ste. Rose, in the seigniory of Lanoraie and Dautraye, in like manner contain small areas of ochre; and it is probable that this substance is common in many of the localities throughout that region.

On the south side of the St. Lawrence, ochre has been observed in a marsh on the fourth lot of the fourth range of Durham, where it was traced one hundred and fifty yards, with a breadth of ten yards, and a depth of from one to four feet. A small deposit of ochre is found resting upon the Potsdam sandstone on Hemmingford Mountain. Upon the Ottawa, ochre occurs in considerable quantity in the Grand Marais, in Durham.

Mansfield, opposite the northern extremity of Calumet Island. It has also been obtained from Paint Lake, at the Black River Chute. In the seigniory of Vaudreuil, overlying a bed of bog iron ore eight feet in thickness, which has already been described, is a layer of about a foot of ochre. In the immediate vicinity, and along the edge of the ore-bed, which it apparently underlies, is a deposit of earthy phosphate of iron, of a bright blue color. The presence of water rendered it difficult to determine the quantity of this substance; but it appeared to be considerable, although somewhat mingled with foreign matters. If obtained in sufficient purity, it might be used as a pigment.

Vaudreuil.

In Western Canada, on the southwest side of the village of Owen Sound, a bed of bright yellow ochre, containing an admixture of carbonate of lime, is found at the foot of a hill in which the rocks of the Clinton formation are exposed. The extent of the deposit has not been ascertained; but it has in some parts a thickness of four feet. On the second lot of the eleventh range of Nottawasaga, on the south side of the river, is a small bed of yellow ochre, which has in some parts a thickness of two or three feet. It is produced by chalybeate springs, which issue from the rocks of the Clinton formation. Small deposits of ochre, from a similar source, are found in various other localities at the outcrop of this formation. A red argillaceous earth, derived from the disintegration of the shales of the same series of rocks, occurs in abundance at McKann's mills in Nassagaweya; where it has been used, mingled with oil, as a paint. A similar earth occurs in many other places along the outcrop of these rocks.

Owen Sound.

SULPHATE OF BARYTES.

This mineral, which has been noticed on page 458, is extensively employed in the arts, as a paint, both by itself, and for mixing with other pigments as an adulteration, for which purpose it is fitted by its great weight. It enters into the composition of the cheaper kinds of white-lead paint; sometimes, it is said, to the extent of seventy-five or eighty per cent. For this purpose, the native sulphate of barytes is crushed, and if necessary boiled with dilute muriatic or sulphuric acid to remove any metallic oxyds which may discolor it; after which, it is ground to a fine powder. An artificial sulphate of barytes is also manufactured by precipitation, and is sold under the name of permanent white, or *blanc fixe*. This is prepared from the native sulphate by igniting it with charcoal, by which a sulphuret of barium is formed. This, by the addition of muriatic acid, is converted into chlorid of barium, from which the sulphate is precipitated by sulphuric acid. The pigment thus obtained is much finer than that prepared by simply grinding the mineral. It is used as a water-color; and also in the manufacture of paper-hangings, for giving a peculiar glossy surface. In

Its uses.

1861, about two tons a week of the precipitated sulphate of barytes were prepared by this process in South Lancashire. The consumption of the ground sulphate of barytes is very considerable. Many years since, about 4,000 tons of the mineral were sold annually in the United States; of which 1,500 tons were imported from England, and the remainder obtained from various parts of the country.

Available deposits of sulphate of barytes exist in several parts of Canada, and it is found in many of the lead veins in the Laurentian rocks. One of these is on the second lot of the seventh range of Lansdowne; where, in an excavation made in search of lead, it was found that the lode, for a length of twenty-eight feet, and a breadth of twenty-seven inches, was filled with pure, crystalline, and almost colorless sulphate of barytes; of which the vein, in this part, would yield about ten tons to the square fathom. A vein of sulphate of barytes, about a foot in breadth, occurs in gneiss, on the fourth lot of the ninth range of North Burgess. It is opaque white, lamellar, and contains no impurity, except small grains of copper pyrites. In the limestone of the Niagara formation, at Port Daniel, a vein of sulphate of barytes, nine inches in breadth, is met with. It contains small portions of copper pyrites, and of green carbonate of copper. Numerous veins of sulphate of barytes, mixed with calc-spar, and not above three inches in breadth, occur in the Gaspé sandstones on the York River. The most abundant source of barytes in Canada will, however, be found the veinstones of the large lodes carrying copper ores, on the north side of Lake Superior, between Pigeon River and Fort William, and in Thunder Bay.

Lansdowne. **Burgess.** **Lake Superior**

V. COMBUSTIBLE AND CARBONACEOUS MINERALS.

It has already been shown in a previous chapter, that, although met with in small quantities in the Devonian rocks, coal cannot be reckoned among the economic minerals of Canada, so far as yet examined. The province, however, possesses great quantities of peat; and it is here proposed to consider this substance, together with bituminous shales, and bitumens.

PEAT.

Great deposits of peat are met with in various parts of Eastern Canada, which seems to present conditions of soil and climate peculiarly favorable to its growth and accumulation. The peat bogs, so far as known, are chiefly confined to the plains along the St. Lawrence and its tributaries, and appear to have been formed in shallow lakes, which have been gradually filled up by a vegetable growth. The peat often rests upon a layer of shell-marl, which at one time formed the bottom of the lake. The vegetation consists, for the most part, of mosses belonging to the genus *Sphagnum*.

Peat bogs

Besides these, however, the bogs often support a growth of tamarack (*Larix Americana*), and of various ericaceous plants, belonging chiefly to the genera *Cassandra*, *Andromeda*, *Kalmia*, and *Ledum*. The leaves, roots, and stems of these help, with the moss, to make up the peat. The peat near the surface of the bog, consists of the moss but little altered, and is very soft and porous; but in the older and deeper portions of the deposit, it is more dense and darker in color; the vegetable tissue having undergone a partial decay, by which its fibrous structure, to a greater or less degree, disappears, and the peat becomes earthy in its texture.

Density of peat. These different forms of peat present very great variations in their specific gravity. That from the surtace of the Bog of Allen, in Ireland, according to Sir Robert Kane, has a density of 0·335, or only one third that of water; while the blackish-brown earthy peat, from a lower layer in the same bog, is from 0·639 to 0·672, or double that of the surface. A peat which is dug near Tavistock in Devonshire, has a density of 0.850. Similar differences will be found in the peat bogs of Canada. A specimen of peat from Sherrington, described on page 642, is still more dense than any of these, being so heavy as to sink in water; while at the same time it only contains 3·5 per cent. of ash. One of the great obstacles to the use of peat is the large amount of water which it holds, and the obstinacy with which it retains this water. The average result of a great number of experiments made in the Irish bogs, show that the general mass of the undrained peat, including both the lighter and denser varieties, contains from 92 to 95 per cent. of water; while the edges of the bog, and parts more or less drained, in the state in which peat is generally cut, contain from 88 to 91 per cent. The turf, as used in that country, often holds from 20 to 35 per cent. of water; while that which has been stacked from six to twelve months, still retains from 18 to 20 per cent., and that which has been kept in a dry house for two years, from 10 to 15 per cent. of water. The above details, and many of those which follow, are taken, in part, from Sir Robert Kane's work on The Industrial Resources of Ireland, and a subsequent report by him on the working of peat; and also in part from a recent paper by Mr. C. Hodgson, read before the Institution of Civil Engineers of Ireland.

Amount of water.

From this, it will be seen that in cutting out and removing the peat from the bog, it becomes necessary to transport about nine tons of water for each ton of real fuel. So long as a turf-cutter works along the edge of the bog, or of one of the main drains, he can spread the material as he cuts it; but when large quantities are wanted, additional laborers are required to carry the peat, with its great weight of contained water, to a proper place for spreading and drying. From the slowness of this process of air and sun drying, moreover, a given district can only produce a small amount of dried peat annually. The consequence is, that, although peat prepared in the ordinary way is a cheap domestic fuel, and is sold at a moderate

Cutting peat.

price, it is found that as soon as the consumption increases in a district, the price increases, and that it is impossible to augment the supply beyond a certain limit. The Irish Peat Company, who a few years since constructed works near Athy, for distilling peat, at the rate of fifty tons daily, had counted upon obtaining this supply at from 2s. 6d. to 3s. the ton; but it was found that before they had secured the quantity necessary for carrying on their works successfully, the price of peat increased to 5s., and ultimately to 6s. 6d., and 7s., sterling the ton. This increase, together, as we are told, with the impossibility of obtaining, at any reasonable price, a much larger supply, were among the causes of the failure of the enterprise. Its cost.

It is obvious, then, that in order to extend the use of peat, either as a combustible, or as a material for distillation, it becomes necessary to introduce great improvements into its manufacture; which will make it possible to free it as rapidly and as completely as possible from the water which it contains. It is also desirable to reduce its volume, for the convenience of transportation; and to give it a solidity and tenacity approaching to coal, which will allow it to be used in ordinary grates and furnaces, and to bear a strong blast. For this purpose, many plans have been proposed, and numerous patents obtained within the last twenty-five years. One of the most satisfactory processes is said to be that now pursued at Ekman's iron works in Sweden, which is similar to that patented by Linning in 1837. According to his specifications, the peat is first ground to a homogeneous mass in a pug-mill, similar to that used by brick-makers, but with longer and sharper knives, placed obliquely. The pulp thus obtained is moulded into convenient shapes, and consolidated by a hydraulic or other press; after which the blocks are dried by artificial heat. The use of hydraulic pressure was several years since tried on an extensive scale, by Mr. C. M. Williams, at Cappogue, in Ireland. He, having broken up the peat, placed it in layers between cloths, and subjected it to a powerful hydraulic press. By this means, he succeeded in reducing it to one half its original weight, and to one third its volume. The remaining water was, however, difficult to be expelled from the consolidated peat; and the more fibrous varieties expanded a good deal in drying. This experiment was lately repeated, on a considerable scale, by the Irish Peat Company: and with similar results. They also built large drying-houses, in which attempts were made to dry ordinary peat by artificial heat; but the quantity of fuel required to expel the great amount of water from the peat, was found to be so considerable that the process was not economical. Compressing peat. Williams's plan.

A different plan was some years since proposed for overcoming certain of the difficulties of the problem; which was, after drying peat in the ordinary manner, to pulverize it by passing it through rollers, then to drive off the remaining water by heat, and consolidate the dry powder by powerful pressure. This process is followed at Rosenheim, in southern Bavaria, where the peat is made into small blocks of eight or ten ounces, and weighing from seventy to eighty pounds to a cubic foot. The latter weight corresponds to a specific gravity of 1·25; which is nearly that of bituminous coal. (Percy's Metallurgy, vol. i., p. 78.) Several patents, based upon this plan of dry compression, have been within the last few years obtained in England; but practical difficulties were met with in the machinery for compression; besides which, as Mr. Hodgson has well remarked, the great problem of obtaining a cheap and abundant supply of dried and powdered peat still remained. This however, according to him, is in great measure resolved by a simple expedient. By passing a very light harrow over the surface of the bog, a thin layer is broken up. After a few hours of exposure to the air, for draining and partial drying, it is removed by scraping; and in this way a powdered peat, far drier than the general mass, may be obtained every day, when it does not rain. The material thus collected costs five-pence the ton, and contains, on an average, forty-five per cent. of solid matter; while recently cut peat contains only ten per cent. It is heaped in embankments, where it is found not to absorb water, and is dried by being spread out over iron plates warmed by the waste steam from the compressing engine. In this way, according to Mr. Hodgson, the peat standing in the bog in the morning may be harrowed and scraped, brought in, dried, compressed, and converted into an excellent fuel before night. He employs for its compression, an engine patented by himself; which he describes as a horizontal reciprocating ram, working in a cylinder five feet long, with a uniform bore. The powdered peat falls into this as the ram draws back at each stroke, and, soon filling the whole length, considerable friction takes place against the sides of the tube. This becomes so great that, as each charge falls in, it is completely consolidated between the advancing ram and the column of peat in the tube, before the frictional resistance of the column is overcome, and the whole mass moves on; so that the blocks formed at the one end are successively discharged at the other, at the rate of sixty a minute; making in a hour about fifteen hundred-weight of compressed peat, equal in density to coal. This apparatus is now in operation at Derrylea, near Monasterevan; and it is said by the inventor to leave no doubt of the practicability of producing dry compressed peat on a large scale, and with profit.

Hodgson's plan.

Peat is not only an economical fuel for domestic use, but is in many countries employed for generating steam, and for the manufacture of iron. For the latter purpose, it is used in Sweden, France, and in many parts of Germany, where the supplies of mineral coal are not abundant. It is particularly well fitted for producing steam, and compressed peat has now for several years been used in locomotive engines in Bavaria; but we are told that before this application was successful, many difficulties had to be surmounted. Several years ago, according to Sir Robert Kane, it was in general use upon the steamers on the river Shannon in Ireland.

In a paper communicated to the Society of Arts in London in November, 1862, Dr. B. H. Paul—whose experiments on the distillation of peat are described farther on—has given some interesting conclusions as to the relative values of peat and coal as fuel. According to him, while the calorific or heat-giving power of carbon is represented as 1000, that of the various mineral coals is equal to from 903 to 906; while that of perfectly dried peat, as deduced from its average composition, will be 660. But as ordinary air-dried peat contains about one fourth its weight of water, its calorific power is reduced to 495; or about one half that of the same weight of coal. The average weight of a cubic foot of solid coal is about eighty pounds, while air-dried peat has a density corresponding to only sixty-four pounds. A cubic foot of broken coal, however, contains about sixty pounds, while the same volume of ordinary peat weighs only about thirty pounds; "so that with but half the calorific power, it takes twice the space; and thus to produce a given effect with air-dried peat, it would require twice the weight, and four times the bulk, of the coal necessary to produce the same effect." This calculation as to bulk, of course refers to uncompressed peat: if reduced to the density of coal, as claimed by Mr. Hodgson's process, its volume is of course diminished one half. From his own experience in Lewes, Dr. Paul found, that, on the moors, where peat was to be had for two shillings the ton, it could be economically used for generating steam, and for burning bricks; while at Stornaway, near by, where the cost of the peat, delivered, was six or seven shillings, coal, which was eighteen shillings the ton, was found more advantageous. He concludes that peat cannot be economically transported to any considerable distance; but that wherever a peat having a fuel-value one half that of coal, can be delivered at the place of consumption at a cost of four shillings sterling the ton, it may advantageously replace coal, where this, under the same circumstances, costs more than ten shillings; but if the price of coal is ten shillings or less, there would be a disadvantage in the use of peat. During four years Dr. Paul used it as the only fuel under stationary steam-boilers, and found it to answer admirably; and he states that Mr. James Napier of Glasgow, having tried it upon a steamer, is of opinion that it might be used in place of coal. This, of course, applies to short voyages, and to conditions where space is not a great consideration. It is a question for Lower Canada whether properly dried peat can be furnished at a price per ton less than two fifths that of coal; in which case, it might perhaps be advantageously employed in our inland navigation.

Peat and coal

Large quantities of peat charcoal are manufactured in France, and in Germany. For this purpose, either ordinary stacks, or cylindrical kilns built of brick are employed. A current of steam, heated to 450° or 460° F., has likewise been employed for the purpose; and the compressed peat has also been distilled in iron retorts, like those used for making coal

Peat charcoal.

gas; by which means, volatile oils and combustible gas are obtained besides the charcoal. Good air-dried peat, in stacks or in kilns, yields from thirty to forty per cent. of its bulk, and from twenty-five to thirty-five per cent. of its weight, of charcoal; much of course depending on the amount of ash which the peat contains. Large quantities of peat, and of peat charcoal, are prepared for the market of Paris; where the latter fuel is largely used for domestic purposes. About fifty miles from Paris, near Liancourt, on the Northern Railway, is a large bog; from which, in 1855, 10,000 or 12,000 tons of peat were obtained. The peat from the whole thickness of the bog, about ten feet, was transferred to flat-boats, trampled, and turned over with shovels, and finally moulded by pressure into small bricks, which when dried are heavier than water. These were charred on the spot, and yielded about forty per cent. of charcoal, which gave 27·0 per cent. of ash; the dried peat itself yielding 10·0 or 11·0 per cent. The wholesale price of this compressed peat in Paris was, at that time, $3·75 the ton of 2200 pounds, while the charcoal made from it was $18·00 the ton; its retail price being about $24·00. Its combustion is slower than wood charcoal, which was sold at about the same price; while both mineral coal and fire-wood were retailed at from $7·50 to $9·50 the ton weight. These figures will aid in obtaining a notion of the comparative value of the various kinds of fuel.

Distillation of peat. The object proposed by the Irish Peat Company, as already mentioned, was the distillation of peat; by which it is made to yield a tar, from which are extracted illuminating and lubricating oils, and paraffine; besides ammonia, acetic acid, and pyroxylic spirit, which are dissolved in the watery products of the distillation. A large amount of combustible gas is also disengaged; which may be employed as a source of heat in various operations, such as distilling, burning bricks, and lime. By distilling the dried peat in retorts, a considerable amount of tar is obtained, besides a residue of coke or charcoal; which, however, is not sufficient to heat the retorts, so that there would be a farther expenditure for fuel. It was therefore desirable to devise some more simple and economical way of conducting the distillation, and the works of the Company at Athy were built in accordance with the system patented by Mr. Rees Reece in 1849. This consists in burning the air-dried peat, by means of a blast, in cylindrical furnaces of brick, shaped somewhat like iron blast-furnaces, but closed at the top, and furnished with pipes for carrying off the volatile products to a proper condensing apparatus. The furnaces, being filled with peat, and closed, are lighted from below, and the blast applied. The heat from the combustion of the peat in the lower part of the furnace serves to distil the upper layers; while the gases from the combustion, together with the volatile products of the distillation, are carried forward by the blast towards the condensers.

Reece's process.

This process was to a certain extent successful; but it was found that when the force of the blast was augmented, in order to obtain a more rapid combustion of the peat, the amount of tar was greatly diminished. Thus, according to Dr. Paul it was found, by experiments in Antrim, with a furnace three feet in diameter and fifteen feet in height, that when one and a half tons of peat were burned in twenty-four hours, 3·1 per cent. of tar were obtained; with two tons in the same time, 1·8 per cent.; with three tons, only 0·98; and when nine tons were burned in twenty-four hours, only two pounds of tar were obtained to the ton. According to the experiments of Sullivan, Irish peat, when distilled in retorts, gave from 1·5 to 3·5 per cent., being an average of 2·5 per cent., of tar: which furnished from 38·0 to 72·0 per cent. of oil, the mean being 52·0 per cent. Of this oil, 5·0 per cent. distilled below 212° F.; 20·0 per cent. between 260° and 320° 35·0 per cent. between 320° and 550°; and the residue at a still higher temperature. Hence, as an average, 100 tons of Irish peat would yield 682 gallons of tar, and 333 gallons of refined oils. It was found that, under favorable conditions, the amount of tar obtained by Mr. Reece's process was very nearly equal to that produced by distilling the same peat in closed retorts. Results.

Dr. Paul has lately undertaken a series of experiments on the distillation of peat on a large scale, at Stornaway in the island of Lewes: the results of which he communicated to the British Association for the Advancement of Science, at Cambridge, in October, 1862. The mountain peat of that region is compact, heavier than water, and is superior for this manufacture to ordinary bog peat. By distillation in a retort, it gave: tar 9·08, coke 31·50, water 37·88, gas (loss) 21·54; = 100·00. The tar thus obtained was a soft solid at 60° F.: it had a specific gravity of ·960, an acid reaction, and gave, by rectification, forty-two per cent. of a refined oil, boiling above 300°; besides from thirty to forty-six per cent. of more volatile liquids. These, as well as the ammonia, acetic acid, and pyroxylic spirit were neglected by Dr. Paul in his experiments. The refined oil contained about one tenth its weight of paraffine (equal to four per cent. of the crude tar). About one half of the oil boiled at a temperature between 330° and 500° F.; it burned without charring the wick, had but little odor, was not explosive at ordinary temperatures, and compared favorably with refined petroleum. The remainder, which boiled between 500° and 600° F., had a specific gravity of ·850, and when mingled with fat oils was an excellent lubricator.

In his early attempts to work this peat on a large scale, by distillation in brick furnaces or kilns, Dr. Paul substituted for the blast the draught of a chimney; but in this way he was unable to obtain more than three per cent. of tar, instead of the nine per cent. which the same peat furnished when distilled in retorts. It was found, moreover, that, on an average, Paul's experiments.

only about fifty tons a week were distilled in each kiln; while in order to give a profitable return it was necessary to work about seventy tons weekly, and to obtain five per cent. of tar. His apparatus consisted of cylindrical brick chambers, five feet in diameter and twelve feet high; furnished at the bottom with a fire-grate having an area of two feet, and at the top with a hopper and lid for feeding. Ten of these kilns were built side by side, in a block; and from the top of each, a pipe of twelve inches in diameter led to a main of three feet, and thence, through a condensing apparatus, to a chimney. In order to secure a regular current of air through the apparatus, a draught was finally established by means of a thirty-inch fan, of Schiele's patent, making 1600 revolutions a minute, and driven by an eight-inch steam-engine; which worked at the same time some pumps, and a winding-drum by which the peat was drawn up an incline to the kilns. This fan was capable of passing 2000 cubic feet of gas per minute, and of maintaining a steady powerful draught through seven inches of water, without raising the combustion at the fire-grate of the kiln to a greater extent than was desirable. By this means the vapor was rapidly drawn from the kilns, and was passed several times through water, and also through four chambers filled with bundles of heather. This contrivance was found effectual to separate the tarry matter mechanically suspended and carried over by the current of gas. This, when discharged from the fan, was highly inflammable, and was led by an underground tunnel to a proper furnace; where it burned with a flame from six to ten feet high, six feet long and six inches thick, and was available for generating steam, distilling tar, evaporating liquids, or drying peat. It was found that the whole of the charred peat was not required for the distillation; so that by means of an arched opening fitted with a door, just above the fire-grate, a portion of the charcoal could be removed from time to time. By this means, the amount of peat which could be worked was much increased. The removal of the charcoal in this way was however attended with difficulty during the prevalence of high winds.

Results. With these improved arrangements, it was found that the amount of peat distilled was always above seventy tons, and in favorable weather upwards of one hundred tons, weekly, for each kiln; while the proportion of tar was raised from 3·9 per cent. to 7·5, and was on average as much as 7·0 per cent. In this way there were obtained in the year 1861–62, from one hundred tons of peat—

749 gallons of oil (with paraffine), at 2s, ...		£74 18 0
From which is to be deducted—		
For 100 tons of peat, at 2s, ...	£10 0 0	
" cost of manufacture,....................	28 14 6	
		38 14 6
Leaving a balance of..........................		£36 3 6

These are given by Dr. Paul as his working results within the last year, and contrast most favorably with those obtained in Ireland, as stated by Mr. Sullivan in his report to the directors of the Irish Peat Company in 1855; according to which, one hundred tons of peat gave—

150 gallons of oil, at 2s.,	£15	0	0			
300 pounds of paraffine, at 1s.,	15	0	0			
52 gallons of wood-naphtha,	2	10	0			
3 cwt. of sulphate of ammonia,	1	16	0	£34	6	0
From which is to be deducted—						
For 100 tons of peat, at 4s.,	£20	0	0			
" cost of manufacture,	14	3	4	34	3	4
Leaving a balance of				£0	2	8

It will be seen that the cost of the Irish bog peat was, for reasons already mentioned, 4s., instead of 2s., the ton; while its yield was so much less than that of Lewes, that, even at an expense of manufacturing which was only one half the latter, its distillation appears to have been no longer profitable; although the wood-naphtha, or pyroxylic spirit, and the sulphate of ammonia, products neglected by Dr. Paul, were preserved. While some of the advantages of the results obtained at Lewes are to be ascribed to the method pursued, the superior quality of the peat is, according to Dr. Paul, a more important element. The light refined oil from the Lewes peat was sold in 1862 in Glasgow, under the name of lignole; and according to the report of Dr. Anderson, it compared favorably with the burning oils from coal, shale, and petroleum; being pale in color, and with much less unpleasant odor than the coal oils. The statements of Armand that peat may be made to yield as much as fifteen, or even eighteen per cent., of tar, do not appear to be confirmed by other investigators. According to Vohl, who in 1858 published an elaborate investigation into the distillation of lignite, peat, and bituminous schists, the various peats, when distilled in retorts, yield from six to nine per cent. of tar; and in the case of a light peat, 5·37 per cent. In rectifying the tar, the distillation may be carried to dryness, when it is wished to obtain the greatest amount of liquid products, as in Dr. Paul's operations. By arresting the process at the proper point, a large proportion of the material remains in the retort, as a kind of pitch; which may be used, like asphalt or solid bitumen, for covering roofs and similar purposes. In this way, according to Vohl, one hundred parts of tar yield forty-two parts of pitch. In order to purify the distilled oil, for burning in lamps, it is first treated with a solution of soda, and afterwards with concentrated sulphuric acid, as in the refining of petroleum. The alkaline solution dissolves a considerable amount of creosote and of carbolic acid; which may be after-

Oil from peat.

wards separated by means of an acid, and have a commercial value. The paraffine separates in a crystalline form from the heavier and less volatile oils, when these are exposed to cold. With the present demand for oils and paraffine, it is more profitable to distill the tar to dryness, than to manufacture a portion of it into pitch. The value of a ton of crude tar, capable of yielding one hundred gallons of oil and paraffine, may, according to Dr. Paul, be estimated at £5 sterling; and he concludes that peat approaching in richness to that of the Highlands of Scotland may be distilled with great profit. It remains to be seen whether some of the extensive peat bogs of Canada may not produce a material equally available. The importance of these deposits as a source of fuel to the country should not, however, be lost sight of; and it is to be hoped that before long successful attempts may be made to introduce compressed peat as a combustible, for the generation of steam and for domestic purposes.

The principal deposits of peat which are as yet known in Canada, will now be noticed. It is to be remarked, that, with the exception of a partial trial made of the peat near Chambly, none of these deposits have ever yet been worked: and that it is only in a few localities that the thickness of the peat has been determined by pits, or by borings. Beginning to the westward, a deposit of peat occurs on the twelfth lot of the fourth and fifth ranges

Sheffield.

of Sheffield; where it overlies a bed of marl already described, and extends over three or four hundred acres. The average thickness of the peat is about four feet, and it is said to be of superior quality. In the level region between the St. Lawrence and Ottawa rivers, described on page 8, several large peat bogs occur: but from their nature, the vicinity has been avoided by settlers, and they are therefore difficult of access. There is said to be a considerable area of peat in the rear of the seigniories of Vaudreuil and

Caledonia.

Rigaud; and also in Caledonia, where its thickness does not appear to exceed three or four feet. Peat occurs at the sources of the Pain River in Roxburgh, Osnabruck, and Finch; and also in Clarence, Cumberland, and

Gloucester.

Gloucester. In the third, fourth, and fifth ranges of the latter township is a tract known as the Mer Bleue, which consists of two long peat bogs, separated by a narrow ridge of higher land, and occupying each about 2500 acres. These deposits were sounded in many places, with a rod, to a depth of twenty-one feet, without finding bottom; in other parts, the peat was from eight to fifteen feet in thickness. This tract is situated only three miles from the Ottawa, and is about 280 feet above the level of the sea.

Nepean.

Three large areas of peat, of from 1000 to 3000 acres each, occur in Nepean and Goulbourn; one of them to the east, and two to the west, of the village of Richmond. It is also found on the third and eight ranges of Beckwith, to the east of Mississippi Lake; and an area of about 3000 acres of peat occurs in Westmeath, in the rear of front A, and from the first to the fifth range behind it. In the ninth and tenth ranges of Huntley, there are about

2500 acres of peat; which in some parts has a thickness of eight or ten feet, while in other parts no bottom was found at a depth of fifteen feet. It is probable that peat may be met with in many other localities throughout this region. Huntley.

On the north side of the Ottawa, three small areas of peat have been observed in Grenville. One of these, on the fourth and fifth lots, covers about thirty-six acres, and has a depth of ten feet. It has been used in the neighborhood, and is pronounced of excellent quality. Another deposit of about the same extent occurs on the first lot of the same range, and is in some parts more than fifteen feet in thickness. A third, of about thirty acres, occurs on the fourth lot of the seventh range. On the fourth and fifth lots of the first range of Harrington, is a bog of about forty acres, the peat of which varies in depth from ten to twenty-five feet. Another bog is described as occurring on the first and second lots of the fifth range of the same township. It extends over about sixty acres, and has a thickness, in some parts, of twenty-five feet. All of these areas might be drained without much difficulty. To the eastward of this, a peat bog is met with in the Rang Double of Mille-Iles. It exhibits a breadth, on the road from St. Janvier to St. Jerome, of about half a mile, and has an area of perhaps five eighths of a square mile. Its depth along the road was found to be in several places from two to eighteen feet, the greater depth being towards the southeast side, and its average may be taken at eight feet. A smaller deposit of peat occurs half a mile nearer to St. Janvier; it has a breadth of about a quarter of a mile, but its superficies and depth have not been ascertained. Upon the same great plain with these, a little to the north of the church of Ste. Anne des Plaines, and on the northeast side of the road leading to New Glasgow, is a peat bog having an area of about a square mile. Its depth was not determined, but it is supposed to average about five feet. The farmers are in the habit of burning the surface of parts of this bog, and employing the ashes as a manure for the underlying portions, until by repeated burnings they reach the subjacent clay; which, mingled with the last thin layer of peat and a portion of the ash, constitutes a very fruitful soil. Grenville. Harrington. Mille-Iles. Ste. Anne.

Near the front of the seigniories of Assumption and St. Sulpice there is a peat bog three and a half miles in length, with an average breadth of half a mile, giving an area of about 1100 acres. Its depth varies from two to fifteen feet; and the result of ten trials, made in two lines across the bog, gave an average of ten feet. In the seigniories of Lavaltrie and Lanoraye, there are two extensive peat bogs, running parallel with each other. Of these, the northern is the larger, and is known as the Grande Savanne. It has a length of about eight miles from northeast to southwest, and a breadth of from half a mile to two miles and a half, covering a superficies of from twelve to fifteen square miles. Two sections were St. Sulpice. Lavaltrie.

made across this bog; one on the line of the railway between Lanoraye and Industry, which traverses it about three miles from its southwest extremity. It here reaches to within four miles of the St. Lawrence, and has a breadth of two and a half miles. The depth along this line was found to be from four to fourteen feet; the average of twelve trials giving about eleven feet. The other section, along the Lavaltrie road, about four miles to the northeast, gave a breadth of half a mile, and a depth of from seven to fourteen feet; averaging, as before, eleven feet. The smaller of these bogs lies between that just described, and the St. Lawrence, at a distance from the last of about two miles. On the line of the railway it has a breadth of over half a mile, and an average thickness of about five feet. It has a length of more than five miles, extending four and a half miles to the southwest of the railway, and a superficies of about three square miles.

St. Maurice. In the fief St. Etienne, about a mile and three quarters southwest of the Grès, on the St. Maurice river, the main road crosses a peat bog, which is there half a mile in breadth, with an average depth of about six feet. Its extent to the northeast and southwest has not been ascertained. Another Champlain. was met with in the seigniory of Champlain, about three miles from the St. Lawrence, and on the road from the church to the river Champlain. Its breadth on the road is about three quarters of a mile, and its average depth, in this part, five feet. Its length from northeast to southwest appears to be about two miles; giving to the bog an area of about a mile and three quarters. In the fief D'Auteuil, on the road between Cap Santé and the village of L'Enfant Jésus, there is a peat bog, with a breadth of about a quarter of a mile, which has not been farther examined. Several other peat bogs are known to exist between this last locality and the vicinity of Quebec.

On the south side of the St. Lawrence, there is a large area occupied by peat on the west side of the river Richelieu. It covers portions of the Lacolle. seigniories De Léry and Lacolle, and of the townships of Sherrington and Hemmingford, embracing perhaps fifteen or twenty square miles. This area is drained in part by the Lacolle River. It has not been carefully examined as yet; but it contains in some parts, particularly it is said in Sher- Sherrington. rington, a very great thickness of peat. Of two specimens from this township, one, which was dark colored, fine grained, compact, and so heavy as to sink in water, gave only 3·53 per cent. of ash: while the lighter peat, from near the surface of the bog, yielded 4·66 per cent. of ash (page 642). Both of these are very pure; and the compact peat, which is remarkable from its great density, and its freedom from earthy matters, is particularly worthy of attention.

Longueuil. A large peat bog occurs in the seigniory of Longueuil, on the road to Chambly; and an attempt was made a few years since to raise the peat, and introduce it to the Montreal market. A peat bog of large size is found in the seigniory of Ste. Marie de Monnoir; and another in the parish of St. Dominique, including parts of Ste. Rosalie and St. Pie. Its dimensions may be five or six miles in one direction, by three or four in another. This extent is covered by a layer of peat; which, from two or three feet at the edges, attains a depth of six feet, and in some parts, it is said, is eighteen feet in thickness. The bog has been partially drained, and portions of the land reclaimed for agricultural purposes. The drained land, being first cleared of trees, is ploughed, and then, in the dry season, set on fire. In this way, eight or ten inches of peat are burned, leaving an ash which serves as a manure, and enables the surface to yield one or two crops of barley or oats. After two years, the soil becomes exhausted, and it requires to be again burned over to render it productive. When, by several repetitions of the process, the peat has been reduced to a few inches, the remaining portion is mingled, by ploughing, with the underlying clay, and a rich mellow soil is obtained. The peat from this bog yields, when heated in close vessels, about thirty-six per cent. of coke, and contains from six to seven per cent. of ash, whose composition has been given on page 642. St. Dominique.

In the seigniory of Rivière Ouelle, there is a peat bog which covers about 4000 acres; and another one occurs in the seigniory of Rivière du Loup, having a superficies of 6000 acres. Its breadth on the Temiscouata road is a mile and a quarter, and its depth in some parts has been ascertained to be eighteen feet. Peat is found in abundance on the first and second concessions of the seigniory of Ile Verte; and from a point two miles below the Rimouski, there is a belt of peat bog extending nearly all the way to the Métis River, a length of over twenty miles. Its distance from the St. Lawrence is from a quarter to half a mile, and its breadth from a quarter of a mile to a mile. The depth of the deposit, where observed, was from one to six feet. To the east of the Rimouski River, there is a peat bog, which has a length of three or four miles, in the townships of Duquesne and Macpes; with a breadth of about three quarters of a mile, and a thickness which was found to be from five to twelve feet: it is said to be in one place, thirty feet in depth. Another locality of peat is stated to be in the townships of Matanne and Macnider, between the rivers Blanche and Matanne. A peat bog of about one hundred acres occurs on the left bank of the Madawaska, just above the twelfth mile-post on the road to the Little Falls. Rivière Ouelle. Ile Verte. Duquesne.

The most extensive peat deposits in Canada are found on Anticosti. Along the low lands on the south coast of the island, from Heath Point to within eight or nine miles of Southwest Point, a continuous plain covered with peat extends for upwards of eighty miles, with an average breadth of two miles; thus giving a superficies of more than one hundred and sixty square miles. The thickness of the peat, as observed on the coast, was from three Anticosti.

to ten feet, and it appears to be of an excellent quality. The height of this plain may be, on an average, fifteen feet above high-water mark, and it could be easily drained and worked. Between Southwest Point and the west end of the island, there are many smaller peat bogs, varying in superficies from 100 to 1000 acres.

BITUMINOUS SHALE.

Bituminous shales.

The bituminous shales or pyroschists of Canada, have been mentioned on page 528; and described, with analyses, on pages 622 and 627. It has there been shown that these rocks contain little or no bitumen; but an admixture of a hydrocarbonaceous substance, which, like peat and coal, yields, by distillation, combustible gases and volatile oils. When sufficiently rich in these matters, bituminous shales are distilled with advantage. The amount of oil furnished by different shales may vary from an insignificant quantity, up to twenty per cent. or more. The bituminous shales of Canada, as already described, belong to two different geological positions; the one in the Utica formation, whose distribution has been given in the tenth chapter, and which may be traced from below Quebec to the shores of Lake Huron; the other belongs to the Devonian series, and, as described on page 387, is only met with in the southwestern portion of Canada, in Bosanquet and its vicinity. These shales, when exposed to heat, give off a vapor, which takes fire and burns into a bright smoky flame. The shales of the Utica formation, in Eastern Canada, so far as yet examined, are less rich in combustible matter, than those farther west. In Collingwood, on the twenty-third lot of the third range, there is an exposure of this shale, where a layer of about seven feet in thickness has been employed for distillation. This rock, as will be seen by the analysis on page 622, is highly calcareous, containing more than one half its weight of carbonate of lime. When ignited in a close vessel, it loses 12·4 per cent. of volatile and combustible matters; of which from three to four per cent. are condensable into an oily liquid. This, when rectified, yields oils fitted for burning and for lubricating purposes, and probably also a portion of paraffine.

Collingwood.

In 1859, works for obtaining these oils were erected on the locality of this shale, near the town of Collingwood. Twenty-four longitudinal cast-iron retorts were set in two ranges, and heated by means of wood; of which twenty-five cords are said to have been required weekly. The shale, broken into small fragments, was heated for two or three hours; from eight to ten charges being distilled in twenty-four hours. In this way, it is said from thirty to thirty-six tons of shale were distilled daily, and made to yield 250 gallons of crude oil, corresponding to about three per cent. of the rock. By a farther continuance of the heat, a small additional proportion of oil was obtained from the shale; but it was found more economical to withdraw the charge after two hours and a half. The bed of shale available for the purpose, adjoins the works, and was furnished, ready broken, at twenty cents the ton. The cost of the crude oil from the shale, was stated by the manufacturers to be fourteen cents the gallon. When rectified and deodorized, it gave from forty to fifty per cent. of burning oil, and from twenty to twenty-five per cent. of pitch and waste, the remainder being a heavy oil fitted for lubricating purposes. After two or three unsuccessful trials, and the repeated destruction of the works by fire, they were at last, in 1860, got into successful operation, and a ready market was found for the oils. Data are however wanting to show whether the enterprise was remunerative; and it was after some time abandoned, partly, it is probable, on account of the competition of the petroleum of Enniskillen, which was about that time brought into the market in large quantities, and at a very low price. Should it however, at any time, be found advantageous to renew the experiment of distilling the bituminous shales of this formation, those of Collingwood offer very favorable conditions, from their accessible position, and also from the ready means of transport afforded both by the lake and the railway. Oil from shale.

The shales of the Devonian series in Bosanquet, whose analysis is given on page 627, are not less rich in combustible materials than those of Collingwood. An experiment made on a small scale, gave 4·2 per cent. of oil, which is equal to about ten gallons to the ton of shale. The specimen was obtained from Cape Ipperwash, where a section of twelve or fourteen feet of the shales is exposed. They here contain so much organic matter, that the broken shale, which forms the shingle of the beach, is said, when set on fire, to continue burning for a considerable time. Large portions have been thus burned, and have assumed a reddish color. These shales are also seen in Warwick, and in Brooke (page 388). Bosanquet.

In describing the rocks near Port Daniel, mention was made on page 445, of beds of bituminous shales. These are said to yield considerable quantities of oil by distillation. The specimens procured from this locality some years ago by the Survey, were lost by shipwreck; and no opportunity of replacing them having since occurred, it is impossible to give any farther facts respecting the shales of this deposit. Gaspé.

BITUMENS.

Under the head of bitumens are generally included both the liquid form, which is distinguished by the name of petroleum or rock oil, and the solid varieties, known as mineral pitch or asphalt. These have been already noticed, and the principal facts relating to their occurrence in Canada are discussed on pages 378, and 521–524. It is now proposed to give some further details as to their economic relations, together with a description of the facts recently observed with regard to the petroleum of Gaspé. As a sequel to this, will be noticed a peculiar mineral resin lately discovered in the Devonian rocks of that region.

It has already been shown that the petroleum of Canada occurs in two distinct horizons; the one in the limestones of the Trenton group, and the other in those of the Corniferous formation. To this it must now be added, that the petroleum of Gaspé probably belongs to an intermediate position, and is to be referred to limestones of Upper Silurian age. It is from the Corniferous formation, which affords a much more abundant supply than the Trenton group, that the springs of Western Canada take their source. In some cases, the wells are sunk directly in the Corniferous limestone; but in Enniskillen they are bored in the overlying shales of the Hamilton formation; which have there a thickness of from two to three hundred feet (page 386), and are overlaid by from forty to sixty feet of clay and gravel. In these latter are sunk what are called the surface wells, from which considerable quantities of oil were at first obtained. The deeper wells have however given by far the greater supply of oil; and in some of them, when first opened, the petroleum has risen above the surface of the earth, constituting what are called flowing wells. One of these, which was sunk to a depth of about 200 feet, is said to have yielded, when first opened, not less than 2000 barrels in twenty-four hours; and several others gave very large quantities. In many cases both oil and water flow into these wells, and the water in some of the deeper ones is saline. The recently opened wells have frequently been observed to furnish petroleum only, which however after some time is accompanied with a portion of water. These wells are chiefly in an area of about four square miles in the first three ranges of Enniskillen. About six miles to the northward however, on lots thirteen and fourteen of the tenth and eleventh ranges of the same township, numerous wells have also been sunk, and considerable quantities of oil obtained. The total amount of petroleum extracted from these various wells in Enniskillen, since their opening, may be seen from the returns kindly furnished by the freight agent of the Great Western Railway; over which the produce of this district finds its way to market. A small portion of the petroleum is refined in the vicinity, and this is included with the crude material in the following statement:

Enniskillen.

Amount of oil.

Previous to July 31, 1861	5,529	barrels.
For the half-year ending January 31, 1862	6,246	"
Do. do. July 31, 1862	25,264	"
Do. do. January 31, 1863	57,550	"
For the month of February, 1863	8,874	"
Number of barrels of forty gallons each	103,463	
Giving a total yield of	4,138,520	gallons.

The region occupied by the Corniferous formation in Western Canada, may be defined as the whole of that portion of the province lying to the south and west of a curved line running from the outlet of Lake Erie, and passing through Stratford, to a point on Lake Huron near the mouth of the Saugeen River. The shales of the Hamilton formation, and those of the Portage and Chemung group, cover this limestone over a small area, but by far the greater part is only overlaid by the superficial clays and sands. It will be seen from the descriptions already given, that the petroleum of Enniskillen appears to be accumulated, either in the superficial sand and gravel, as in the surface wells; or in the shales which overlie the true oil-bearing rock. In the same way, the oil wells of western Pennsylvania, and many of those in Ohio, are sunk in a thick mass of Devonian sandstone, which there overlies the Hamilton formation, but which has been removed from southwestern Canada by denudation. This sandstone appears, like the overlying shales and the gravels of Enniskillen, to have served as a reservoir, in which the oil rising from the limestone has been held, and prevented from flowing away at the surface. Over a great part of Western Canada, on the contrary, the oil-bearing limestone is destitute of any covering except the superficial clays and sands; and thus, during long ages, the petroleum has been escaping from the surface, and has been lost, instead of being retained, as in the case where higher rocks are present. In Oxford and Mosa, and in Dereham, where only clay and sand overlie the Corniferous limestone, natural springs are found, yielding small quantities of oil; but neither the wells sunk in the clays of these regions, nor the borings into the limestones beneath, have as yet furnished any large amount of petroleum. Small portions of it are however still escaping at these points; which are on the lines of anticlinal fold and fracture, and are thus the natural localities both for the accumulation and the discharge of the petroleum contained in the subjacent upraised strata. These oil-springs are seen along the banks of the Thames, for a distance of about four miles, in the townships of Oxford and Mosa. The Corniferous limestone is here covered by a considerable depth of clay, through which several wells have been sunk, and the rock beneath in some cases has been drilled. One of these wells, at a depth of seventy feet in the clay, yielded a few hundred gallons of oil; but the vicinity has not so far furnished any considerable quantity. Near Tilsonburg, in Dereham, two wells were sunk in 1861. In one of these, after passing through thirty feet of clay, a boring of ninety-six feet was made in the Corniferous limestone. A fissure yielding petroleum was met with at twenty-five feet in the rock, and another at thirty-eight feet, which discharged small quantities of oil, with abundance of water and of gas at intervals. Some oil was also obtained beneath the clay, at the surface of the rock.

Its accumulation.

Oxford.

Tilsonburg.

The wells of Enniskillen continued to yield large supplies of petroleum during a period of eighteen months; but about the commencement of 1863 it was announced that the discharge from the flowing wells had become intermittent, and finally ceased entirely; although there are many wells which have continued to furnish considerable quantities of oil by pumping. Some of these wells have however, it is said, resumed their flow again at intervals; and it is not improbable, that, as the rising of the oil to the surface, or above it, is dependant upon hydrostatic pressure, the partial check to the flow of the superficial waters, dependant upon the winter frosts, may be one of the causes of the diminished discharge of petroleum. At the same time, it must be remarked, that the experience of the oil region in Pennsylvania has already shown that the supply from these flowing wells soon diminishes, and eventually fails. It has also been observed, that contiguous wells are frequently connected with the same oil-yielding fissure, so as to affect one another's supply. In some cases, air passes down one shaft when the oil is pumped from an adjoining one. In like manner, it was found in Enniskillen that when one of the most abundant of the wells was allowed to flow for some time, the oil disappeared from several of the adjoining wells. It is evident that the exhaustion of these reservoirs of oil is but a question of time; but while the petroleum springs of some regions have failed, those of Burmah, Persia, and Zanté still continue to flow. The present demand for petroleum has however caused a great number of wells to be sunk in the oil regions of America, which must tend to a proportionally rapid exhaustion of the sources. It is however not improbable that farther supplies of this material may ultimately be found in other portions of the country underlaid by the Corniferous formation; and the possibility of its occurrence in available quantities in some part of the Trenton formation should not be lost sight of, although this has never hitherto furnished any considerable amount of petroleum.

Future supply.

The presence of petroleum in the rocks of Gaspé has been mentioned on pages 402 and 521. Subsequent explorations have shown several additional localities in the vicinity of Gaspé Bay. The limestones of this region, which are regarded as of Upper Silurian age, and referred to the Lower Helderberg group of the New York geologists, are observed in various points on the Dartmouth, York, and Malbay Rivers to be more or less impregnated with petroleum. These limestones are generally dark bluish-grey, with layers and nodules of chert, and are traversed by numerous veins of white calc-spar, sometimes including drusy cavities. These often hold petroleum, which impregnates the calc-spar, and is seen to rise to the surface when freshly broken fragments of the rock are thrown into water. Few or no fossils are found in these beds, and no petroleum was obtained at Cape Gaspé in the fossiliferous portions of these limestones. In many places throughout this region the limestone is overlaid by a

Gaspé.

sandstone, the lower portion of which is regarded as of the age of the Oriskany formation (page 403). This rock near the mouth of York River, is, like the limestone, impregnated with petroleum; and on the same river, about twelve miles from the entrance of Gaspé Basin, small portions of solid bitumen were found in the cavities of a trap dyke cutting the sandstone. A similar dyke at Tar Point has already been described.

At the oil spring at Silver Brook, a tributary of the York River, the petroleum oozes from a mass of sandstone and arenaceous shale, which dips southeastwardly at an angle of 13°, and is nearly a mile to the south of the crown of the anticlinal. The oil, which here collects in pools along the brook, has a greenish color, and an aromatic odor, which is less disagreeable than that of the petroleum of Western Canada. From a boring which has been sunk in the sandstone to a depth of about 200 feet, there is an abundant flow of water, accompanied with a little gas, and very small quantities of oil. Farther westward, at about twelve miles from the mouth of the river, oil was observed on the surface of the water at the outcrop of the limestone. Petroleum is met with at Adams's oil spring, in the rear of lot B of York, nearly two miles east of south from the entrance of Gaspé Basin. It is here found in small quantities floating upon the surface of the water; and near by is a layer of thickened petroleum, mixed with mould, at a depth of a foot beneath the surface of the soil. A mile to the eastward, at Sandy Beach, oil is said to occur; and again at Haldimandtown, where it rises through the mud on the shore. These three localities are upon the sandstone, and on the line of the northern anticlinal (page 398), which passes a little to the north of the Silver Brook oil spring. Farther to the southeast, on the line of the southern anticlinal, and about two miles west of Tar Point, which takes its name from the petroleum found there (page 402), another oil spring is said to be found, three quarters of a mile south of Seal Cove. On the south side of the Douglastown Lagoon, and about a mile west of the village, oil rises in small quantities from the mud on the beach. A well has here been bored to a depth of 125 feet in the sandstone, which dips to the southwest at an angle of 10°; but traces only of oil have been obtained. Farther to the westward, oil is said to occur on the second fork of the Douglastown River. Traces of it have also been observed in a brook near St. George's Cove, on the northeast side of Gaspé Bay. In none of these localities do the springs yield any large quantities of oil; nor have the borings, which have been made in two places, been as yet successful. The above indications are however interesting, inasmuch as they show the existence of petroleum over a considerable area in this region, some part of which may perhaps furnish available quantities of this material. Silver Brook.

The petroleum of Western Canada is, like that of other regions, a mixture of hydrocarbons differing in volatility; which are partially separated in the process of distillation. The less volatile and denser portions, which contain a quantity of paraffine in solution, are employed for the purpose of lubricating machinery, either alone or mingled with a fat oil; while the more volatile and lighter portions, after being properly purified, are employed for burning in lamps. The offensive, and somewhat alliaceous odor of the unrefined petroleum of Enniskillen, is probably due, in part, to some sulphuretted compound which the oil contains. When the crude petroleum from this place is rapidly decomposed at a red heat, and converted into gas, this is found to contain a little sulphuretted hydrogen. Some of the petroleums from Pennsylvania yield, by distillation, a considerable quantity of very volatile hydrocarbons; which give off so much vapor, even at ordinary temperatures, as to form explosive mixtures with air. The proportion of these more volatile oils in the petroleum of Enniskillen is however much smaller. These oils are now separated by the refiners; and as a substitute for oil of turpentine, they have become an important article of

aphtha.

commerce. They are frequently known by the name of benzole; but they are really a kind of mineral naphtha, and contain no benzole, or only but traces of it. They are consequently sold at a price very much less than true benzole; which is valuable as the source of aniline, now so much used in the manufacture of fine dyes. Benzole, which differs widely from these naphthas in composition, is a result of the distillation of coal; and as petroleum and its products were introduced to common use as a substitute for the oils previously obtained from coal, it is easy to understand how the name of benzole became transferred to the naphtha, and that of coal oil to the products which have now so generally replaced it. The

efining.

purification and de-odorization of the distilled petroleum is effected chiefly by treatment with strong sulphuric acid, which is followed by a solution of caustic soda. The process is now succesfully practiced in several parts of Western Canada. The acid and alkali required for this purpose are imported from Great Britain.

sphalt.

The solid bitumens, or asphalts, are sometimes distilled for the preparation of oils, and are also extensively employed in the manufacture of mastic for paving. The half-dried bitumen of the gum-beds of Enniskillen (page 524) is well fitted for distillation; but such a process would not perhaps be profitable at the present price of petroleum. The limestones from Kincardine and Manitoulin Island (page 522), which contains from eight to twelve per cent. of mineral pitch or asphalt, may, if found in sufficient quantities, be employed for the preparation of mastic. The minerals used for this purpose are similar natural mixtures of solid bitumen with sandstone, or with limestone, the latter being preferred. The proportion of bitumen in these is however seldom sufficient to give to the mastic the cohesion required. A proper mixture for paving is one containing about fifteen per cent. of bitumen; and for this purpose the pulverized asphaltic mineral is mixed, by the aid of heat, with a sufficient quantity of solid bitumen obtained by the distillation of asphalt, or with an artificial bituminous mixture capable of replacing it. In this way the asphaltic limestones of Switzerland and of Italy, with the addition of from three to five per cent. of a ductile bitumen, are employed for the pavements of Paris. Mastic.

The black mineral which has been described on page 525, as probably a product of the alteration of bitumen, and which is met with in considerable quantities among the rocks of the Quebec group, on the island of Orleans, at Quebec and elsewhere, has been found to yield a fine black pigment; and when ground with oil, to serve the same purpose as ivory-black.

The presence of small portions of mineral coal in the Devonian sandstones of Gaspé has been mentioned on page 394. Some beds of these rocks contain besides, a peculiar resinous matter, which forms the cementing material. It appears on the fractured edges of the beds, as in the form of irregular laminæ, rarely an eighth of an inch in thickness, and generally much less. It has a vitreous lustre, a conchoidal fracture, and is tough, with a hardness nearly equal to calc-spar. Its color is deep reddish-brown, but it gives a fawn-colored powder; and when in thin plates or fragments, is translucent, and has an orange-red color. This substance has neither taste nor odor; it is insoluble in alcohol, naphtha, or potash-ley, and is but slightly attacked by nitric acid. It is scarcely fusible; but at a high temperature is decomposed, with a slight softening and swelling up; giving off abundance of inflammable vapors, and leaving a small quantity of brilliant spongy coke. It has the characters of a fossil resin, somewhat like amber, but in its characters approaches more nearly to what have been named scleretinite, and middletonite. Fossil resin.

The portions of sandstone impregnated with this resin, burn, when kindled, with a brilliant flame, and much smoke; and the residue, which consists chiefly of silicious sand, has very little coherence. Partial analyses were made of four fragments of this rock, which were supposed together to represent an average of the mass. The amount of volatile matter, of fixed carbon or coke, and of the incombustible residue was as follows: Its analysis.

	I.	II.	III.	IV.
Volatile matters,......	32·4	22·8	42·8	30·4
Carbon	8·9	8·1	7·4	8·9
Residue..............	58·7	69·1	49·8	60·7
	100·0	100·0	100·0	100·0

The purest specimen is seen to yield the smallest amount of fixed carbon. The excess of this in the others is due, in part, to the small portions of mineral charcoal generally present among the layers of this resinous sandstone. This material could be made to furnish large quantities of illumi-

Use for gas making. nating and lubricating oils by a process of distillation similar to that applied to coal and to bituminous shales. In some experiments made on a small scale to test its power of producing illuminating gas, it was found that a few pounds of this material, which lost, by distillation, 26·0 per cent. of its weight, yielded two and a quarter feet of gas of superior illuminating power, to the pound. As this quantity of volatile matter corresponds to about 33·0 per cent. of resin, it is evident that if obtained in a state of greater purity, this material would become valuable as a substitute for coal in gas-making.

The specimens which served for the preceding experiments were obtained from a bed of from fourteen to fifteen inches thick, which was found near Shaw's mill, on the north side of Gaspé Basin, and was traced for a distance of about 200 feet before it became concealed by overlying sandstones. York River. In numerous localities along the York River, for a distance of nearly thirty miles, small interrupted beds of a similar nature are met with in the sandstones. Those observed have a thickness of from four to twelve inches, and are sometimes a hundred feet in length. Some of them are composed in great part of laminæ of a brilliant brownish-black matter; which, when examined in thin fragments, show the same reddish translucency as the resin just described, and are apparently similar to it in composition; although in some cases mingled with more coaly matter, and containing less ash. A specimen from one of these beds on the York River gave of volatile matters 52·4, carbon 26·3, residue 21.3 ; = 100·00. The greater proportion of volatile hydrocarbons which may be obtained from this would render it still more valuable for distillation than the bed whose analysis has been given above. These curious deposits are evidently worthy of further study from an economic point of view.

VI. REFRACTORY MATERIALS.

Those matters which are used in the construction of furnaces, or of crucibles, or generally for purposes of withstanding heat, are technically designated refractory substances. Under the head of Refractory Minerals are here included plumbago, mica, soapstone or steatite, pyrallolite, potstone, sandstone (in so far as it is used for furnaces), fire-clay, and moulding sand. Besides the uses indicated in the present classification, several of these materials have other economic applications, which will also be pointed out.

PLUMBAGO.

Plumbago or graphite, which is also commonly known as black-lead, receives several applications in the arts. The finer varieties which have the color, texture, and purity required, are employed for the manufacture of pencils, and command a very high price. Inferior qualities of black-lead, if free from earthy matters, are made use of as an application for preventing friction in machinery; and considerable quantities are employed for imparting a lustre to iron, especially for stoves in domestic use. The most important use of plumbago is, however, for the manufacture of crucibles and for melting pots, which are very refractory, and are much esteemed by metallurgists. Small furnaces for assayers and chemists are also constructed of plumbago. For these purposes it is ground to a fine powder, and mixed with a portion of clay, which gives plasticity to the mass, and allows it to be moulded. The plumbago for these uses is obtained in Bavaria and other parts of Germany, and in Ceylon; while the finer varieties for pencils are in great part procured from Russia and from Cumberland. This last owes its value rather to its peculiar state of aggregation than to its purity, since it often contains more foreign matter than some of the crystalline Ceylon plumbago, of much less price. The black-lead of Passau in Bavaria, which is extensively used in the manufacture of crucibles, contains only from 35·0 to 42·0 per cent. of pure plumbago, the residue being of the composition of clay; yet this is extensively used for the manufacture of crucibles, which are highly esteemed. They are said to be made by mixing two or three parts of the impure mineral with one part of clay. The value of comparatively pure crystalline plumbago, like that of Ceylon, or of Canada, which contains but a small proportion of earthy matters, is said to be about twenty pounds sterling the ton. Argillaceous matters, although they reduce its value, are, as has been seen, not prejudicial; but the presence of carbonate of lime is very objectionable, inasmuch as the lime forms a fusible compound with the intermixed clay when the crucibles are exposed to heat. The beautiful process of Brodie, by which plumbago is freed from all impurities, and reduced to a state of minute division, is applied to the finer varieties of this mineral, which are to be fitted for the manufacture of pencils.

Black-lead.

Crucibles.

The principal facts connected with the occurrence of plumbago in Canada are given on page 529. The black plumbaginous slates of the Eastern Townships, belong in part to the base of the Quebec group, and in part to the overlying Upper Silurian series. Neither of these has yet been found to contain any available quantities of plumbago; but it is not impossible that workable deposits of the mineral may be met with in some parts of their distribution. The plumbago of the Laurentian series furnishes the mineral in a comparatively pure form; sometimes however associated with carbonate of lime. In addition to the facts already mentioned with regard to its occurrence, the principal localities of plumbago may now be noticed. On the north side of the Ottawa, several deposits are known; all of which probably belong to one of the limestone bands of that region. On the tenth lot of the fifth range of Grenville there is a mine of plumbago, Grenville. which was many years since worked to a small extent. The rock, which is here somewhat disturbed by an intersecting trap dyke, consists of a white crystalline limestone, which, in the immediate vicinity of the plumbago, contains a bed composed of pyroxene, tabular spar, feldspar, and quartz. Large cleavable masses of sphene, with phlogopite, zircon, garnet, and idocrase, are also met with in this aggregate. With this the plumbago is more or less mingled; although the greater part of it occurs in two or three strings or irregular beds, from which a small quantity was at one time taken, and sent to the English market. About half a mile to the northward, a deposit of plumbago, which is perhaps a continuation of the last, is met with. Here also the mineral appeared to be divided into three layers, of which the widest was eleven inches, and it was accompanied by a bed containing pyroxene, tabular-spar, sphene, and zircon. Plumbago is also said to occur on the thirteenth and fourteenth lots of the fourth range of Grenville; where the limestone band just noticed, is repeated on the other side of a synclinal. Farther to the northeastward in the continuation of this same band, good specimens of plumbago are found on the north half of the second lot of the tenth range of Grenville; and beyond this, on the fifth lot of the fourth range of Chatham Gore, masses of it are found on the surface, in the vicinity of the crystalline limestone. To the westward, in the Augmentation of Grenville, this limestone band re-appears in another synclinal; and a bed of plumbago has been traced along it, at intervals, for a distance of about three miles, running a little to the east of north. On the third lot of the second range, where an opening was made, a thickness of ten inches of pure foliated plumbago occurred; but this was found to have a lenticular form, and to be separated from other similar masses by portions in which the plumbago was mingled with limestone. Farther northward on the third lot of the sixth range, the bed of plumbago has a thickness of three feet, but is somewhat impure from earthy matters. Specimens of very pure plumbago, associated with quartz, have lately been found in the seigniory of Petite Nation. A few miles to the westward is the township

Lochaber. of Lochaber, from the twenty-fourth lot of the seventh range of which, very excellent plumbago has been obtained. The adjacent township of Buckingham is also said to afford good specimens of the mineral.

Burgess. To the south of the Ottawa, plumbago of a good quality has been discovered by Dr. Wilson in the township of Burgess. It occurs disseminated very generally through the Laurentian limestones in the rear of Kingston. Near the outlet of Gold Lake, on the sixth lot of the ninth range of Loughborough, it forms a bed in the limestone, from three to eighteen inches in width. The mineral is intermingled with vitreous translucent quartz, in which portions of pure plumbago are sometimes imbedded. A small vein of this mineral is also found on the west side of Mud Lake in the same township. It is not more than an inch in breadth, and is described as cutting the strata of gneiss. On the eighteenth lot of the ninth range of Bedford, specimens of plumbago are met with in the crystalline limestone; and on Bird Lake, in the same township, the mineral is found with quartz in the limestone, both on the north shore of the lake, and on the south side of a small island which occurs near its eastern end. It is probable that these limestones, which are so widely distributed throughout the Laurentian series in Canada, will be found to yield, in many localities, valuable deposits of plumbago. Bedford.

MICA.

On page 494 will be found a description and analyses of the magnesian mica, or phlogopite, which occurs in various localities associated with the limestones and pyroxenes of the Laurentian series. It is frequently found in large masses, which may be separated into thin transparent plates. Mica in this form, as is well known, receives various applications in the arts, being employed for the fronts of stoves, for lanterns, and for the chimneys of lamps. As it is not liable to be broken by concussion, it is also used instead of glass in the windows of ships of war; and it has received several other applications of less importance. That hitherto employed, at least such as is obtained from Russia and from the United States, has been chiefly the mica of granitic rocks, called muscovite; which differs in chemical composition from the phlogopite. The two species however resemble one another closely in physical characters, and may be used for the same purposes. The value of mica depends upon the size, the transparency, and the perfection of the plates. The ordinary price of cut and dressed sheets of the usual size, in New York, is said to be \$1·50 the pound; while their present value in London is about seven shillings sterling. A quantity of large and carefully selected sheets from the locality in North Burgess, to be mentioned below, was sold last year in Paris for the use of the French navy, at \$2·00 the pound. Several hundred-weights of large selected crystals from the same locality, fit for splitting into thin plates, were also sold in London at two shillings sterling the pound; while from fourpence to sevenpence were given for inferior qualities. There is also a large demand for smallar sizes of mica, and for the refuse portions from its working. These, among other uses, are employed in making letters for window-signs. Ten shillings a hundred-weight were lately offered in London for fifteen or twenty tons of such material. These figures will serve to give some notion of the values which may be expected for the different qualities of mica. Its uses. Its price

Mica in masses sufficiently large for economic purposes, has been observed in several localities in Grenville. One of these is on the ninth lot of the sixth range, from which small quantities have been extracted and sent to market. A crystal from this place was so large as to furnish Grenville.

sheets measuring twenty-four by fourteen inches. Good mica has also been found on the tenth lot of the fifth range, and on the first lot of the tenth range of Grenville; as well as farther to the westward in the Augmentation of this township. On the seventeenth lot of the ninth range of North Burgess, large crystals of magnesian mica are found in abundance in a bed of soft pyroxenic rock. The mica has been traced for about 300 feet; and considerable quantities have been extracted and sold, as mentioned above, by Mr. Alex. Cowan. Some of the plates are twenty inches square, or even larger. Mica also occurs on the sixteenth lot of the above range, and on the twenty-first lot of the fifth, as well as on the first lot of the fourth range of South Burgess. It appears probable that by further exploration in this region, and in Grenville, sufficient quantities of mica could be obtained to supply a large demand.

Burgess.

SOAPSTONE.

Soapstone, or steatite, is a more or less pure compact talc,—for descriptions and analyses of which, the reader is referred to page 469. When pure and compact, soapstone is much used as a refractory material for lining furnaces, especially those destined for anthracite. From its softness, it is readily cut with knives and saws into the required shape, and it is infusible in any ordinary furnace heat. Slaty varieties, and such as contain crystals of spar, or other foreign minerals, are however to be rejected; inasmuch as they are liable to split and exfoliate by heat. Steatite is also used in the construction of small portable furnaces, and of open stoves, which are made of plates of it held together by iron rods and bands. Culinary vessels are made of it; and it has also been bored for water-pipes, and used for the lining of cisterns for acid and alkaline liquids. When very strongly heated, steatite loses the small portion of combined water which it contains, and becomes much harder, and susceptible of a polish. It may then be colored by various solutions; and it has lately been used in this manner for the manufacture of buttons, and of some other small articles. Jets for gas-burners are also made of this hardened steatite, and have the advantage of not being liable to rust or corrosion. When reduced to powder, the softness and unctuosity of steatite have caused it to be used, like plumbago, as a lubricator to diminish friction; and the finely ground mineral is also said to be used to give a surface to some kinds of paper-hangings. Its use as a cheap paint has already been alluded to (page 767); and it may here be mentioned, that the Venetian chalk which enters into certain cosmetics, and which is also used for tailors' crayons, is steatite.

Steatite.

Its uses.

Steatite is rare among the Laurentian rocks, where its place is generally supplied by pyrallolite, presently to be noticed. The only deposit of steatite yet known in this series is in Elzivir, and it is impure from an admixture of carbonates. In the altered rocks of the Quebec group, however, it is characteristic of the magnesian band in the second and third synclinals (page 710). A bed of steatite, associated with dolomite, occurs on the twelfth lot of the seventh range of Sutton. It is however mixed with crystals of bitter-spar, pyrites, and small octahedrons of chromic iron. It is enclosed in micaceous slates; and has adjoining it on the southeast side, a bed of magnesite, described on page 457. A similar impure soapstone occurs near the dolomite in the vicinity of Knowltonville. In many parts throughout the distribution of this magnesian band of rock, steatite is associated with serpentine, dolomite, magnesite, or chlorite; one of these rocks often appearing to take the place of the other, as noticed on page 248. Thus on the fourth lot of the fourth range of Bolton, the belt of magnesian rocks is represented by a breadth of about twenty-five yards of steatite holding bitter-spar and intermingled with patches of dolomite; while about 300 yards to the northeastward, on the strike, it passes into a bed of dark green slaty serpentine, containing asbestus, with grains of chromic and magnetic iron. This is bounded on the northwest by a bed of steatite; and beyond this is a bed of actinolite, mingled with asbestus and talc; the whole occupying a breadth of fifty yards. On the sixth lot of the second range of Bolton, is a band of soapstone, which occupies a breadth of about thirty yards, and is limited on the southeast side by a bed of dark green serpentine a foot in thickness, to which succeed nacreous clay slates. The steatite is more or less mixed with crystals of bitter-spar, which to the northwest side predominate; so that the rock passes into a dolomite, which is bounded by slates similar to those on the opposite side of the band.

Sutton.

Bolton.

Along the western side of the Missisquoi valley, the western outcrop of a portion of the second synclinal is traced for a distance of about twenty miles, through Potton and Bolton; and is marked by the band of magnesian rocks already noticed; which in many places present beds of soapstone, sometimes, but not always, associated with serpentine. On the twentieth lot of the fifth range of Potton, a workable bed of it, three feet in thickness, is met with; and a locality which furnishes a steatite of superior quality, is on the twenty-fourth lot of the sixth range of Bolton. Here it is associated with chlorite, and with dolomite. Resting upon a band of the latter, is a layer of about three feet of impure steatite, overlaid by four feet of dolomite. This is followed by a layer of a few feet of chlorite; to which succeed about five feet of steatite; the upper two feet of which are very pure and compact, and furnish large blocks free from flaws. The bed of steatite however appears here, as in some other places, to have a lenticular shape, thinning out, and being replaced by the chloritic rock.

Potton.

On the eastern side of the Missisquoi River the same band of magnesian strata appears along the western margin of the third synclinal, whose outcrop has already been described in connection with the copper ores which accompany it. Here, as might be expected, on the opposite side of the anticlinal, the apparent position of the steatite to the great mass of the dolomite is reversed, and it appears to the east of it. A bed of steatite occurs on the seventeenth lot of the ninth range of Bolton, and forms one limit to the bed of magnesite described on page 458, which is bounded on the other side by serpentine. There is little doubt that workable beds of steatite like that of Potton, will be found in many localities in the magnesian band along the outcrops of the various synclinals. Steatite is met with farther to the northeastward, in the valley of the Chaudière, at the fall of the Bras in Vaudreuil. Here a bed of it occurs, associated with dolomite, in argillite. The steatite of this locality contains imbedded crystals of carbonate of magnesia, and is stained green by nickel, traces of which generally accompany the steatites of this series.

PYRALLOLITE.

As already remarked, true steatite is of rare occurrence in the Laurentian rocks in Canada, and also in northern New York; but its place is often supplied by a mineral which is similar to it in chemical composition, softness, and refractory properties, and was by Prof. Emmons of New York called rensselaerite. This, as will be seen on page 470, is regarded as identical with what had previously been named pyrallolite. According to Emmons, this mineral is capable of being turned in a lathe, and wrought like soapstone, and has been made into small vases, inkstands, and similar objects. Some varieties of it are nearly white, and have the translucency of porcelain; others are greenish, and others nearly black. Much of the figure-stone or pagodite, in which the Chinese carve various ornaments, appears to be pyrallolite. It was also used by the aborigines for their calumets. One of these, found in an Indian tomb on Lake Huron, was found to be carved from a nearly white translucent pyrallolite.

This mineral appears to form beds, associated with the Laurentian limestones, and has been observed in several places. A bed of it, associated with serpentine, occurs between the gneiss and the limestone, on the Grenville. thirteenth lot of the fifth range of Grenville. It may be traced thence into the sixth range, and appears to be in considerable quantity. Another bed of it is found between quartz and crystalline limestone, on the east side Ramsay. of the eighth lot of the sixth range of Ramsay, and would furnish considerable masses of the material. Other localities of pyrallolite have been mentioned on page 470; and it is probable that it will be found in many places accompanying the Laurentian limestones. In the Saguenay region, at the lowest rapid of the Peribonka River, a thin band of a soft greenish rock, which resembles pyrallolite, is interstratified with a great mass of coarsely crystalline violet-blue labradorite; which has here a breadth, across the strike, of about six hundred feet.

POTSTONE.

Potstone, or compact chlorite, receives its name from the fact that it was formerly used in some parts of Europe for the construction of culinary vessels. From its softness, it may be cut and turned like steatite, with which it is often confounded. Among the chloritic rocks which abound in Eastern Canada, beds of pure compact chlorite are sometimes met with. One of these, on the twenty-sixth lot of the second range of Bolton, has a breadth of about twenty feet, and affords large blocks, from which plates measuring several square feet have been cut by a common mill-saw. A description and analysis of this rock will be found on page 607. It will probably prove a less refractory material than steatite, and has less of the unctuosity which characterizes this mineral, but may be applied to many of the same uses. A bed of pure compact potstone occurs on the fourth lot of the twelfth range of Broughton.

Chlorite.

Bolton.

In this connection may be mentioned a soft micaceous rock which occurs on the eighteenth lot of the fifth range of Shipton. The description and analysis of this rock are given on page 494. In its softness and texture, it so closely resembles potstone as to have been mistaken for it, and it may probably be employed for similar uses. The portion of the bed exposed has a breadth of five feet, but its whole thickness is probably much greater.

SANDSTONE AND SAND.

These materials are much used for the construction of the furnaces used in smelting metals, and in other metallurgical operations. The nearly pure silicious sandstone of the Potsdam formation is in some places well suited for such purposes. That from the Grès Rapids on the St. Maurice was used in the iron works of that vicinity, and of Batiscan; and is employed at the Radnor furnaces. The blocks of stone have a thickness of from twelve to eighteen inches, a breadth of twenty inches, and a length of four feet. They are found to answer an excellent purpose, and do not require renewal oftener than once in two years. The rock here is of a freer texture than in many other parts of its distribution. It is probable that sandstones equally well adapted for this purpose may be found in many other places along the extended outcrop of the Potsdam formation, which has been described in the sixth chapter. On the twentieth lot of the first range of Pittsburg, there is an exposure of a thickness of twenty feet of this sandstone, which is extremely friable, and readily reduced to powder. In this state it is

Fire-stone.

sought for by iron workers, who employ it to protect the sides and bottom of their furnaces. About 1500 tons of it are annually supplied to the two cities of Montreal and Toronto. The material is delivered in Montreal for about three dollars a ton.

Moulding-sand. The moulding sand employed by iron founders is a fine quartzose sand, containing at the same time small quantities of argillaceous and ferruginous matters. Sands of this composition, possessing the required texture, are known to exist in several localities in the country. Thus the moulding sands employed at St. Maurice and at Batiscan are found in the vicinity. At Perth, at Brockville, and at Kingston sands fitted for this purpose are also met with; and in the neighborhoods of Dundas, Durham, and Owen Sound are beds of fine sand, which have been successfully employed by iron founders. It is probable that similar materials may be met with in a great many localities.

Artificial mixtures for the moulder's use are often made, especially by the German founders, and for fine castings. For this purpose, sandstones and argillaceous rocks are carefully ground to powder and sifted. A good mixture is also said to be obtained with two parts of iron ochre, three parts of clay, and ninety-three parts of fine quartzose sand. A deposit of such sand, twenty feet or more in thickness, occurs at Laval, on the right bank of the Bras, at its junction with the Montmorenci River. This material, from its exceeding fineness, has been employed at Quebec as a polishing powder, and might probably be used for the preparation of a moulding sand. A nearly pure silicious sand is employed in England for the manufacture of the celebrated Dinas fire-brick. This material, which contains from 96·0 to 98·0 per cent. of silica, constitutes the under-clay of a coal bed, in the vale of Neath in Glamorganshire. It is mixed with about one hundredth of lime, and sufficient water to make the mass coherent. The paste is then compressed in iron moulds, dried, and burned for several days, at a high heat. These bricks are very refractory; and as they expand by heat, instead of contracting like those of fire-clay, they are greatly preferred in the construction of many parts of furnaces. (Percy's Metallurgy, vol. i, p. 237.) It is probable that some of the silicious sands of this country might be advantageously used for the manufacture of similar fire-bricks.

Laval.

Fire-brick.

Glass-making. The white silicious sandstone of the Potsdam formation affords in many places a material sufficiently pure for the manufacture of glass. Furnaces for this purpose were formerly in operation at St. Johns, and at Vaudreuil on the Ottawa; but have been abandoned from the difficulty of competing successfully with glass of foreign manufacture. Beds of sandstone well fitted for this purpose are found on Isle Perrot, in Vaudreuil, and at Lachute and Ste. Scholastique. The same formation in many parts of Beauharnois furnishes a sandstone which from its freedom from iron, would furnish a good material for the purpose. One of the best localities of the stone in this seigniory is at Williamstown. Large quantities of fine white sand from the disintegration of a sandstone of this formation, are found on an island in Charleston Lake in Escott.

VII. MATERIALS FOR BRICKS, POTTERY, AND GLASS.

Under this head may be noticed the clays for the manufacture of common bricks, tiles, and coarse earthenware. No clays fit for the finer kinds of pottery have as yet been found in the country. In Vermont however, at the western base of the Green Mountains, valuable beds of kaolin or porcelain clay, belonging to a tertiary formation, are met with in several localities. It is not improbable that these deposits may be continued into Eastern Canada; but if such be the case, they are concealed by the superficial clays and sands of the region, and have yet to be sought for along the base of the Notre Dame Mountains. Feldspar, which enters into the composition of porcelain, is found in considerable quantities in granitic veins among the Laurentian rocks, and may in some places occur in sufficient purity to be available for the use of potters. In describing the phosphate of lime of this series of rocks, allusion has been made to the fact that this material, in the form of calcined bones, enters largely into the composition of English porcelain, and that the purity of some of the apatite of Canada is such that it may perhaps be employed for a similar purpose. The fitness of some of the Potsdam sandstone for the manufacture of glass, has been mentioned above. The specimens of this stone from Vaudreuil, at the Exhibition of 1851, attracted the attention of English glass manufacturers, who import a similar material from the United States, and who afterwards made inquiries as to the price at which the sandstone could be furnished in England.

Kaolin.

BRICK-CLAY.

Clays suited for the manufacture of bricks are found in a vast number of places throughout the province. In Western Canada, the clays are divided into two classes. The older and underlying deposit is comparatively free from oxyd of iron, and yields white bricks, which generally however have a somewhat yellowish tinge. The white-brick clay is unconformably overlaid by another deposit, which gives red bricks. The history of these two clays will be given in detail in the succeeding chapter. These white bricks, which are more esteemed than the red, are made in a great many localities from the shore of Lake Huron as far eastward as Brockville. The average number of bricks made annually in Toronto is from eight to ten millions, of which from three to five millions are white bricks. The ordinary price of these at the kiln is from \$5·50 to \$6·00 the

Brick-clay.

White bricks.

thousand; while that of the red bricks is from \$3·00 to \$4·00. Besides the superficial clays of Western Canada, the soft argillaceous beds of the Medina formation, and of the Hudson River group, are successfully employed for the manufacture of bricks. At Dundas there is an argillaceous band about twenty feet in thickness, near the base of the Clinton formation. This rock readily disintegrates, and, being washed down by the rains, is deposited from the water in the form of a clay, which is collected and used in the iron foundries of Dundas and Hamilton. It is said that this is of a refractory nature, and serves as a fire-clay. Many of the best materials of this kind are furnished by the under-clays of the coal formation (page 572); and it is not improbable that beds of a similar kind, which have been mentioned on page 395 as occurring in the Gaspé series, may be found to yield a fire-clay.

Dundas.

Fire-clay.

In Eastern Canada, the two kinds of clay which are distinguished in the west are no longer met with; but an extensive deposit of marine clay extends throughout the valleys of the Ottawa and St. Lawrence, and furnishes everywhere material for bricks. The two principal manufacturers at Montreal produce each about six millions of bricks annually. The ordinary price of these is about \$5·00 the thousand. Some beds of these clays are employed for the manufacture of coarse earthenware; which is manufactured, among other places, at Beauharnois, at Yamachiche, at Yamaska, and near Quebec. Drain tiles for agricultural purposes, are also made at several places, as at Montreal, at Treadwell upon the Ottawa, and at Missisquoi Bay. Pipes for sewerage draining are manufactured on a considerable scale at Quebec, where upwards of 150,000 feet of them have been laid for main sewers and for house-drains. They are covered with a lead glaze; and have a considerable strength, resisting, it is said, a pressure of fifty pounds to the square inch.

Pottery.

VIII. MATERIALS FOR CEMENTS AND MORTARS.

Under this head may be included, first, limestones which yield lime for ordinary mortar, and secondly, limestones fit for water-lime or hydraulic cements. To these may be added gypsum or plaster of Paris, which has already been noticed on page 762, and also magnesite. Magnesia, which may be obtained by the calcination of this mineral, has been recommended for the preparation of a hydraulic cement especially adapted for constructions which are to be exposed to the action of sea-water. The localities of magnesite, and some details with regard to the preparation of the cement, have been given on page 756.

Magnesite.

LIMESTONES.

The Lower Silurian limestones of the Chazy formation and of the Trenton group, afford throughout their distribution, abundant material for the manufacture of lime, and they are extensively burned in the vicinity of Kingston, Ottawa, St. Hyacinth, Montreal, and Quebec. Analyses of some of these limestones are given on page 621. They sometimes contain an admixture of small quantities of argillaceous matter; but from their general purity, and from their freedom from iron and magnesia, they yield a white lime well adapted for making fine mortar, for whitening walls, for agricultural purposes, and for the purification of coal-gas. The amount of lime annually burned at Montreal is about 270,000 bushels, and its price is about seventeen cents the bushel. The limestone of the Birdseye division of the Trenton group, which is burned at St. Anne near Montreal, yields a lime which is much esteemed. That from Ste. Rosalie, near St. Hyacinth, whose analysis has been referred to, yields a lime remarkable for its purity and whiteness. The stone cannot be distinguished from that which is burned at Highgate in Vermont, and which belongs to the same formation. The quarries in both localities contain interstratified beds of an inferior magnesian limestone. The Devonian limestones of the Corniferous formation, which underlies a great portion of southwestern Canada, resemble in composition those just mentioned, and yield a similar pure lime. Lime

The Middle and Upper Silurian limestones of Western Canada, including the Niagara, Guelph, and Onondaga formations, are generally magnesian, and have the composition of dolomite (page 624). When burned, they yield a meagre or magnesian lime, which is for the most part very free from impurities. These magnesian limes yield very strong mortar, but are considered to be less proper for agricultural purposes than those which contain no magnesia. The Calciferous formation, which underlies the Chazy in some parts of Canada, yields in like manner a magnesian lime, and the same is true of many of the limestones of the Quebec group. These often contain a considerable quantity of carbonate of iron, which gives a yellowish or ochrey tint to the lime. For analyses of them, see page 613. Pure limestones are however sometimes associated with these dolomites, as at Point Lévis. Throughout the Quebec group, a band of limestone, for the most part magnesian, is generally the accompaniment of the copper ores, in describing which many of its localities have been indicated. The distribution of this limestone band in a district where silicious rocks prevail, assumes a considerable economic importance. To the southeast of the Quebec group, the upper slates (page 709) are associated with good limestones, which are sometimes more or less magnesian, and are quarried and burned on Lake Memphramagog, at Dudswell, and on the Famine River. Magnesian lime. Quebec group

Limestones occur among the Upper Copper-bearing rocks of Lake Superior, and also in the Huronian series. The distribution of these latter limestones is given in the fourth chapter, and on the map which accompanies it; and analyses of some of them will be found on page 596. The limestones of the Laurentian series are very important, both from their extent, and from the fact that wherever they occur, the Laurentian region presents fertile valleys fit for cultivation; so that the principal settlements found among these rocks are upon the outcrop of the limestone bands. These limestones, which afford excellent lime, as well as good marbles and building materials, are sometimes pure, and sometimes magnesian. Descriptions and analyses of some of these are given on page 592: and their distribution is explained in the second chapter, and in the map, which represents their arrangement in a part of the Ottawa district. About three miles below Tadousac, on the St. Lawrence, and a little to the east of the mouth of the Rivière Baude, the Laurentian gneiss is cut by a perpendicular vein of calc-spar, which runs northwestward, and has a breadth of twelve feet. This spar, which is coarsely crystalline, contains only scattered grains of copper pyrites; and if burned, would yield a good lime, which, in this locality, remote from any other known deposit of limestone, is of some importance. Mention has already been made of the fresh-water marls as suitable for the manufacture of lime; and the considerable deposits of calcareous tufa, which is a nearly pure carbonate of lime, and abounds in many parts of Western Canada, may in some cases be applied to a similar purpose. As this material contains no carbonate of magnesia, it will furnish a lime better fitted for agricultural purposes than the dolomites of the region, which yield a magnesian lime, generally regarded as injurious to the soil. Deposits of calcareous tufa occur in many places along the base of the Niagara formation in the counties of Grey and Simcoe. The most considerable known is on the banks of the Beaver River, in Euphrasia and Artemisia, which probably covers 1000 acres. An area of about 300 acres of tufa, with an average thickness of five feet, occurs in a similar geological position at the falls of the Noisy River in Nottawasaga.

Laurentian limestones.

Marl and tufa.

HYDRAULIC CEMENTS.

Certain impure limestones yield by calcination, a substance which, instead of slaking with water, like ordinary lime, forms with it a paste, which after a greater or less lapse of time sets or becomes hard even under water. This property is now known to depend upon an admixture of clay or silicate of alumina, containing an alkali; and artificial mixtures are prepared by mingling chalk, or any other carbonate of lime, with a proper quantity of clay, and calcining the mixture. In this way the so-called Portland cement, and many other similar compositions are prepared, both in England and in France. The pozzuolana of the Italians, and the trass of the Germans, are argillaceous materials of volcanic origin, which when mingled with pure lime, yield hydraulic cements; and these substances may also be imitated by calcining ordinary clays, and then grinding them to powder. Where however natural admixtures of clay and carbonate of lime can be obtained in abundance, it is more advantageous to employ them than to resort to artificial preparations. When a limestone contains ten or fifteen per cent. of clay, it yields a lime possessing hydraulic properties, which increase with the proportion of clay; and when this amounts to one third of the lime, the mixture yields a mortar which hardens almost immediately under water. The proportion of clay may even rise to sixty per cent. without destroying this property. Magnesian limes yield hydraulic cements equally good with those of pure lime, and, as already noticed, a mixture of magnesia with pozzuolana or with calcined clay forms a valuable water-cement.

Water-lime.

Argillaceous limestones and dolomites yielding good hydraulic cements, are known in many parts of Canada, and have been employed to some extent. In the following descriptions, advantage will be taken of the analyses of some of the cements of Canada, made in 1855, by Mr. Delesse, one of the jurors at the International Exhibition at Paris, and published in the report of the Imperial Commission. In the Quebec group, a black thin bedded dolomite, noticed on page 268, occurs at the Mountain Portage, about five miles from the mouth of the Magdalen River in Gaspé. By its analyses, given on page 614, it is seen to contain about twenty-five per cent. of clay. When calcined, it becomes of a buff color, and yields a cement which hardens under water after five minutes, and soon acquires a great degree of solidity. Beds of a similar rock occur at the Grande Coude, six miles below Great Pond River; and other beds may probably be found in many parts of this region.

Gaspé.

The black limestone of Quebec, which is employed for the manufacture of a hydraulic cement, differs from that just described in the absence of magnesia. This stone, whose hydraulic properties were first noticed by General Baddeley, R.E., contains a large proportion of clay, and is colored by a carbonaceous matter, which disappears by calcination, when the rock becomes of a yellowish color. A specimen of the calcined and ground stone, prepared for use by Mr. Gauvreau of Quebec, gave 11·6 per cent. of water and carbonic acid, and the residue consisted of lime 52·49, magnesia traces, silica 27·40, alumina and oxyd of iron 12·16, sulphate of lime 7·95; = 100.00. The proportion of sulphate of lime in this cement is remarkable; but it remains to be determined whether it belongs to the rock, or is added in preparing the cement. It becomes solid, according to Delesse, in twenty-five minutes after mixing with water; but is of a quality inferior to the Thorold cement.

Quebec.

In the Chazy formation, a bed of grey argillaceous magnesian limestone occurs a few feet above a blackish-brown band, which is marked by the shells of *Leperditia* (page 128). This magnesian layer, which weathers of a yellowish color, has a conchoidal fracture, and holds small geodes of calc-spar, may be traced by its mineral characters, and by the underlying fossiliferous bed, from Hawkesbury as far westward as Allumette Island. Nepean. At Nepean, on the shore of the Ottawa, it has a thickness of six feet, and has for many years been quarried for the manufacture of a hydraulic cement. The analysis of the stone from this place is given on page 619. A specimen of the cement gave to Delesse, lime 39·70, magnesia 9·58, soluble alumina and oxyd of iron 19·74, insoluble argillaceous residue, 30·98; = 100.00. It is probable that this bed may yield a similar cement in other parts of its distribution. Beds of limestone from the Calciferous formation in Hawkesbury, Argenteuil, and Chatham are said to have been tried on a small scale, and to yield a cement. In the township of Loughborough, on the first lot of the eighteenth range, are beds which resemble those of the Chazy just described, and have been found to yield a hydraulic lime. A similar bed, three feet in thickness, occurs in the ditch around Kingston. the fort at Kingston, and has been used as a cement. There is little doubt that when a larger demand for such materials exists, many localities of water-lime may be found, both in the Calciferous and Chazy formations.

In the Niagara formation near Thorold, a band of dark grey argillaceous Thorold. limestone, eight feet in thickness, (page 323,) yields an excellent cement. Its color after calcination is yellow. A specimen examined by Delesse contained 3·37 per cent. of moisture, without any carbonic acid. Its farther analysis gave lime 53·55, magnesia 2·20, silica 29·88, alumina and oxyd of iron 12·70, sulphate of lime 1·58; = 99·91. This cement was found to set in ten to fifteen minutes, with disengagement of heat. A portion placed in water ten minutes after mixing, became as solid as another portion which had set in the air, and was only immersed at the end of two hours. The resistance of this cement to traction, according to Delesse, was represented by 85, while that of Quebec was 49. This cement has been largely used in the construction of many public works, and was employed in building the piers of the Victoria Bridge. Its price at St. Catherines is from twenty to twenty-five cents the bushel. This layer of water-lime does not appear to be continuous throughout the Niagara formation. At Limehouse, in Esquesing, there is a band of nine feet, which is wrought to a considerable extent, and yields a good hydraulic lime. At Rockwood also, a band of limestone three and a half feet thick, associated with a layer of chert, is said to yield a water-lime. The last two localities are in the Niagara formation, but are not supposed to be the equivalents of the Thorold stone.

In describing the Onondaga formation in the thirteenth chapter, it has been stated that many of the beds of argillaceous dolomite which are associated with the gypsum, yield a hydraulic cement; for which purpose they are largely used in the state of New York. Analyses of this dolomite from Oneida, and from Paris, are given on page 625. The calcined rock from the first locality gave to Delesse, lime 36·93, magnesia 26·74, clay 36·33; = 100·00. It heats very slightly when mixed with water, and yields a cement of good quality. The calcined material from Paris contained lime 53·82, magnesia 35·93, clay 10·25. A specimen from this formation, on the fourteenth lot of the second range of Brantford, yielded a cement which hardened under water in the course of five minutes. Similar beds are found at Point Douglas on Lake Huron; and it is probable that materials fit for the manufacture of water-cement may be found almost everywhere along the outcrop of the Onondaga formation. Oneida.

IX. GRINDING AND POLISHING MATERIALS.

Under this head will be noticed materials for two very different uses:—first, those employed in the construction of millstones for grinding grain; and second, those which are used for grinding, sharpening, cutting, and polishing metals and stones. Besides the various grindstones and whetstones, mention may also be made of garnet-rock, which from its hardness is sometimes used as a substitute for emery. Small beds of granular red garnet occur with the quartzites to the west of the crystalline limestone at St. Jerome, forming a band of four or five feet, which is divided by thin layers of quartz and of feldspar. Some of the beds consist of grains of hyacinth-red garnet, with small crystals of yellowish pyroxene; besides occasional grains of white-weathering greenish feldspar, scales of plumbago, and more rarely black grains, apparently of tourmaline; the garnet however greatly predominating. Strata of garnet-rock occur in similar conditions near the crystalline limestone in Rawdon, and also at the north-east side of Bay St. Paul, where beds, which run nearly east and west, are made up of red garnet with a little white quartz, and are interstratified with layers of micaceous schist. The whole band occupies a breadth of about sixty feet, of which the garnet-rock constitutes about one third. Garnet.

MILLSTONES.

The French buhrstone, which is preferred to all other materials for the construction of mills for grinding grain, is a peculiar chert-like silicious rock, having a porous or cellular texture, which renders its surface especially adapted for the purpose. Similar silicious rocks are found to some extent in several other parts of the world, and generally form beds in stratified rocks. In the Laurentian series in Canada however, a cellular

Millstones. chert of this kind occurs in large veins, apparently of aqueous origin, cutting the intrusive syenite of Grenville, and has been described on page 41. One of these veins appears on the first lot of the sixth range Grenville. of Grenville, running east and west. Another vein, parallel to it, has been traced across the southern part of the lot just mentioned, to the front of the second lot of the same range, and to the third of the fifth range. Its breadth is from four to seven feet, and it includes in some parts masses of the wall-rock. It is white, often banded with yellowish or reddish colors, Chert. which are parallel with the sides of the vein. The chert, which much resembles the French buhrstone in its characters, has been pronounced to be equally well fitted for the manufacture of millstones. The portions at the surface are however injured by the weather; and the difficulties of quarrying the material from a vein in the hard syenite are such, that it would probably prove more expensive than the imported buhrstone.

In various parts of the country, millstones, inferior to the French stones, but answering a very good purpose, are made from different hard silicious rocks. Along the north shore of the Ottawa, the reddish coarse grained Gneiss. Laurentian gneiss is often had recourse to; and the large boulders, which are abundant upon the surface, are found more convenient for working than the rock in its original beds; inasmuch as they require only to be split and dressed. At the Crooked Falls, on the Rivière des Aulnais, in the Saguenay district, a rock made up of red orthoclase and brown mica, has been successfully employed for millstones; and it appears probable that some of the crystalline lime-feldspar or labradorite rocks, which are so abundant in the Laurentian series, and are found in rolled masses along the valley of the St. Lawrence, might be used with advantage for the same purpose.

Many of the tough feldspathic rocks, and the quartzose conglomerates of the Eastern Townships, would doubtless make good millstones. A granitoid gneiss, which is found near the serpentine in St. Joseph on the Chaudière, furnishes a material of which millstones are made, that have been used in the vicinity for years, and pronounced to be of an excellent quality. The Potsdam formation in many places contains conglomerate beds adapted for Sandstone. millstones. In the parish of St. Cuthbert, a band of about eight feet, in beds of from one to two feet in thickness, has been used for this purpose, and found to answer well for grinding wheat. Similar conglomerates occur in this formation in the seigniory of Vaudreuil, both at the Cascades and the Pointe du Grand Detroit. From one of the layers at the latter place, millstones have been made; and it is probable that material suited for the purpose may be found in many other places along the outcrop of the Potsdam formation. Near White Cape at Murray Bay, good millstones have been made from beds of quartzose conglomerate, which there occur in the Trenton formation. The Oriskany sandstone from Oneida and Cayuga, described on page 360, is in some parts well fitted for a similar purpose; and good millstones for grinding oats and barley are manufactured from it at De Cewville in Cayuga.

GRINDSTONES AND WHETSTONES.

A sandstone well adapted for grindstones is found at Nottawasaga, in what is called the Grey band of the Clinton formation, and is here twenty feet in thickness. The stones, roughly hewn by hand, are sold in the vicinity at the same price as those imported from Ohio. This band is traceable along the outcrop of the formation for a great distance (page 316), and has been employed in many other places for grindstones. Coarse whetstones for scythes are also made of it; and a stone for the same purpose is obtained in Collingwood from the fine grained sandstones of the Hudson River formation. Sandstone beds belonging to the Chazy formation, which yield stones for sharpening axes and carpenters' tools, occur at several places on the Ottawa. Among these are Whetstone Point on the Chaudière Lake, Sheriff's Mills at the Chats, and the Allumette Falls. Common whetstones were also at one time manufactured from the fine grained micaceous schists of the Laurentian series, which are found on the fourth and fifth lots of the sixth range of Madoc (page 32). A finer stone, fitted for giving an edge to razors and delicate instruments, is found in many places among the greenish silicious slates of the lower part of the Huronian series (page 56). A locality of this kind occurs on Ottertail Lake on the Thessalon River. Grindstones Whetstones

In the Eastern Townships, a band of very fine grained micaceous rock has been traced from Whetstone Island in Memphramagog Lake, by Lee's Pond to the head of Massawippi Lake in Hatley, a distance of twelve miles; and yields in many places whetstones which are well fitted for most purposes. From a description published forty years since in the *American Journal of Science* (vol. v., page 406), it would seem that the material then obtained on Whetstone Island was so highly esteemed that a mill for cutting the stones had been erected on the shore of the lake; and that large quantities were annually prepared for exportation. Among them it is said were oil-stones equal to those of Turkey. Whetstones are also obtained on the fourth lot of the ninth range of Stanstead, on the twenty-third lot of the sixth range of Bolton, and on the seventh lot of the second range of Kingsey, where they were manufactured a few years since. There is a range of slates, fitted in some parts for this purpose, running on each side of the valley from Melbourne to Danville. A hone-stone of a very fine quality has been obtained from the slates near the serpentine, on the ninth lot of the eighteenth range of Orford (Crown Land Survey). Memphramagog.

X. BUILDING STONES.

Although Canada possesses in great abundance every kind of stone required for the purposes both of common and decorative architecture, but little has yet been done to bring these materials into notice. With the exception of the common limestones, the building materials of Canada have until recently been almost altogether neglected. It is proposed to notice in succession the principal materials of this class; including first, feldspathic rocks, such as granite, syenite, and gneiss; then sandstones, limestones, marbles, serpentines, flagstones, and roofing-slates.

GRANITE, SYENITE, AND GNEISS.

These three rocks may be considered together, inasmuch as they may be said to pass into each other. True granite and syenite are regarded as intrusive rocks; but there are varieties of stratified gneiss, which have the same mineralogical composition, and can only be distinguished by traces of a stratified structure, (pages 600 and 647). The most characteristic intrusive granites in Canada, are those which have been described on page 434 as cutting the upper slates and limestones of Eastern Canada. In the township of Stanstead, a mass of this granite covers an area of about six square miles; occupying the first six lots of the fourth, fifth, and sixth ranges, and of a part of the seventh range. It here cuts the limestones, which are also intersected by numerous dykes of the intrusive rock. This granite is a rather fine grained and uniform mixture of white orthoclase and white quartz, with a sparing amount of black mica, giving a light grey color to the mass. The rock is free from iron pyrites, and appears to be but little affected by the weather. It is capable of being easily split by wedges into blocks of almost any required size. This stone appears to compare favorably with the best granites of Great Britain and of New England. Although granite is more expensive to quarry and to dress than limestone, its superior beauty and durability cause it to be preferred for structures destined to be of a lasting nature; and it is only the remoteness of this beautiful granite from any line of transport, which has prevented its use in our cities. With the facilities now offered by railways, it is to be hoped that the granites of this eastern region will soon find their way into the Canadian markets.

Granite.

Stanstead.

Many other masses of granite similar to that of Stanstead are found in its vicinity. In the townships traversed by the Grând Trunk Railway may be mentioned the granite of Barnston, on the first lot of the ninth range, and also on the lots from seven to fifteen of the tenth and eleventh ranges. In Barford, a beautiful granite occurs on the first and second ranges, from the fifth to the ninth lot. It is also met with in the nineteenth and twen-

Barford.

tieth lots of the fourth and fifth ranges of Hereford; and in many localities around the lakes at the sources of the St. Francis and Megantic Rivers. Great Megantic Mountain is a mass of granite, which covers an area of twelve miles in the townships of Marston, Hampden, and Ditton; and Little Megantic Mountain, also of granite, occupies six square miles in Winslow.

In this connection may be mentioned the gneiss of St. Joseph on the Chaudière, whose application to the construction of millstones has already been noticed. This band of rock, which has a breadth of from fifty to sixty feet, and can scarcely be distinguished from a fine grained, rather quartzose granite, would make a good building material. A similar rock occurs on the fourth lot of the sixth range of Shipton, and consists of white quartz and orthoclase, with a little black mica, the quartz greatly predominating. This stone, which yields large massive blocks, was employed in the construction of the Grand Trunk Railway bridge across the Nicolet River. Gneiss.

Among the intrusive rocks of the Laurentian series, is a reddish syenite, which is noticed on page 39, and forms an intrusive mass having an area of about thirty-six miles among the Laurentian rocks in the townships of Grenville, Chatham, and Wentworth. It is composed chiefly of a deep flesh-red orthoclase feldspar, and a greenish-black cleavable hornblende. Small portions of a white feldspar, probably oligoclase, and of grey translucent quartz, are scattered through the rock; which is pretty uniform in its character, and generally reddish from a predominence of the orthoclase. To the eastern side of the mass however, in Chatham, a light colored feldspar prevails. This rock is in some localities traversed by two sets of parallel joints at right angles to each other, which much facilitate the quarrying of small blocks. In other places, these joints are far apart; but the rock splits with much regularity in any direction, by the aid of wedges. Blocks of a fine red variety of this syenite have been obtained from the second lot of the fifth range of Grenville. The porphyries, which are associated with this syenite, will be noticed in the next class. A very fine variety of syenite is obtained from Barrow Island in the St. Lawrence near Gananoque; and it is said to be common in numerous small islands from this nearly to Brockville. It differs from the last in containing but a small proportion of greenish hornblende. The quartz, which is more abundant than in the Grenville syenite, is somewhat bluish and opalescent; and this, with the rarity of the hornblende, gives to the rock a brighter red color, which is very agreeable to the eye, and resembles that of the red Aberdeen granite. Syenite. Grenville.

The gneiss of the Laurentian series is in many localities well fitted for building purposes; but, like the syenites, it occurs in districts removed from the towns, and has received but few applications. A greyish hornblendic gneiss has however been used in the construction of the reservoir for the Quebec water-works, near Jeune Lorette on the river St. Gneiss.

Charles. The rock, which occurs near by, splits and dresses well, and is easily obtained in blocks of large size. On the Batiscan River, near the site of the old iron-furnace, is a quarry of gneiss, which appears to have been once wrought, and which would afford an abundance of good blocks for building purposes. At Bay St. Paul, near the bridge across the Rivière des Mares, a fine grained greyish-white gneiss is found, which would make a good building stone. It splits readily into rectangular blocks, and can scarcely be distinguished from a true granite. A similar light grey granitic gneiss occurs on the Ottawa, on the first lot of the first range of Clarendon. Many other beds of a like quality, and others of reddish gneiss, often well fitted for building purposes, may be obtained in a great number of places along the north shore of the Ottawa. The Laurentian rocks in many parts near the line of the Rideau Canal, would probably afford similar materials. A fine red granite has been obtained by Dr. Wilson in Bathurst. The labradorite or anorthosite feldspar rocks, which are abundant in many parts of the Laurentian region, would make a strong and durable building material; but they are generally dark and sombre in color. A pale yellowish variety of this near Chicoutimi was observed to break with facility into great rectangular blocks.

The various intrusive rocks of the district of Montreal yield building materials of a coarse description. The mountains of Brome and of Shefford have already been described on page 656, as composed of a granitoid trachyte. This rock consists of crystalline grains of orthoclase, with small portions of mica and hornblende; and differs from granite in the absence of quartz; which not only adds to the hardness of the true granites, but seems to bind together the crystals of the feldspar. From the want of quartz, these trachytes of Brome and Shefford Mountains are more subject than granite to crumble from atmospheric influences; and their ruins form a coarse gravel, which makes up a large portion of the surface-soil in their vicinity. From the existence of regular joints, these rocks are readily divided into rectangular blocks, which may be found sufficiently durable for building purposes. They are of an agreeable greyish or yellowish tint, and much resemble granite. The rock from the southern side of Shefford Mountain appears to be finer grained, and firmer than in some other localities. The granitoid diorites of Yamaska, Belœil, and Mount Johnson, described on pages 663–665, would furnish also abundance of a strong coarse material for building purposes; and being situated in a region of soft shaly rocks, are of some local importance. The dolerites of Rougemont, Montarville, and Mount Royal, (pages 665–667,) are, for the most part, highly augitic, dark colored, and too subject to decay to furnish a good building material. In the vicinity of Montreal however some of the dykes of finer grained intrusive rocks, in great part trachytes and dolerites, are occasionally employed for coarse constructions; and they are also broken up

Trachyte.

Brome.

Shefford.

Diorite.

Dolerite.

for macadamizing roads, for which purpose they are much better fitted than the limestone that is often substituted for them.

SANDSTONES.

In describing the sandstones and the limestones which are capable of being employed for building purposes, it will be convenient to keep in view the geological classification hitherto followed, and to begin with the older formations. Without noticing the rocks of the Huronian series, and the newer strata of Lake Superior, both of which will doubtless, one day, yield abundance of sandstones fitted for building purposes, the rocks of the Potsdam **Potsdam.** formation may be noticed. This, in its distribution to the eastward of Kingston, furnishes in many places a fine white sandstone, which is often free from stains, and capable of yielding blocks of a pure quartzose sandstone of considerable size. It is a durable stone, which is not only capable of resisting the weather, but, unlike the limestone, is fire-proof, not being liable to crack by the effects of a high heat. The toughness and closeness of its grain, and its hardness, which is much greater than that of many of the sandstones hereafter to be noticed, constitute the objections to its use.

At Lyn, near Brockville, massive beds of a superior quality are **Lyn.** found, from which sandstone has been procured for the new Parliament buildings at Ottawa. The further distribution of this sandstone is given on page 91, and the succeeding pages. It is exposed over a wide area in the county of Beauharnois. The beds here are generally even, and of **Beauharnoi** very varying thicknesses. As they are readily separable, but little difficulty is found in quarrying the stone. The color is generally white or slightly yellowish or greyish; and the stone, although hard, may be smoothly dressed, and preserves its sharp edges. There is a quarry in the village of Beauharnois; and another on the one hundred and fifty-first lot of the second range of Williamstown, from the stone of which several houses have been erected. Very fine blocks of this sandstone have also been procured for building purposes on the eightieth lot of the second range of Hemmingford. This sandstone formation extends across the river, including Isle Perrot, and is found from the Cascades to Rigaud on the south side of the Ottawa, **Vaudreuil.** and also on the opposite side; passing by Lachute to St. Jerome. At Ste. Scholastique, the beds are fine grained, white, very even, and of varying thickness, some of them as much as two feet. Beds of the rock, suitable for building purposes, may be found in a great many localities throughout this area. Ascending the Ottawa, good massive sandstone occurs in the front of the Augmentation of Grenville, and also at Quin's Point in the seigniory of Petite Nation. This stone is also exposed on the twenty-sixth, **Nepean.** twenty-seventh, and twenty-eighth lots of the fifth and sixth ranges of Nepean; where a quarry has been opened, from which stone has been taken for the Parliament buildings at Ottawa. Good stone may also be obtained from the beds of this formation in Ramsay and in Pakenham. The distribution of the Potsdam formation on the north side of the St. Lawrence, is described on page 95. It affords in many places good material for building and for paving. The large blocks of sandstone which are used for lining furnaces, and are obtained from the St. Maurice on its right bank, at the foot of the Gabelle rapid, have been already mentioned.

St. Maurice.

Sillery.

The Sillery division of the Quebec group affords massive beds of a greyish-green sandstone, which consists chiefly of grains of translucent quartz in a greenish argillaceous cement. Small portions of feldspar are occasionally present, and a little mica between the beds. This stone is obtained in several places between Quebec and Cape Rouge. The beds are there massive, and dip to the south-south-east, at an angle of fifteen degrees. A thickness of about forty feet has been quarried. The upper beds of this are even, and split well, both with the layers and across them; but the lower portions are inferior in this respect. The stone has been used in the construction of many houses in and around Quebec, and in various parts of the walls of the fortress. It is however apt to exfoliate by the action of the weather, and to wear irregularly.

Chazy formation.

A band of sandstone is found in the Chazy formation, below the water-lime, whose distribution has been indicated on page 806. This sandstone from the vicinity of Hawkesbury, was used in the construction of the locks of the Grenville Canal; but it is inferior in quality to that which is met with farther west in the same formation, in the township of Pembroke. Here it is exposed on the river about four miles below the village, and farther up, on Allumette Island, where it is found on the fifth range of the township, from the forty-fourth to the forty-eighth lot. The sandstone here occupies a thickness of three or four feet in beds of from six to eighteen inches. It is of a warm grey tint, sometimes inclined to reddish; and being soft, is easily wrought and carved. It is however sufficiently tough to retain sharp angles; and it will make a very superior building stone, which may probably be found elsewhere in the distribution of the band. A soft fine grained greenish sandstone, which occurs at the base of the Trenton group, on Matchedash Bay on Lake Huron, has been described on page 192.

Pembroke.

Grey Band.

In Western Canada, a belt of sandstone strata, known as the Grey band, is traced, with some interruptions, from Queenston to Collingwood. Its distribution is described on pages 313–317. The thickness of this band of sandstone varies from ten to twenty feet or more; the separate beds being from a few inches to two or three feet. It is fine grained, compact, and sometimes nearly white in color, at other times light grey, occasionally with a greenish tinge; and it furnishes an excellent material for building purposes, for which it is largely used in many towns of Western Canada. University College at Toronto, and many other buildings both in that city and in

Hamilton, are constructed of this sandstone. It is extensively quarried for these purposes at Georgetown, in Esquesing on the Grand Trunk Railway; and also at Hamilton and in its vicinity, at Dundas and at Waterdown, where the band is ten or twelve feet thick. This sandstone is also quarried to a smaller extent at various localities along its outcrop. At Nottawasaga, the band attains a thickness of twenty feet; and is employed for the manufacture of grindstones and whetstones, as mentioned on page 809. The Oriskany sandstone of the Devonian series has been noticed on the same page as furnishing a material fitted for millstones. This rock furnishes in some parts of its distribution, massive beds of a fine grained white sandstone from one to three feet in thickness, which are well adapted for building, and are quarried for this purpose on the forty-eighth lot of the first range of North Cayuga.

Hamilton.

Oriskany formation.

The Gaspé sandstones would yield an abundance of good building material in many parts of their distribution. In Anticosti, on the north side of the island, there is a band of about fifty feet of sandstones, belonging to the summit of the Hudson River group, which is exposed for several miles along the coast near Cape James, and also at Table Head. The sandstones are greenish-grey, and often in massive beds, which are sometimes five feet in thickness and of a free grain well fitted for working. Immense blocks of this stone, which have fallen from the cliff, are seen on the beach at Cape James.

Anticosti.

LIMESTONES.

In describing the materials for the manufacture of lime, the principal facts as to the distribution of limestones have been briefly noticed; and it now remains to mention such localities as afford stones fit to be quarried for building purposes. It is customary to distinguish by the title of marbles, such limestones as are adapted for decoration; and under the present heading therefore, these will only be incidentally mentioned. The Laurentian limestone would yield in many localities materials adapted for building. The coarser grained varieties of it are often however subject to crumble by the action of the weather; but the finer and more compact ones are in many cases suitable for marbles, and will be noticed under that head. The crystalline limestone of Macnab, there to be described, has recently been employed by the Board of Works in the construction of a bridge across the Madawaska River.

Laurentian limestone.

The Calciferous formation, whose distribution has been described in the seventh chapter, consists for the most part of a bluish-grey crystalline magnesian limestone or dolomite, in many places marked by small geodes holding calc-spar, and more rarely sulphate of barytes, gypsum, and quartz. This rock is employed in some parts of the province for building purposes, and is a strong, durable material; but it soon becomes yellow by the action of the weather. It was extensively used in some of the locks of the Rideau Canal, and is employed for building purposes at Brockville and at Prescott. Near the former town, it is quarried on the second lot of the first range of Elizabethtown, and on some adjoining lots. Good quarries of it are also found both above and below the town of Prescott. The numerous exposures of this formation farther down the St. Lawrence, and upon the Ottawa, would furnish abundance of common building stone; but the limestones next to be noticed, are generally preferred.

Brockville.

The Lower Silurian limestones, comprising the Chazy formation and the overlying Trenton group with its subdivisions, form a great limestone belt, whose distribution has been already given in detail. The Chazy formation is unknown to the west of Kingston; but the limestone of the Trenton group forms numerous islands in Lake Huron, and is traced from Nottawasaga, by Lake Simcoe, to the shore of Lake Ontario; where it appears near Oshawa, and at Bowmanville has been quarried for the purposes of the Grand Trunk Railway. Thence downward to Kingston, the Trenton limestones underlie the whole of the lake shore and of the peninsula of Prince Edward, extending back for a considerable distance. The lock on the Otonabee Canal is constructed of massive beds of limestone, from the lower part of the Trenton group, which was quarried near Warsaw, in Dummer; and good beds of similar stone are to be obtained in many other places in this region. The upper beds of this group are usually too thin, shaly, and irregular to be employed with advantage for building purposes: and hence it is that although standing upon limestone, the houses of Cobourg, Trent, and Belleville are in great part of brick. The limestone of which Kingston is chiefly built, is taken from beds which are supposed to belong to the base of the Trenton group. This material, although affording good blocks, is fine grained and compact, with a conchoidal fracture, and has the defect of brittleness. In descending the St. Lawrence, these limestones afford excellent building material in the township of Cornwall, where quarries have been opened on the fifth and sixth lots of the second range. Here are exposed two compact beds of black limestone, each from three to five feet in thickness, which were used in constructing the locks of the Cornwall Canal. Near Mille Roches in the same township, is another quarry of similar stone; and good beds of black limestone are wrought in the townships of Winchester, Finch, Charlottenburg, and Lancaster. These black beds are overlaid in some places by grey limestones, which furnish good building material in the township of Kenyon, and in Lochiel.

Bowmanville.

Kingston.

Cornwall.

Beds yielding fine blocks of limestone are found both in West and East Hawkesbury. Stone from the latter was employed in building the Carillon Canal. On the north side of the Ottawa, in Grenville and Carillon, a bed of limestone, two or three feet in thickness, is quarried in several places for building purposes. This limestone, which, like that of Hawkesbury, belongs to the Chazy formation, lies below the sandstones of this region, already noticed. Farther to the westward, in the vicinity of Ottawa, the Gloucester quarries, which furnish the stone chiefly used in that city, yield a grey granular stone; which, like that of Montreal, belongs to the lower part of the Trenton formation. The beds here vary from three to twenty inches, and the price of good blocks of stone at the quarries is said to be about twenty cents the cubic foot. At the Hogsback lock, on the Rideau Canal, quarries are opened in a limestone which is somewhat lower in the series, and belongs to the Birdseye and Black River formation. At this place there are said to be two solid beds, one two feet, and the other two feet eight inches in thickness. Ottawa.

The Chazy formation at Grande Isle in the St. Lawrence, near the head of the Beauharnois Canal, affords a strong bluish-grey limestone in beds of about two feet thick, which were quarried for the locks of the canal. Large quantities of stone for this purpose, and also for the upper locks of the Lachine Canal, were obtained from Caughnawaga, where massive beds of the same formation, grey in color, with red spots, furnish an excellent building stone. This limestone crosses the west end of the island of Montreal, and is exposed at Ste. Geneviève, where it yields very fine blocks; and on Isle Bizard, where it was quarried for the Carillon Canal. The formation is also exposed in a quarry at La Chapelle's bridge, and again near Montreal. Grande Isle. Caughnawaga. Isle Bizard.

The stone quarried at Pointe Claire, which is black, compact, and in massive beds, belongs, like the similar stone of Cornwall, to the lower portion of the Trenton group. At this quarry there is an exposure of about thirty feet of solid beds, varying from one to three feet in thickness. From these were obtained the stone for the piers of the western half of the Victoria Bridge. The blocks quarried for this purpose weighed from four to seven tons each. The stone for the eastern half of the bridge was brought from Isle la Motte, in Lake Champlain, and from beds which are said to be in the same stratigraphical position as those of Pointe Claire. Pointe Claire.

The chief part of the limestone quarried in the immediate vicinity of the city of Montreal, is derived from the grey beds which are near the base of the Trenton formation, but overlie the black beds of Pointe Claire. These latter belong to that division of the Trenton group which is known as the Birdseye and Black River formation. This grey band has a thickness of from eight to twelve feet, and is made up of beds which vary from three to eighteen inches. In tracing the individual beds from one quarry to another, they are found to vary in thickness; one of them occasionally dividing into two or more, or several thin layers uniting into one solid bed. The trap dykes which intersect this limestone are noticed on page 143. Montreal.

These grey beds consist in great part of the remains of crinoids and cystideans; and it is the crystalline texture of these organic remains which gives a granular structure to the rock. The grey limestone is overlaid by black nodular beds, which are accompanied by shales of the same color; and a layer of black limestone is also interstratified with the grey beds. These black portions are used for inferior constructions, or for burning into lime.

Black beds.

There are four principal quarries in this band near the city; and from these are derived the stone used in the best buildings in Montreal. The still lower grey beds, belonging to the Chazy formation, which have just been noticed as occurring at the quarries of St. Geneviève and Isle Bizard, are exposed near Montreal, in a range running parallel with the last, and about three quarters of a mile to the westward. This stone has also a granular texture, due to the great quantity of organic remains which it contains. It is less uniform in color than the higher strata nearer the city, and is liable to become yellow by the action of the weather; but the beds yield large and solid blocks, which have been extensively employed for the quays and canal-docks of Montreal. Numerous quarries are opened in this stone near the Mile-End toll-bar, and thence along the road to Sault au Recollet; where they show in many places beds of from one to two feet thick of good grey stone.

The quantity of limestone annually taken from these quarries in the immediate vicinity of Montreal is very considerable. For the year 1861, it was as follows:

313,200 cubic feet of cut stone..............	28,600	tons.
5,252 toises of rubble....................	63,024	"
	91,624	"

A French toise of stone is equal to 9·68 cubic yards English. The average price in Montreal of good stone from these quarries, was in 1861 as follows:

Undressed ashler...............................	$0·13¼	per	square	foot.
Dressed "	0·30	"	"	"
Heavy rough blocks (from six to thirty cubic feet)..	0·60	"	cubic	"
" " (of sixty cubic feet)..........	1·00	"	"	"
Mouldings; average	0·45	"	square	"
Fluted columns of 18 inches diameter; for the stone,	1·00	"	rising	"
" " " " for cutting,.	2·50	"	"	"

The Chazy formation yields excellent grey granular stone on Isle Jesus, a mile and a half south of Terrebonne; where two beds, each of five feet thick, were wrought for the construction of the lower locks of the Lachine Canal at Montreal. Massive beds of the same formation are quarried in Lachenaye, near St. Lin; where some portions of it are of a red color, and

St. Lin.

yield a good marble. At Industry, near the upper bridge, it presents good grey limestone, in beds of two or three feet thick. Near this, the higher grey beds of the Trenton formation are quarried, and were employed for the railway bridge at this place. Similar beds, near the Dalles on the Naquareau River, give a good building stone. **Industry.**

Farther down the St. Lawrence, the limestones, which form a broad belt along the north shore, are generally covered by the superficial deposits as far as the Grondines. Here a large amount of stone fitted for lime-burning, and for ordinary building purposes, is exposed. In the fourth range of the seigniory of La Chevrotière, and three or four miles from the St. Lawrence, grey beds of the Trenton formation yield an excellent building material, which is much used at Quebec, where it is known as the Deschambault stone. The beds which are here wrought are nearly horizontal, and are three in number. The upper and lower ones have each a thickness of eighteen inches, while the middle one is three feet, and the bed underlying these is said to be four feet in thickness. This stone has a yellower tint than that of Montreal, and does not become discolored by the weather; it is also more granular, softer, and more easily wrought; but does not preserve such sharp angles as the Montreal stone, nor receive as good a surface by what is called picking. In the rear of the same seigniory, a somewhat similar stone, in thinner beds, occurs at the St. Olivier bridge on the Ste. Anne. In the first range, stone was obtained for the constructions on the Quebec and Richmond Railway: the blocks are massive, but are penetrated by thin shaly layers and patches, which injure the aspect of the stone after exposure to the weather. At Pointe aux Trembles, near Quebec, are massive beds, which furnish large blocks of a harder and less granular grey limestone, more resembling the Trenton beds at Montreal. This stone is quarried for the Quebec market. In the continuation of the limestone band thence to Beauport and Montmorenci, great quantities of stone fit for lime-burning, and for common building purposes, are met with. At Château Richer also there are several quarries, from which large quantities of limestone are obtained for building in Quebec; but the best stone for the use of this city is brought from La Chevrotière and Pointe aux Trembles. **Chevrotière.** **Beauport.**

The dark grey limestones of this formation at Bay St. Paul and Murray Bay afford a serviceable building material. At the latter place, the arenaceous limestones noticed on page 162, furnish beds from eight to sixteen inches in thickness, of a light grey stone, which becomes yellowish when exposed to the air. The strata dip to the northeast at an angle of about fourteen degrees. They are easily wrought and dressed, and have been used in the construction of the church and several other buildings at Murray Bay. The Lower Silurian limestones about Lake St. John afford, near the mouth of the Metabechouan River, massive granular beds, fit for building purposes. The thick beds of yellowish-white granular lime- **Murray Bay.** **Saguenay.**

stone at the Mingan Islands, noticed on page 134, would afford a superior building material. At Southwest Point in Anticosti, the yellowish-white limestone, mentioned on page 304, yields large blocks, which are easily dressed, and have been employed in the construction of lighthouses there and at Heath Point.

Anticosti.

It has been shown on pages 205 and 273, that what is called the Deschambault anticlinal brings to the surface, a little to the east of the Yamaska River, a narrow band of the Lower Silurian limestones. Along this line, at the St. Dominique quarries, a thickness of thirty or forty feet, exhibiting many massive beds, is quarried. Like the limestones of Ste. Geneviève and Caughnawaga, it belongs to the Chazy formation, but it is darker colored and more compact. It is used for building at St. Hyacinth, and was employed in the constructions of the St. Lawrence and Atlantic Railway. The superior lime obtained from this band at Ste. Rosalie has already been noticed. To the southward, what appears to be a continuation of this anticlinal exposes the limestones at Highgate Springs, in Vermont; and a dislocation a little to the eastward brings up those of Phillipsburg. At the latter place the band is nearly two miles wide, and dips with a gentle angle to the southeastward. The rock here, unlike that near St. Hyacinth, is somewhat crystalline, apparently from a commencement of metamorphism, and near the base is mixed with small veins and patches of white quartz. Higher in the series, massive beds occur, some of which would furnish a good building material. Its color varies from nearly white or light grey, to dark grey or black; some of the beds being banded or mottled with different colors.

St. Dominique.

Phillipsburg.

In Western Canada, a band of limestones not less extensive than that whose distribution through the eastern part of the province has just been described, is traced from the Niagara River northwestward to Lake Huron. It includes the Niagara and Guelph formations, already described in the twelfth chapter, and yields excellent building stone in many parts of its distribution. Unlike most of the Lower Silurian limestones, this band is almost everwhere magnesian, and generally has the composition of a true dolomite. Great quantities of excellent building material are obtained from this series in various parts along its outcrop. Near Niagara Falls it has been quarried for the construction of the piers of the Suspension bridge, and large quantities of good stone are obtained at Thorold, (page 328). Quarries are also opened in it at Galt, Hespeler, Puslinch, and many other places. The quarries at Guelph are in the Guelph formation, and show a thickness of about fifteen feet of workable beds, which range from a few inches to three feet. The stone, which is easily worked, and is of a superior kind for building purposes, has been extensively used in the town of Guelph. These dolomites are frequently somewhat cellular, but are strongly coherent. They have been described on page 624.

Niagara Falls.

Guelph.

At Rockwood in Eramosa, there is an exposure of more than 100 feet of crystalline dolomite belonging to the Niagara formation, in beds varying from a few inches to ten feet in thickness. Of these, about thirty feet are nearly white, the remainder being of a light grey. This stone, which does not become discolored by exposure, has been used for the piers of the railway viaduct over the Eramosa River. At Owen Sound, a similar exposure of this formation occurs, and is capable of furnishing a great supply of blocks of any required size of a light yellowish-grey stone, which resists the action of the weather, and does not become discolored. The quarries are about half a mile from the harbor; and the stone has been used for building purposes in the town of Owen Sound, and for the construction of several lighthouses along the shore of Lake Huron. Rockwood Owen Sound.

The Onondaga or gypsiferous formation, which overlies the preceding rocks, consists chiefly of a dolomite, which is generally too thin-bedded for building purposes. On the fourth lot of the second range of Brant however, at the Oxbow on the Saugeen River, it presents several thick beds of a very fine-grained yellowish-grey dolomite, which appears to be well fitted for architectural purposes. It is free from stains, may be split with regularity, and works with facility; when fresh from the quarry, it may be cut with a saw, but soon hardens on exposure. Two bands of this stone, each of about ten feet in thickness, occur in this formation. The higher one, which is at its summit, is here exposed at the surface, and offers facilities for quarrying. It is made up of massive beds, some of them two feet in thickness; and a bed of three feet occurs in the lower band. Beneath the upper band is a bed of light grey oolitic rock, seventeen inches in thickness, which has been used with advantage in the neighborhood for supporting the axles of mill-wheels. Brant.

The pure limestones of the Corniferous formation, in various parts of their distribution, yield a stone which is well fitted for building purposes, and is quarried in many places along its outcrop, as at St. Marys and at Goderich. At Malden, near Amherstburg, the limestone is more granular than to the eastward, and is of a whitish or a buff color. The beds, which are here from one to two feet in thickness, are extensively quarried for building, and the stone is carried to considerable distances. In some parts of this formation, the limestone becomes so much mingled with chert as to be unsuited for building, and the cherty portions are then employed with advantage for macadamizing roads. Malden.

MARBLES AND SERPENTINES.

The name of marble is applied to those varieties of limestone which, from their fineness of texture and color, and from their susceptibility of polish, are proper for decorative architecture, or for sculpture. Marbles may consist either of pure or of magnesian carbonate of lime. The presence of foreign minerals generally renders a limestone unfit for use as a marble; but serpentine, which does not differ much from carbonate of lime in hardness, is often intermingled with it, and gives rise to some fine varieties of marble. This mineral may greatly predominate over the limestone, or even exclude it altogether; thus giving rise to serpentine rock, or ophiolite, which through these admixtures passes into the marbles proper. As all of these have about the same hardness, and are employed for similar uses, they are not unfrequently confounded under the technical name of marble. For convenience therefore, the serpentine-marbles and serpentines will be noticed in connection with the true marbles of the province.

Serpentine.

But little use has yet been made of these various materials in Canada; and with the exception of three or four cases which will be mentioned, the only trials as yet made of the marbles and serpentines of the province, have been by the Geological Survey; who have selected from various localities, blocks which have been cut and polished. These being from the surface of the rocks, are frequently more or less affected by the weather, and give but imperfect representations of the capabilities of the material. In this way however have been obtained the collection of marbles in the Geological Museum, and those which were sent to the Great Exhibitions of 1851, 1855, and 1862. The great variety of these, and the beauty of many of them, attracted particular attention on these occasions; and the collection of Canadian marbles was especially commended in the Report of the Paris Exhibition. It is proposed to notice first the marbles and serpentines of the Laurentian series, then those of the Quebec group, and finally the marbles of the more recent Silurian strata.

Laurentian series.

The crystalline limestones of the Laurentian series yield in many cases a strong white marble, which, although not generally fine enough for statuary, is well fitted for purposes of decoration. Among the localities on the Ottawa may be mentioned the Calumet Falls, Portage du Fort, and Fitzroy Harbor; which last has been employed for the Parliament buildings at Ottawa. Portions of the Portage du Fort marble are of a tolerably fine grain, pure white in color, and of a quality well fitted for all purposes but that of statuary. Near Beverley, in the township of Bastard, beds of this limestone are wrought as a marble for tombstones. It is strongly coherent, but greyish-white in color, and contains small spangles of mica and of graphite. Similar marbles may be found among the limestones on the north side of Charleston Lake, and in many other parts of this region; but where they have the requisite strength and fineness of grain, they are often mixed with small portions of foreign minerals, generally quartz, pyroxene, hornblende, or mica. In the township of Madoc, on the thirteenth lot, and near the road between the seventh and eighth ranges, is a band of a fine-grained yellowish-white magnesian limestone, which would apparently yield a marble. Large blocks of

Portage du Fort.

Bastard.

a very good white marble have also been obtained from the adjoining townships of Elzivir and Marmora: that from the latter place is extremely pure, white, and compact. Marmora.

A fine white marble is found in the township of Barrie, where the Laurentian limestones are said to be extensively developed on the twenty-seventh, twenty-eighth, and twenty-ninth lots of the ninth and tenth ranges. Blocks of considerable size have been brought from this locality, and show a fineness of grain and a strength equal to the best foreign statuary marbles. Grains and spots of tremolite, and more rarely of quartz, are however disseminated through this marble, and detract from its value. Specimens of an equally fine grained marble from the same locality, have a uniform pink or rose tint, and others are of a dove-grey color. Besides these, variegated marbles of blue and white, and of purple and brown colors are said to be found here, which appear to be more free from foreign minerals, and may probably yield abundance of colored marbles for the purposes of interior decoration. Barrie.

At the mouth of the Madawaska in MacNab, on the Ottawa, there is a great extent of crystalline limestone, which is colored of a bluish-grey, apparently from an admixture of plumbago. This color is irregularly distributed, some portions being nearly black, and others almost white, so that the rock often presents a striped or barred appearance. In many cases however the beds are very much corrugated, and sections of it exhibit curious complicated patterns like the grain of certain woods; the white, bluish-grey, and black colors being so arranged as to give very pleasing effects. Different portions of the marble vary in the size and arrangement of the colored bands; and their aspect changes as it is cut with or across the beds. The stone is somewhat coarse grained, and contains a little tremolite; but it takes a good polish, and is obtained in large blocks, which are easily wrought. A mill has been erected in the vicinity, at Arnprior, for the purpose of sawing and polishing this stone, which is known as the Arnprior marble, and has begun to be employed both for interior decoration, and for funeral monuments; for which last, by its color, it is well adapted. The price of the marble delivered in Ottawa, is stated to be \$1·50 the cubic foot; or sawn into slabs, \$0·45 the square foot. Arnprior.

The serpentine which is mingled with the crystalline limestones of the Laurentian series in many parts of their distribution, gives rise to varieties of marble in which grains or small masses of the serpentine are disseminated through a white crystalline base, with a banded arrangement which marks the stratification of the rock. The serpentine is generally of some shade of olive-green or oil-green, but is occasionally of a sulphur-yellow color. Specimens of these marbles may be obtained in many parts of Grenville, and of its Augmentation. On the sixteenth lot of the third range of Grenville, a mill was some years since erected at the fall of the Calumet Serpentine-marbles. Grenville.

River, for the purpose of sawing a marble of this kind. The limestone strata here dip to the northwest at a high angle, and are overlaid by a micaceous gneiss, which holds garnets. A dyke of dolerite, several feet in thickness, cuts the strata; and a thin layer of greenish translucent serpentine, half an inch or more in thickness, sometimes with a fibrous coating, occurs bounding the trap on each side of the dyke, as if filling up a space left between the intrusive rock and the limestone. A description and an analysis of this serpentine, to which the name of retinalite was given by Dr. Thompson, will be found on page 471. On the eighteenth lot of the first range of Wentworth, a similar limestone, mixed with smaller grains of serpentine than the last, is met with, and would yield a more pleasing variety of marble.

Wentworth.

On the thirteenth lot of the fifth range of Grenville, a massive serpentine is associated with the pyrallolite already described on page 789. This serpentine, from which slabs of considerable size have been cut, is of a pale green color, marked with spots and clouds of a rich red-brown color, due to disseminated peroxyd of iron, and forms a fine ornamental stone. A similar pale green serpentine, marked with red, has been found by Dr. Wilson, in Burgess. An analysis of this, and of some others of these ophiolitic rocks, will be found on page 591.

Serpentine.

Serpentines are still more abundant among the crystalline portions of the Quebec group, where they constitute great rock masses; which have already been described, with numerous analyses, under the name of ophiolites, on pages 608–612. They are generally darker colored, tougher, and better fitted for ornamental purposes than those of the Laurentian series. The distribution of these rocks in Eastern Canada has been given in detail in the eleventh chapter. It may be said that they are almost everywhere found as a part of the magnesian band in the second and third synclinals of the Quebec group (page 710). Among these ophiolites are many which are well fitted for ornamental purposes. These are chiefly mixtures of limestone or of dolomite with serpentine; the latter mineral generally predominating. No attempt has as yet been made to work these serpentine-marbles; and it will for the present be sufficient to mention those localities from which blocks available for ornamental purposes have been obtained by the Geological Survey.

Quebec group.

Melbourne.

In the township of Melbourne, a band of serpentine has been traced for about four miles on the fifth and sixth ranges, and it attains in one place a breadth of a mile. In this part, on the twenty-second lot of the sixth range, some beds of the rock assume the character of a very calcareous conglomerate, the pebbles of which are arranged in such a way as to mark the stratification of the rock. Other portions are apparently homogenous in texture, and are dark green, banded or chequered with lighter green lines. A very beautiful variety which is found here has a dark or blackish-green ground, through which small and more or less angular spots of a much lighter green are equally distributed, giving to the rock the aspect of a porphyry. Blocks of this a foot or more in diameter have been obtained entirely free from flaws, and receiving a fine polish. A paler green serpentine occurs on the twentieth lot of the fifth range; and near the middle of the band is a dark green variety veined with red, which resembles somewhat the Cornish serpentines.

Orford. In the township of Orford, fine blocks of serpentine have been obtained from the twelfth lot of the eighteenth range. Some portions of this have the aspect of a breccia of dark green serpentine in a lighter green paste of magnesian carbonate of lime; while others, which are more homogenous, and resemble one of the varieties from Melbourne, have a dark green base, with veins of paler green. Large slabs have been obtained from this quarry, and columns of three feet in length and a foot in diameter. The rock is solid, free from flaws, and susceptible of a fine polish.

St. Joseph. The serpentine of St. Joseph on the Chaudière, has also furnished fine masses of a brecciated or conglomerate green serpentine veined with white. **Mount Albert.** At Mount Albert in Gaspé, the serpentines, which are there associated with chloritic, epidotic, and hornblendic slates, and which have been described on page 266, cover an area of no less than ten square miles. Much of the serpentine is distinctly stratified, and is often striped with red and brown colors. There is little doubt that both here and in many other localities throughout this region, fine varieties, well fitted for ornamental purposes, may be obtained in any quantity required. The serpentines of Roxbury and Cavendish in Vermont, which are found in a continuation of the formation of Eastern Canada, have been extensively wrought and sold under the name of verd-antique marble. **Verd antique.** They resemble the verd-antique found in ancient Roman ruins, the original locality of which is unknown. It is a mixture of serpentine with limestone or dolomite, similar in composition and in aspect to many of the serpentine rocks of Vermont and of Eastern Canada. Much difficulty was at first met with in giving a fine polish to the Vermont serpentines: but a substance for **Polishing serpentine.** the purpose was at length discovered in the actinolite which often accompanies them. This mineral is reduced to an impalpable powder by grinding and mixing with water. In this way the coarser material is separated rom the finer portions, which remain for a long time suspended, but are at length deposited as a fine paste of actinolite, which is found to be much superior to any other substance for polishing serpentine. A bed o' actinolite rock which occurs in Bolton, and has been noticed on page 797, would probably furnish an ample supply for this purpose.

Serpentines similar to those of the Eastern Townships are extensively wrought in Italy, France, and England, and are employed for tables, chimney-pieces, columns, and the decoration of churches. The price of blocks of the fine varieties of French and Italian serpentine in Paris was in 1855 from \$3·00 to \$5·50 the cubic foot, and that of polished slabs from \$0·60 to \$0·70 the square foot. The serpentine of the Lizards in Cornwall is still more esteemed, and is now extensively wrought at Penzance; where it is not only made into tables and chimney-pieces, but is turned into vases, candlesticks, and many other articles of use and elegance. In this serpentine the green color is beautifully blended with red, which is often very brilliant. This material is very durable when not exposed to the weather, as may be seen in tombs made of serpentine from Cornwall, more than 150 years old, in Westminster Abbey. Rain and frost however slowly destroy its polish. The price of blocks of undressed Cornish serpentine was stated in 1855 to be from five pounds to ten pounds sterling the ton, according to its quality; and that of polished slabs an inch in thickness, from eight to twelve shillings the square foot.

Cornish serpentine.

Red marble.

St. Joseph.

The Quebec group presents a red limestone associated with red shales, near the river Guillaume, at St. Joseph on the Chaudière. Polished slabs of this limestone have a color approaching to brick-red, with dark brown and black spots, apparently from imbedded pebbles, the whole traversed by numerous small veins of white calc-spar. The rock is somewhat argillaceous, and does not receive a fine polish. The limestones near Phillipsburg in St. Armand, already mentioned (page 820), afford several varieties of fine-grained marble, some of which is white, and takes a good polish, although seldom very pure in tint. It is not unfrequently clouded with pale greyish-green: a dove-grey variety with white spots, is also met with here. Not far from this locality, and about a mile and a half to the southeast of Phillipsburg, a very good black marble was at one time quarried. The beds dip to the eastward at an angle of about twelve degrees, and some of them are of considerable thickness.

St. Armand.

The Chazy and Trenton limestones afford in many places beds of a fine texture, which receive a good polish, and are capable of being employed as marbles. At Caughnawaga some of the beds are grey, with an abundance of small shells which are dark brown in color, and of other shells and corals of a bright pink or rose-red. The stone takes a fair polish, and yields a pleasing marble. The quarries in the same formation at Ste. Geneviève, Isle Bizard, and Montreal, afford a similar stone, with red spots; and at St. Lin the whole rock becomes of a dull red color, in which the fossils appear of a brighter red tint. The limestone of the same formation at St. Dominique is of a dove-grey, with spots or clouds of white. It is solid, easily wrought, and takes an extremely fine polish. Similar beds belonging to this formation on Esquimaux Island, in the Mingan group, would yield abundance of fine-grained drab colored marble.

Caughnawaga.

St. Lin.

St. Dominique.

The black strata of the lower part of the Trenton group, already mentioned, afford in many places a good black marble. Two beds, each of about two feet in thickness, are found at Cornwall and at Pointe Claire, the lower one of which is the better fitted for cutting and polishing. The black marble of Pointe Claire has often a brownish or greenish hue when polished. Near the same geological horizon, in the township of Pakenham, a chocolate-brown or wood-brown limestone occurs, which is fine grained, and takes a good polish. It occasionally contains fragments of chert, which renders it necessary to employ care in the selection of the stone. A mill was at one time established in the vicinity, for the purpose of working this brown marble. Grey beds of the Chazy formation, thickly marked by small bivalve shells filled with white calc-spar, have been wrought to a small extent near L'Orignal; but the stone is not well fitted for a marble, inasmuch as the shells are readily detached from the rock. The parti-colored limestone beds found in Seymour (page 187), and at the base of the Trenton outliers in Marmora, and in Madoc, yield a fine-grained grey marble thickly mottled with red and yellow colors.

Cornwall.

Pakenham.

The grey limestones, both of the Chazy and Trenton formations, from the vicinity of Montreal, are sometimes cut and polished as marbles. They are however of a dull grey color, and take but an indifferent polish. Similar material has also been obtained from Terrebonne and from Gloucester. The marbles of Caughnawaga, St. Lin, St. Dominique, and St. Armand are much better fitted for the ordinary purposes of decoration; and as they are abundant and easily wrought, they might be furnished at prices which would lead to their general adoption.

Montreal.

In Dudswell, on the twenty-second lot of the seventh range, the beds of the somewhat altered limestones, probably of Devonian age, afford a great variety of marbles. Some of these are cream colored, with ochre-yellow veins; others present a kind of breccia of dark grey and yellow colors; and others still are black. In some specimens obtained from this locality, a nearly black ground is traversed by veins of an ochre-yellow, giving rise to a variety strongly resembling the Portor marble from northern Italy, which is commonly known as black and gold. A more detailed description, with analyses of these limestones, is given on page 617. They have never yet been wrought; but it appears probable, from the trials which have been made by the Survey upon a few blocks from this locality, that it may furnish several fine varieties of colored marble.

Dudswell.

FLAGSTONES.

Many of the stratified rocks already mentioned under the head of building stones and marbles afford thin beds which are well fitted for floors, hearths, sidewalks, and street-crossings. As yet however but little attention has been given to these materials in Canada. Brick and wood are very generally used in our towns; and in some cases flagging-stones have been imported from the state of New York, and even from Great Britain, Flagstones. although abundance of good material of the kind may be found in various parts of the province. The more micaceous parts of the Laurentian gneiss afford in various localities thin beds adapted for paving. Such may be found in Horton and Clarendon on the Ottawa, and in Bagot at Calabogie Falls on the Madawaska. In ascending Lake Temiscaming, about seven miles above the Galère, the cliffs, which extend for about five miles on the right-hand side, present great quantities of thin even-bedded micaceous gneiss, which would yield good flagstones of large sizes. In many places along the north side of the Ottawa, and of the St. Lawrence, similar stones, two or three inches in thickness, and of large size, may be obtained. Among other localities may be mentioned the flank of the hills between the Batiscan and Charest Rivers, and a similar rock at the St. Joachim Falls on the Ste. Anne (Montmorenci).

Laurentian gneiss.

Among the crystalline rocks of the Eastern Townships, the mica slates of Sutton Mountain will doubtless afford, in some parts, good flagstones. They are seen in several places along the south road across the mountain, especially on the nineteenth lot of the second range of Sutton. It is probable that farther research in this region will discover other localities. On the fifth lot of the second range of Inverness, is a band of greyish-green talcoid silicious slate, which has been quarried to a small extent. It splits with facility into very even slabs of three inches in thickness, which may be obtained as large as seven by four feet. The higher rocks on the west side of Memphramagog Lake, at Potton Ferry, and on the east side for some miles above the Outlet, afford beds of a greyish-brown somewhat calcareous sandstone, which splits readily into slabs, some of them as thin as two inches. These may be obtained of almost any required size, up to six feet by three, and often ten feet by five. The slabs are very regular in thickness, but their surfaces are somewhat rough, and would require a little dressing. Great quantities of these stones might be easily obtained along the lake shore. In the township of Dudswell, on the sixth range, to the east of the Quebec road, is a series of thin grey limestone beds, which might be employed for flagging. The rock, which is crystalline, separates readily into plates of two or three inches thick, which receive a polish, and are used in the vicinity for tombstones. Similar beds may be looked for in other parts of the distribution of these limestones.

Sutton.

Memphramagog.

Dudswell.

On both sides of the Rivière du Loup for some miles above its junction with the Chaudière, beds of fine-grained dark bluish-grey sandstones are met with, some of which divide with the bedding into layers sufficiently thin for roofing slates; while others would yield excellent flagstones, which may be obtained five or six feet long, by two or three feet wide, and not more than an inch in thickness. Similar flagstones and slates are met with on the eighteenth lot of the third range of Tring, and the twenty-ninth lot of the fifth range of Brompton. The rocks of the Gaspé series furnish in many places thin-bedded sandstones fitted for flagging.

The Potsdam formation in many parts of its outcrop yields thin-bedded sandstones, which are generally very hard and strong, and well fitted for flagging. On the twelfth lot of the ninth range of Storrington, the beds in a bank by the roadside are very regular, and some of them would furnish slabs of a large size, and from one to two inches in thickness. Similar thin beds of this sandstone are found at Grindstone Point at the north end of Knowlton Lake, and also on Eel Lake in an outlying portion of the formation on the eleventh lot of the ninth range of Loughborough. In Hemmingford, on the eighteenth lot of the second range, to the east of Covey Hill, the same sandstone presents beds of from two to four inches, which are fit for flagging. To the west of the same hill, on the Outarde River, are also thin layers of sandstone; interstratified however with thick massive beds. Flagstones of from one to three inches in thickness may be obtained here; but the stone is brittle, and apt to break into irregular shapes. It is inferior to that from Malone in New York, which is much esteemed for flagging purposes, and is imported into Canada. It may be expected that beds of sandstone equal to those of Malone may yet be found in that vicinity. Potsdam sandstone. Storrington. Hemmingford.

On the Naquareau River, just below Mr. Dorwin's saw-mill, and near the southeast limit of Rawdon, about four feet of white sandstone belonging to the Potsdam formation appear well fitted for flagging. The stone divides into layers of two or three inches, and slabs of large size could probably be obtained. In the same formation, on Cote Ste. Catherine, in the parish of St. Cuthbert, about four and a half feet of similar sandstones are met with. They are quarried for use in the vicinity, and slabs two or three inches in thickness may be obtained seven feet in length by three or four in breadth. The sandstone at the Grès, on the St. Maurice, already mentioned as furnishing materials for furnace linings, and for building purposes, (page 799,) presents a thickness of about eleven feet of thin white beds fit for flagging. Rawdon. St. Cuthbert.

The limestone of the Trenton group furnishes in a great many places thin beds, which are extensively used for flagging and paving in many of the towns along the line of its distribution. At Cap Santé, regular calcareous beds, two or three inches in thickness, are interstratified with the black shales of the Utica formation, and are used in the vicinity for hearths, window-sills, and similar purposes, but are traversed by joints which render them liable to break. These beds are well exposed at Pointe à l'Abri. The thinner beds of the calcareous sandstone of Murray Bay (page 819) would probably furnish a good material for flagstones. Trenton limestone. Cap Santé.

In Western Canada the Hudson River group furnishes thin-bedded sandstones fitted for flagging, which are exposed on the banks of the rivers falling into Lake Ontario in the vicinity of Toronto, and in other parts of its distribution farther west. The grey band of the Clinton for- Toronto.

mation (page 316) affords along its outcrop thin beds of sandstone, which are well fitted for flagging, and are extensively used for that purpose in Toronto and in Hamilton.

ROOFING SLATES.

The complete absence from the rocks of the Laurentian series of anything like argillite or clay slate, has already been mentioned. The Huronian rocks however occasionally present strata approaching to argillite in character, but seldom fitted for the purpose of roofing slates. Specimens, said to be found about five miles up the Montreal River, a tributary of Lake Temiscaming, are firm and strong, but are more than a quarter of an inch in thickness, and do not seem capable of being split thinner. Among the Upper Copper-bearing rocks of Lake Superior are argillites, which may in some cases be fit for roofing slates. Examples of these are seen on the Kamanistiquia; and the Slate Islands and Ance à la Bouteille are said to afford roofing slates.

Argillite.

Among the rocks of the Quebec group in Eastern Canada, argillites fit for this purpose are met with in a great many places, and have been successfully wrought. The Walton slate quarry, on the twenty-second lot of the sixth range of Melbourne, has been opened within the last three years. The band of slate, which is here in contact with a bed of serpentine, has a breadth of about one third of a mile, and dips to the southeast at an angle of 80°. It is so exposed as to offer facilities for extensive working; and within the last two years considerable quantities of these slates have been brought into the Canadian market, where they are likely to replace to a great extent the metal roofing hitherto so commonly employed. The slate of Melbourne is bluish-purple in color, fine grained, and splits with facility into thin plates, which have the smoothness and strength required for good roofing slates, and will compare favorably with the best from other countries. This slate is entirely free from carbonate of lime, and does not appear to be affected by the action of the weather. In the subjoined table may be seen some of the sizes of slates obtained from this place, the number of these in a square, and the price per square delivered at the Richmond railway station, a mile and a half from the quarry.

Melbourne.

Walton quarry.

Inches.	Number.	Price.	Inches.	Number.	Price.
24 × 14	98	$4·25	16 × 9	246	$3·75
22 × 12	126	4·25	14 × 8	327	3.00
20 × 10	169	4·25	12 × 8	400	2.50
18 × 10	192	4·00	12 × 6	533	2.00

Cleveland.

On the sixth lot of the ninth range of Cleveland is a continuation of the slate band of Melbourne. A quarry was opened here in 1854, but was afterwards abandoned; although there seems no reason to doubt that with a judicious expenditure, it might be made to furnish as good slates as the Walton quarry. On the fourth lot of the first range of Kingsey, roofing slates occur in a band of argillite, which is associated with dolomite. This locality was at one time wrought, and good slates were obtained. Their color inclines to a reddish-purple, and they are not quite so hard as those just mentioned. Roofing slates, resembling those of Melbourne, are found on the fourteenth lot of the first range of Halifax; and farther to the northeast, in the township of Frampton. It is probable that the argillites which belong to the Quebec group will furnish good roofing slates in many other parts of their distribution. Kingsey.

On the second lot of the fifth range of Orford, there are slates which are of a dark bluish color, and not unlike those of Melbourne, although less smooth in their cleavage. What appears to be a continuation of these is found on the twenty-ninth lot of the fifth range of Brompton. The argillites from these two localities belong to the Upper Silurian series, in which similar roofing slates are found in Westbury on the St. Francis River. These upper rocks will probably yield slates in many other parts of their distribution. Those which are associated with the flagstones in Tring, and on the Rivière du Loup, have already been noticed. Orford.

X. MATERIALS FOR ORNAMENTAL PURPOSES.

Under this title may be considered certain porphyries, and other feldspathic and silicious rocks, which are capable of being employed for vases, tables, inlaid work, and for various articles of ornament. The hardness of these materials, and the consequent cost of cutting and polishing them, prevents their employment to any great extent, and causes the preference to be given in many cases to marbles and to serpentine. The latter, from its softness, and from the ease with which it is cut and turned in a lathe with the aid of ordinary tools, is much employed in various countries for ornamental purposes. Some of the varieties of serpentine which are found at Melbourne, and elsewhere in the Eastern Townships, are apparently well fitted for such uses. The recent application of a variety of diamond to the turning of stones in a lathe has however greatly facilitated the working of these harder materials, which are now fashioned into shape at a much less expense than formerly. Few countries afford more beautiful or more numerous varieties of hard rocks of this kind than Canada: among these are the porphyries, the labradorite, and the other opalescent feldspars about to be noticed.

The agates which are common in the amygdaloidal rocks of Lake Superior, and are abundant in the form of pebbles along the shores of Thunder Bay, and of Michipicoten and St. Ignace Islands, admit of being Agates.

cut for ornaments. They are often of considerable size, and exhibit a fine variety of colors. The agates which are found in the conglomerates of the Bonaventure formation (page 404) are scattered abundantly along the coast where this rock prevails, and are known by the name of Gaspé pebbles. They are of small size, but are often of fine colors, and admit of a good polish. Agates however are very common in many countries, and, unless of considerable size and perfection, they have but little value.

Gems. Canada has as yet afforded but few gems. The zircons or hyacinths in the Laurentian limestones at Grenville are occasionally transparent, and have a fine color; and the presence of small portions of red and blue varieties of corundum in these same limestones in Burgess may also be noticed. This mineral constitutes the gems known as sapphire and ruby; and it is worthy of remark, that the sapphire of Ceylon is found, with chondrodite, in similar crystalline limestones. The transparent green garnet of Orford, which owes its color to oxyd of chrome, has hitherto been met with only in small crystals; but if found of large size, it would constitute a gem as beautiful as the emerald. Amethysts abound in some parts on the coast of Lake Superior; but the specimens hitherto brought from that region have seldom been sufficiently fine in color for the jeweller's use. The so-called Quebec diamonds, which are sometimes cut and polished for ornaments, are nothing more than rock crystal.

PORPHYRIES AND FELDSPARS.

The dykes of quartziferous porphyry which cut the intrusive syenite of Grenville, have been described on page 39, and again on page 654. This rock consists of an extremely hard fine-grained base, which in different specimens varies from dark green to red, purple, dark grey, and various shades of black. In this base are imbedded grains or crystals of rose-red or flesh-red feldspar, sometimes accompanied by grains of quartz. A fine example of a brownish-black porphyry, with well defined crystals of red feldspar, occurs on the south side of the road between the seventh and eighth ranges on the eighth lot of Chatham. The dyke has a breadth of about twenty feet, and runs nearly east and west. On the fourth lot of the sixth range of Grenville, there is a great mass of this porphyry, which varies in color from leek-green to blackish-green, and is marked with small red, brown, and black spots. It is very compact, and has a conchoidal fracture. This green porphyry is here about fifty feet in breadth; and to the northward it passes into a chocolate-brown variety, which is still more abundant. Small specimens of several varieties of these porphyries have been cut, all of which receive a fine polish, and are very beautiful. They may be obtained in large blocks, and do not appear to be much harder than the granites of Aberdeen, and of other regions, which are now cut and polished on a great scale; while they would far surpass these rocks in beauty.

Porphyry.

Grenville.

A beautiful variety of albite, which is described on page 477, occurs on the nineteenth lot of the ninth range of Bathurst, where it is found in veins cutting the Laurentian strata, and has been called peristerite. It is white or pearl-grey in color, and shows a beautiful blue opalescence, mingled with pale green and with yellow. Large masses of this feldspar are without any admixture; but in other portions of the vein, it is mingled with a little quartz, forming a kind of graphic granite. Specimens of this rock, when cut and polished, are very ornamental. A locality of a similar feldspar in Dummer has been described on page 36. Peristerite.

The name of perthite was given to a reddish variety of orthoclase, described on page 474, which forms with quartz a coarse grained granite on the third lot of the sixth range of Burgess. This feldspar is barred with flesh-red and brownish-red colors, and shines with golden or copper-red reflections, like the sun-stone or aventurine. Cut surfaces of it several inches square have been obtained, which when polished are very beautiful. This mineral, like the peristerite, was brought into notice by Dr. James Wilson of Perth. Perthite.

The labradorite or labrador-feldspar, so called from the region from which it was first brought, is sometimes beautifully opalescent, and exhibits, especially when polished, reflections of blue, green, gold, and purple colors. The geological distribution and the composition of a class of rocks made up chiefly of this, and of similar anorthic feldspars, have been given on pages 33, 480, and 588. Besides the locality mentioned by Dr. Bigsby on Lake Huron, the only spot in which the opalescent labradorite has been seen in place, in Canada, is at Cap Mahue in the tenth range of Abercrombie. Here, in a fine grained lavender-blue labradorite rock are imbedded cleavable masses of the feldspar, sometimes several inches in diameter, and exhibiting blue, golden-green, and bronze-green reflections. The rolled masses of anorthosite or labradorite rocks which are common along the shores of the Ottawa, especially in the vicinity of Grenville, often contain small portions of the opalescent feldspar. The mass of the rock receives a high polish, and presents a clouded dark greyish-green ground, with spots of an opalescent blue, forming an ornamental stone which may be applied to the same uses as the polished porphyries and granites. It is somewhat inferior to these in hardness, and would therefore present less difficulty in the working. Large blocks of this material may readily be procured. The syenites and many of the varieties of granitoid gneiss from the Laurentian series are well adapted for cutting and polishing. A peculiar fine grained reddish gneiss, which is traversed by veins of a pea-green epidote, and is very ornamental when polished, occurs near Carleton Place in Ramsay, and at the Falls of the Mingan River, as described on page 37. In this connection may be mentioned a fine grained mixture of pale green epidote with quartz, which is found on the Matanne River, Labradorite. Epidote.

and is described on page 497. This rock, which forms great masses in the Shickshock Mountains, is very hard; and as it receives a fine polish and has a bright yellowish-green color, it might be used as an ornamental stone.

JASPER.

Sherbrooke. A bed of jasper occurs in the town of Sherbrooke, and is traced for a considerable distance, having in some parts a breadth of six feet. Its color is blood-red, and it includes small grains of red hematite, and occasionally passes into a jaspery iron ore. In the parts exposed, this jasper does not appear to be sufficiently compact to be wrought for ornamental purposes. Rivière Ouelle. A small bed of jasper occurs imbedded in the red shales at Rivière Ouelle. Its colors are dark green and reddish-brown, and it is penetrated by small veins of white chalcedony. This jasper is compact and uniform in its texture, and receives a good polish. In some parts, the reddish-brown base is marked by clouds of a brilliant red. The jasper conglomerate of the Huronian series, which has been described on page 57, consists of pebbles, chiefly of red jasper, imbedded in a base of white or greenish-white quartzite. The jasper is fine in texture, and often brilliant in color, and the whole rock is extremely solid, and receives a polish which makes it well fitted for ornamental purposes. Great beds of this jasper conglomerate Lake Huron. are met with on the north shore of Lake Huron; where rounded masses of it, often of large size, are also found. These are abundant at the Bruce Mines.

XII. LITHOGRAPHIC STONE.

Lithographic stone. A very fine grained and compact limestone is required for the purposes of lithography, and beds having these characters are found in the Birdseye and Black River formation at the base of the Trenton group throughout a considerable part of its distribution, from Hungerford to Rama on Lake Marmora. Couchiching. In the township of Marmora, as described on page 182, there is a section of about twenty feet of light grey limestone, which is compact, with a conchoidal fracture, and holds no organic remains. Some of the beds contain numerous small lenticular crystals of calc-spar, and are marked by crystallites like those described on page 632. There is however a bed of two feet in thickness, which is extremely fine in its grain, and yields a lithographic stone of excellent quality. It has been repeatedly tried by lithographers, both in Canada and England, with most satisfactory results; but owing to the remoteness of the locality, no attempt has hitherto been made to work the stone. It is probable that equally good material for the purpose may be found in other parts of this band, which, as already mentioned, may be traced for about a hundred miles.

Beds of a fine grained yellowish-grey stone, well fitted for lithographic purposes, have lately been found among the dolomites of the Onondaga formation in the township of Brant. They occur in the bed of a small stream about half a mile south of Walkerton, where several strata of the stone from two to eleven inches in thickness occur in a section of fifteen feet. The beds at this place are traversed by natural joints, which cause the rock to divide into somewhat narrow portions; but the stone is found to be well adapted for lithography, and larger slabs may probably be found elsewhere in the same formation. Equally good specimens of it were obtained from the Oxbow on the Saugeen River, on the third lot of the seventh range of Brant. The stone from this formation, being magnesian, is attacked by acids more gently and with less effervescence than ordinary limestone. This peculiarity in the action of acids, which are employed in the lithographic process, is said to be an advantage. Brant.

CHAPTER XXII.

SUPPLEMENTARY.

LAURENTIAN SERIES; DISTRIBUTION OF LIMESTONES; ANORTHOSITES; THEIR APPARENT UNCONFORMABILITY; DOLERITE DYKES.—HURONIAN SERIES; ITS FARTHER DISTRIBUTION.—QUEBEC GROUP; ITS DISTRIBUTION NEAR PHILLIPSBURGH; ROCKS OF STANBRIDGE; OF SWANTON; POTSDAM GROUP; ST. ALBAN'S.—CONGLOMERATES OF POINT LEVIS; THEIR ARRANGEMENT AND THEIR ORGANIC REMAINS.—ROCKS OF THE STRAITS OF BELLE ISLE AND OF NEWFOUNDLAND.—GASPE SERIES.—SUPERFICIAL GEOLOGY; ROUNDED ROCKS AND ICE GROOVES; BOULDER FORMATION AND ERRATIC BLOCKS; ERIE AND SAUGEEN CLAYS; ALGOMA SAND; ARTEMISIA GRAVEL; ANCIENT BEACHES, TERRACES, AND RIDGES; LOCAL DEPOSITS OF FRESH-WATER SANDS; STRATIFIED CLAYS AND SANDS OF EASTERN CANADA; SUPERFICIAL GEOLOGY OF MONTREAL ISLAND.—LIST OF FOSSILS.—AURIFEROUS DRIFT; MIOCENE OF VERMONT.—RECENT DEPOSITS.

In the preceding chapter is included all the information collected by the Survey, on the subject of Economic Geology, up to the termination of 1862; but in the first sixteen chapters of the Report, comprehending the General Geology, the description of the various rock formations and of their distribution through the province has been brought only to the end of 1861. It is proposed in the present chapter, to introduce such additions and modifications as are authorized by the field explorations of last season; to be followed by a general account of the facts ascertained from the commencement of the Survey in regard to the Drift. In giving this additional matter, the various rock formations will be considered in the order observed in the previous portion of the work.

LAURENTIAN SERIES.

The additional information respecting the Laurentian series is confined to the area represented on the map; which shows the distribution of the crystalline limestones in the counties of Ottawa, Argenteuil, Montcalm, and Two Mountains. On page 43, it is stated that the Grenville band had been traced in all its windings from Lachute to the seigniory of the Petite Nation. It has now been farther traced nearly across this seigniory in additional undulations. Starting from the exposures which have been followed northward through the Augmentation of Grenville to the middle of Harrington on the Rivière Rouge, it sweeps round to the southern extremity of Lake Papineau. It thence proceeds northward, on the east

Limestones. Grenville band.

side of this lake, to the upper end, and turning in Ponsonby, runs southward on the west side, and follows the river Kinongé (discharging the lake) to its mouth on the Ottawa. It appears to follow the Ottawa to Papineauville, partially covered over by the Silurian deposits on the south side of the river; and then again proceeds northward by Côte Ste. Julie, which is about as far as it has been traced. In the Augmentation of Grenville, on Papineau Lake, and on the Kinongé, the limestone appears to be divided into two parts by a band of gneiss, which makes a considerable display in the first named locality, but which from Papineauville to Côte Ste. Julie has not yet been observed. A similar dividing mass of gneiss is observed at intervals in that part of the Grenville limestone which runs across the first three ranges of Harrington, on the east side of the township; but it did not here seem to be of sufficient importance to be indicated as a separate feature on the map. Petite Nation

A band of limestone has been traced on the Maskinongé River, across four of the ranges of Ponsonby; and though it approaches somewhat near to the Grenville band, at the head of Papineau Lake, it is supposed to be distinct from it, and to be a continuation of the Green Lake band (4 of the section on page 45), its probable connection with which is indicated by a dotted line on the map. This relation however has yet to be verified by observation. Ponsonby

It has been stated on page 43 that the Laurentian strata in the area in question, are affected by two sets of undulations, the axes of the more important running north and south. What appeared to be one of the most prominent of these was given as starting in Chatham from the intrusive syenite observed there, and gaining a position toward the west side of Howard. When this was stated, there were indications which seemed to render it probable that the Grenville band of limestone, where it runs northeast from the north end of Lake Louisa, would be traceable northward through Wentworth, and establish an anticlinal between the limestones of Harrington and those of Morin. After much exploration, we have not succeeded in tracing the band in the direction expected. It appears rather to return along the north edge of the lake, and to join the limestone on the east side of the Harrington trough, in the second range of Wentworth. This distribution would materially alter the supposed relations of the Morin and Grenville bands. The former could not then be considered as superior to the latter, but as either its equivalent, or inferior to it. In the former case, there would still be a prominent anticlinal between the Harrington and Morin bands; but in the latter case, the Morin limestone running under that of Harrington, the prominent anticlinal will disappear. Undulations. Morin limestone.

Although the dips of the strata in this whole region are of very little avail in establishing the sequence of the deposits, yet the preponderance of such evidence as they in this instance afford, would rather favor the supposition that the Morin band is inferior to that of Grenville. The Morin band, in that part of its distribution which approaches St. Jerome, is flanked on either side by an interstratification of orthoclase gneiss with a pyroxenic anorthosite; and as it there approaches the great area of anorthosite which occurs to the east, this interstratification of beds of the two rocks was considered as indicating a passage from the orthoclase gneiss of Grenville to the anorthosites of Morin, Abercrombie, Rawdon, and Chertsey. But by placing the limestone band of Morin beneath that of Grenville, the orthoclase gneiss of Grenville will intervene stratigraphically between the beds at St. Jerome and the anorthosites to the east (which are still considered newer rocks), and will interrupt the passage. In this position, the Morin band would correspond with that of the Lake of Three Mountains and of Green Lake in Clyde, and with that of Great Beaver Lake and Lake Sam; the latter lake being on the west line of the township of Grandison. In other parts of its distribution no anorthic feldspars have been observed to be associated with the band, except at the Lake of Three Mountains; where in addition to the mass of albitic rock supposed to be a vein (page 36), the gneiss bounding the limestone on the east side contains an admixture of a white anorthic feldspar, which may be oligoclase or albite. This gneiss, which contains at the same time orthoclase and quartz, is however very distinct from the anorthosite rock of St. Jerome; and if it be regarded as its stratigraphical equivalent, it would be necessary to suppose such a variation in the composition of the original deposits of the two localities, as is not unfrequent in other sedimentary strata.

Anorthosites

From Lake Sam and the Trembling Lake, the two limestone bands (4 and 2 of the section on page 45) which underlie the Grenville band, have been traced southward through the township of Desalaberry, folding in succession upon an anticlinal axis, and returning northward to the sixth and eighth ranges respectively. The higher of the two bands however, in the sixth, seventh, and eighth ranges, and a little farther northward on the west side of the anticlinal, is interrupted by a mass of anorthosite or labradorite rock, which apparently covers it up. A similar phenomenon appears to occur in Morin, where the limit of the labradorite rock described on page 33, starting from the southwest boundary of Abercrombie, and running across the north corner of Mille Iles, immediately flanks the limestone band on the north. On entering Morin, it is separated from the limestone, in the first and second ranges, by a considerable mass of brown-weathering gneiss. The margin of the labradorite approaches the limestone band again in the third range, and this band is concealed in its farther progress westward. Thence the margin crosses the southeast corner of Howard, enters Wentworth for a short distance, and returns to Howard; which it traverses northward, obliquely crossing the line between it and Montcalm, and then the line between Montcalm and Wolfe, about two miles

Overlying labradorite.

Howard.

west of Beresford. From this it is said to gain the northeast line of Wolfe, not far from Grandison. From the interruption by it of the Morin limestone near Howard, it seems probable that the anorthosite rock overlies the whole Grenville series unconformably, and that the mass of it on the west side of Desalaberry is an outlying portion. If on exploration to the eastward of the Trembling Mountain, it should be farther ascertained that the two inferior limestone bands of the Grenville series disappear on reaching the margin of the anorthosite, it may be considered as conclusive evidence of the existence in the Laurentian system of two immense sedimentary formations, the one superimposed unconformably on the other, with probably a great difference in time between them; and it will be an interesting subject of inquiry whether the intrusive rocks which have been found intersecting the lower division, give any clue to events which may have happened in the interval. Two formations.

Should it be established that the great mass of anorthosite feldspar rocks really belongs to a distinct and more recent formation than the immense series of orthoclase gneiss beneath, it would be in strict conformity with the principle laid down on page 573. According to this, the proportion of alkalies to the alumina in silico-aluminous rocks will, other things being equal, be greater in the older sediments; and the group of rocks in which the alumina is combined with potash and soda, almost to the exclusion of other bases, would seem to belong to a far earlier period than that giving rise to rocks in which a large proportion of these alkalies is replaced by lime. This newer formation, although characterized by a predominance of anorthosites, appears to contain in some parts, interstratified beds of orthoclase gneiss, quartzites, and limestones, all of which are found associated with it near New Glasgow.

Some of the dolerite dykes among the intrusive masses have during the past season been traced to much greater distances than stated in the previous part of the Report. Taking them in the order in which they are given on page 38, it will be seen by the map that the one on the thirteenth lot of the fourth range of Grenville has now been traced as far as the fifth lot of the second range of the Augmentation of Grenville, a distance of six and a half miles; in the course of which it sweeps down toward the mouth of the Rouge, and touches the north side of the Ottawa. On the most western lot to which it has been followed in the Augmentation, it appears to join another dyke, which is probably a branch having a more direct course from the lot in Grenville already mentioned. Eastwardly, after running about a mile, the dolerite, as stated on page 38, is cut off by the syenite; but it occurs again in three of the bays indenting the south side of the syenite, in the intervals between which it is interrupted and destroyed by this newer intrusive rock. It continues beyond the syenite, and is seen on the line between the seventh and eighth lots, and between Dolerite dykes.

Chatham. the seventh and eighth ranges of Chatham. It is farther seen in Argenteuil, about three miles beyond the east boundary of Chatham, on the right bank of the North River; the whole distance which it has now been traced being upwards of twenty miles.

Grenville. The dyke occurring on the eleventh lot of the fifth range of Grenville to the west of the syenite, is probably to be identified with one to the east of this intrusive mass, on the tenth and eleventh lots of the eighth range of Chatham, which answers better for the dyke mentioned on page 39, than the more southern one there assigned to it. To the westward, it has now been followed to the west boundary of the Augmentation of Grenville, near the line between the third and fourth ranges. It is accompanied by a parallel dyke, seen at intervals, about a quarter of a mile to the north of it. The two probably come together on the twenty-fifth lot of the fifth range of Grenville; but they separate again after the distance of a lot, and remain distinct to the line between the Augmentation and the seigniory of the Petite Nation. The distance between the east and west points to which this dyke has been thus traced, would be about twenty-four miles; but a dyke occurs four or five miles farther on, which has been traced at intervals for about seven miles, through Côte Ezilda to Côte St. Joseph of the seigniory. To the north and south of it, in this vicinity, other nearly parallel dykes occur; and the whole of these will probably be found to have some reticulating relation to the two ranges of dykes already mentioned.

Wentworth. The great dyke of Wentworth (page 38), from the point where it is intersected by the syenite on the twenty-second lot of the first range of this township, has now been traced westward to the western boundary of the Petite Nation seigniory in Côte St. André, a distance of thirty miles; and eastwardly, about seventeen miles, to Côte St. Eustache of Mille Iles. The whole distance which it has been followed is thus about forty-seven miles, but it probably ranges very much farther in both directions. Its width in Côte St. Eustache is about 230 yards; and as there are about five miles between this and the sixth lot of the fourth range of Chatham Gore, in which the details regarding it are but imperfectly known, it may be found that in swelling to this increased measure, it has been joined by some important but undiscovered dyke. Between the twenty-fourth lot of the ninth range of Grenville and the fifth lot of the sixth range of the Augmentation, there are about four miles in which the details of the dyke have still to be made out. In its whole course, the bearing of this main dyke is about five degrees south of west and north of east. The dykes to the south of it are nearly parallel with this; but on the whole, they probably converge toward it westwardly.

Small exposures of similar dykes have been met with in several places, but the only additional instances worthy of mention are two: one of them running from the sixth range of Harrington to the eighth of Wentworth;

and another near the north line of the former township, running from the twelfth to the twenty-third lot: only the extremes of this however have been observed. Both of these dykes run nearly parallel with the main one already mentioned.

HURONIAN SERIES.

It was stated on pages 61 and 62 that between the St. Mary and Mississagui Rivers the rocks of the Huronian series are arranged in the form of a trough, the longitudinal axis of which runs along the valley of the Thessalon; and that a flat anticlinal arch appears to separate this trough from another to the eastward of the Mississagui. It was further stated that a band of limestone (belonging to the division 5 of the Huronian series, given on page 56), which had been met with on the Little White River, about five miles above its junction with the Mississagui, probably constituted a part of the western outcrop of this eastward trough, but that this band had then still to be traced around it. Thessalon

The work of the past season, in connection with the Huronian rocks, has been devoted chiefly to the investigation of their distribution in the supposed synclinal area in question. The band of limestone on the Little White River, sweeping round on either hand from the position where it crosses it, trends at some distance from the opposite sides of the river toward the Mississagui, leaving on its tributary a peninsular-shaped area of the lower slate conglomerate, 4 of the section mentioned above; but as the band of limestone approaches the valley of the main stream, it becomes lost under the drift, and has not again been seen either up or down the Mississagui. The strike of the lower slate conglomerate 4, however leads to the supposition that in the downward bearing of the Mississagui the limestone attains the valley of the Marsh River; and that following this in a southeasterly direction across the township of Thompson, and for five miles beyond, it then turns upon a synclinal axis, and reaches the Lake of the Mountains, on the Blind River. The upward course of this stream gradually diverges from that of the Marsh River, of which it is a tributary, and the limestone is traceable up its valley by various exposures for about nine miles, to the neighborhood of Lake Macomang. Running about a mile inland, parallel with the southwest side of this lake, it comes upon its shore, and is seen on the northeast side, at the narrows, about four miles from the foot of the lake. Beyond this, it probably turns a little westward of north, but it has not been farther traced. Limestone Mississagui Lake Macomang.

In the upward bearing of the Mississagui, above the mouth of the Little White River, the course of the upper slate conglomerate, 6 of the Huronian series, indicates that the limestone probably crosses the main stream about four miles above its tributary; that it traverses it again about six miles farther up, and that turning eastward of north, with a change in the course of the river, it crosses Salter's base line, near the western extremity of Lake Katigamaigouska. Here large loose angular slabs of limestone are mingled with others of a slate so like the limestone in aspect and hardness, that without the aid of an acid it would be difficult to distinguish the one from the other. Neither of these rocks were seen in place, but it is probable that the parent beds of both were not far distant. Two miles beyond this point the Huronian rocks are interrupted by hills of granite.

Katigamaigouska. Lake Katigamaigouska appears to lie wholly in the upper slate conglomerates 6, with the exception of the most northeastern bay, which presents the base of the red quartzites 7; while Lake Wahcomatagaming, which receives the water of the previous lake, shows the upper slate conglomerates 6, on its west side, and the red quartzites 7, on its south and east sides; with the exception of its most eastern bay, where the base of the red jasper conglomerates 8, is exposed. A peninsula, extending longitudinally from the western extremity, divides Lake Wahcomatagaming into two parts. Wahcomatagaming. The eastern three fourths of this peninsula, presenting a rugged surface, are composed of the red quartzites 7, which here display a band of purple slates at their base. At the summit of the upper slate conglomerate 6, as was remarked in other parts of this lake, but more particularly on Lake Katigamaigouska, about 600 feet of this division 6, is a green flinty slate which appears to be almost destitute of pebbles. The northern shore of the lake, and the mountains north from it, appear to be composed of granite and syenite; in both of which there is occasionally observable an obscure gneissoid structure, giving them the aspect of gneiss, so that here, as in the valley of the Spanish River (page 61), it is very difficult to say whether they are intrusive or altered rocks. They are supposed however to be of Laurentian age. Striking along the lake, they run parallel with the stream discharging it, and come upon the Mississagui about three miles above Salter's base line. On the shore of Lake Wahcomatagaming, these Laurentian rocks are in contact with masses of greenstone, but the relation between the two is uncertain. From Lake Katigamaigouska, the base of the red quartzites 7, strikes for Lake Kaikaquabick, a tributary of the Little White River; but this stream itself, as far as ascended (which was about five miles in a straight line above the band of limestone), flows over the upper slate conglomerate 6; which is here, as on Lake Katigamaigouska, characterised at the summit by green flinty slates without pebbles.

The total thickness of the strata which came under observation in the area examined, may be estimated as given in the following ascending series; in which the numbers prefixed to the divisions correspond to those on pages 56 and 57:

	Feet.		
4. Lower slate conglomerate, being only the higher part of it,........	900		Section.
5. Limestone,..	300		
6. Upper slate conglomerate, with 600 feet at the top without pebbles,..	2,600		
7. Red quartzites,..	2,000		
8. Red jasper conglomerates, being only the lower part,.............	500		
	——	6,300	

All of these divisions, with the exception of the limestone band 5, and the green slates without pebbles at the top of 6, are interstratified with masses of greenstone. Some of these masses in the red jasper conglomerates 8, may be from fifty to eighty feet thick, and those in the red quartzites from 50 to 100 feet; while one in the upper slate conglomerates, seen on Lake Macomang, was estimated at from 150 to 200 feet. A considerable area of greenstone, associated with the lower slate conglomerates of 4, occurs along the Mississagui, but it was not found practicable to determine its volume, from the flatness of the country and from the nearly horizontal attitude of the strata. Upon the whole, the amount of interstratified greenstone in this region does not appear to be quite so great as in the Thessalon trough. There is also less greenstone in the form of dykes. Two of these however which are seen on Lake Waheomatagaming are respectively thirty and forty yards wide, and cross from the peninsula to the east shore, converging northeastwardly. Another dyke not far from the foot of Lake Macomang, is between fifty and sixty yards wide, and runs nearly east and west; while a fourth which intersects the Mississagui at the third fall, in the bearing N. 65° W., is about twenty-five yards wide, and appears to be accompanied by a dislocation.

Greenstones

Dykes.

Indications of copper ores were observed in several parts of the area under description. The principal of these occur at the east end of the line between the townships of Patton and Thompson, in an interstratified mass of greenstone, which appears to belong to the upper slate conglomerate 6. This greenstone is situated near the synclinal axis, upon which the limestone band has been shown to turn near the Lake of the Mountains, and it is intersected by numerous parallel quartz veins running nearly east and west. Most of these contain both iron and copper pyrites: and in some of them, varying in breadth from one to five feet, the latter ore occurs in quantities which render them worthy of trial. A mass of greenstone belonging to the same slate conglomerates of 6, but not far above the limestone band 5, occurs on a small island in the west bay of Lake Macomang, in front of the position where the limestone is exposed on the northeast shore. The greenstone is intersected by a vein, which is three feet wide, and contains bitter-spar lining the walls, with calc-spar in the middle, which is traversed by reticulating strings of bitter-spar. Iron pyrites is disseminated in large quantity in this vein, associated with a smaller amount of yellow copper ore.

Copper ore.

Moderate dips. Synclinal. Anticlinal.

Throughout the whole area examined, the strata present very moderate angles of inclination, in much of it not exceeding five degrees. They seldom rise to fifteen degrees, and twenty degrees may be considered as exceptional. The geological forms which guide the distribution of the strata, are in consequence not readily reduced to rule; and until the contour of the outcrop is more fully traced out, it would be premature to say much of the structure of the area. But it may be inferred from what has been shown that there is in it at least one shallow synclinal, the axis of which runs between the Marsh and Blind Rivers, nearly parallel with the Mississagui; and that this synclinal is traversed by a low transverse anticlinal arch, coincident with the valley of the Little White River.

QUEBEC GROUP.

The investigations in connection with this group during the past season have been confined chiefly to two localities at the opposite extremes of Eastern Canada; the one being in the neighborhood of Phillipsburgh, and the other on the Strait of Belle Isle.

Phillipsburgh. Section.

On pages 275–279, a partial series of the rocks occurring near Phillipsburgh, with their enclosed fossils, is given in detail. In the following list these rocks are comprehended in the divisions A and B, in the description of which the lists of fossils, and the more minute particulars, are not repeated. To this series are now added the divisions C and D, which are given with their ascertained fossils, and with such general characteristics as have been observed. The whole succession is, in ascending order, as follows:

		Feet.	*Feet.*
	A.		
Division A.	1. Dark grey and yellowish-white dolomites, weathering grey and yellowish-brown,	400	
	2. White and dove-grey pure compact limestones,	100	
	3. Reddish-grey brown-weathering dolomites, and black dolomites with some thin-bedded black limestones,	200	
			700
	B.		
Division B.	1. White and dove-grey pure limestones, with some yellow-weathering magnesian bands,	120	
	2. Dark grey and black limestones, some of the beds magnesian,	120	
	3. Dark bluish-grey thin bedded nodular limestones, with thin layers of bluish-grey slate, probably magnesian; the surfaces of some of the beds weathering into a red or yellow ochreous arenaceous earth,	150	
	4. Black slaty thin bedded nodular limestones, with two or three thick beds of purer limestone toward the base,*	300	
	5. Black limestones, some of them massive, weathering bluish-grey; interstratified toward the bottom with black and dark grey yellow-weathering magnesian beds,	350	1040

* It is stated on page 279 that the parts 4 and 5 of this division are absent on the province line. Part 5 is wanting; but the chief portion of 4, with certain thick beds toward the base, which are not mentioned on page 279, appears to be in place there.

C.	Feet.	Feet.
1. Black and dark grey compact pure limestones, weathering lead-grey, with a few bands of dove-grey. The beds are all massive, and afford abundance of a few species of testaceæ; the whole of which appear to have the peculiarities of being large-sized and thick-shelled, and of occurring in numerous isolated patches, which vary in diameter from about three to ten feet. The fossils are several undescribed species of *Murchisonia* and *Pleurotomaria*, *Ecculiomphalus Canadensis*, *E. intortus*, *E. spiralis*, several undescribed species of *Ophileta*, *Maclurea ponderosa*, several undescribed species of *Orthoceras*, and one of *Nautilus*. Toward the base, *Maclurea ponderosa* seems to be somewhat smaller than in the upper part of the deposit, and toward the top one or two beds appear to be of a partially conglomerate character,..	150	
2. Black slates, or possibly thin bedded black limestones, with a few thicker beds toward the top; the mass is altogether very imperfectly seen,..	170	
		320

Division C.

D.		
1. Black limestone conglomerates, composed chiefly of the ruins of the thick bedded limestones of division C. The enclosed masses vary in size from pieces of an inch in diameter, to blocks containing between fifty and sixty cubic feet, and are cemented together by a calcareo-magnesian paste. Of this, however, from the closeness with which the masses are packed together, there is but a very small quantity. The limestones are generally close grained, and black or dark grey in color, but there are mingled with them a few scattered blocks of a lighter colored yellow-weathering dolomite, some of them a foot in diameter. Many of the masses of limestone contain fossils, and the species are almost wholly confined to those already stated as characterising the parent beds C 1. There appear to be at least two principal bands of this conglomerate, each varying in thickness in different parts from about 50 to 100 feet. There is an interval between them of from 100 to 150 feet, occupied by black slates holding rounded masses of limestone, which convert parts of the mass, varying in thickness from ten to twenty feet, into slaty congomerates. In some parts, either the interval between the main two bands of conglomerate increases considerably, or there is a third band, with similar slates, intervening between it and the second. The whole is contained in a thickness of from 250 to....	300	
2. Black and greenish argillaceous slates, probably interstratified with occasional thin calcareous bands, and thin lenticular patches of limestone conglomerate, as well as more important bands of yellow-weathering dolomitic slates. The whole is terminated by a band of black limestone conglomerate similar in character and thickness (from 50 to 100 feet) to those already mentioned, and containing *Maclurea ponderosa* in one of the few places in which the band has been seen. This whole mass of strata is very imperfectly exposed, and much uncertainty exists as to its true general character. Its thickness may be from 750 to..................	1000	
3. Grey and black striped slates, some parts of which are calcareous, and weather slightly brownish. They are interstratified with occasional thin beds of black limestone, weathering lead-grey, as well as		

Division D.

Conglomerates.

Conglomerates.

	Feet.	Feet.
many strong and solid beds of brown-weathering magnesian limestone, and brown-weathering dolomitic slates. Some of the latter are marked by an abundance of fucoids resembling *Buthotrephis flexuosa* of Emmons. Occasional beds of sandstone, from one to three feet in thickness, are met with. About the middle of the mass there has in one place been observed a bed of limestone conglomerate from five to ten feet thick, and other similar ones may occur in different parts of the vertical thickness,	1500	2800
		4860

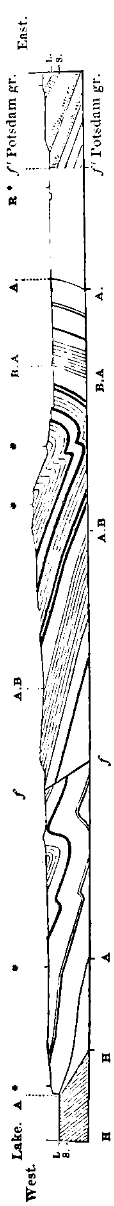
Dolomitic slates.

It has been stated on page 276, that on the province line, the limestones included in division B of the above series, are arranged in the form of a trough, with a moderate dip on the west side, and a precipitous one on the east; and on page 279, that the axis of this synclinal occurs near one of the iron posts marking the boundary of the province, on the summit of a hill west of Rock River, as represented in the annexed figure 442. The bearing of the axis is about S. 22° W. In this bearing, at the distance of about 300 yards from the iron post in question, the black limestones near the base of part 4* of division B, are seen to turn upon the axis; and the white limestones of B 1, mentioned on page 280 as probably concealed at this point, have also been seen to turn upon this axis about 350 yards beyond. The thin bedded black limestones belonging to part 3 of division A, are exposed upon the axis about 500 yards still farther on; but before reaching the white and dove-grey limestones, 2 of division A, where they are seen upon the axis, there is an interval of about a mile and three quarters, occupied by an alluvial flat. The outcrop of these white limestones is, without difficulty, traceable southward from the province line, along the Phillipsburgh and Highgate Springs road, for about a mile and a quarter; but it separates from the road farther on, and, crossing the Rock River between 500 and 600 yards from its mouth, the base of the limestones 2, after showing a subordinate twist of some importance, comes upon the main synclinal axis about 400 yards somewhat south of west from the house of Mr. Church. The dolomites of part 1, division A, sweep round behind the pure limestones, A 2, and, crossing the road a little south of Mr. Church's house, come against the red Conocephalites beds of the Potsdam group. The strata, A 1, occupy a place on the axis for upwards of a mile; beyond which, the limestones, A 2, again make their appearance, perhaps let down by a transverse dislocation, and here seem to constitute an outlier, with a length of about three quarters of a mile, and a breadth of nearly half a mile at the widest part. At the southern extremity of this outlier, the strata appear to converge toward the synclinal axis; on the east side of which, amidst some confusion, they show a westerly dip, as they approach to within fifty or sixty yards of the red beds of the Potsdam group, near the house of Mr. Robey.

Province line section.

* On page 280 these limestones were stated to belong to part 2 instead of to part 4.

442.—SECTION ON THE PROVINCE LINE, EASTWARD FROM LAKE CHAMPLAIN.



Horizontal and vertical scale, three inches to a mile.

L L, level of Lake Champlain; S S, sea level; H H, Hudson River slates. A, B refer to the divisions of the Quebec group given on page 844; f f, fault; f' f', proximate position of break or overlap, bringing up the Potsdam group. The asterisks mark the iron posts of the boundary-line of Vermont and Canada, and R the place of the Rock River.

From the province line northward, the white and dove-grey limestones, 2 of division A, follow the Phillipsburgh road for nearly two miles, occupying the valley of Strite's Pond, and running parallel with the coast of Lake Champlain at a distance of about 800 yards. Near Phillipsburgh they are seen on Mr. Cheeseman's land, on the fifth lot of St. Armand: and though they thence gradually diverge from the margin of the lake, they are traceable in a continued straight course to the vicinity of Blood's Corners, nearly three miles farther on. In this neighborhood, the higher beds of these limestones enter the township of Stanbridge on the first lot of the ninth range, and, crossing the lot obliquely to the north side, they fold over an anticlinal axis on the Bedford road, where they show a precipitous dip to west of north.

Phillipsburgh series.

Anticlinal.

From the province line, the white limestones, 1 of division B, maintain a course parallel to those of division A, and are traceable, without difficulty, for the same distance northward. East of Philipsburgh, they are a little more than three quarters of a mile from the lake-shore; and the more fossiliferous overlying black limestones, and thin bedded red-weathering limestones, B 2 and B 3, which succeed, form an escarpment to the east of them. The surfaces of these upper beds here weather to a red ochreous earth, and abound in the casts of fossils, from which the calcareous matter once filling them has been dissolved out. More than a mile farther northward, near the house of Mr. Hollis Hastings, they present the same relation to the white limestones, B 1, and the same weathered and fossiliferous condition. It is probable that these strata are equally fossiliferous throughout; but the undecomposed rock being very hard and tough, it is only when favorably weathered, that the organic forms can be obtained in a state sufficiently perfect to be identified, or indeed can be detected at all, unless with great difficulty. From the exposure last mentioned, the white limestones, B 1, preserve their course in a well marked valley until they enter the township of Stanbridge, on the first lot of the ninth range; beyond which they are obscure. The magnesian limestones, A 3, which immediately underlie them, can however be followed from the first to the second lot of this range, where they fold over the anticlinal axis already mentioned. The evidences of this are met with on the Bedford road, near the house of Mr. J. Hall; and indications of the white limestones, B 1, occur a little farther eastward on the same road; where they are probably very near the axis, but somewhat on the north side of it.

Stanbridge.

Anticlinal.

The bearing of this axis is about N. 65° E., and the evidences of the anticlinal form are sufficiently well marked for upwards of a mile farther on this road, to the line between the seventh and eighth ranges of Stanbridge; though it is necessary to proceed about a quarter of a mile to the southeastward of the road for some of the facts which prove the case. These are on the second lot of the eighth range, where the dip of the strata is southward, at angles of from ten to twenty degrees; while on the north side of the road it is northward, at angles of from forty-five to eighty-five degrees, and often a few degrees beyond the perpendicular. Along this part of the road, the escarpments not being well preserved, and the general color of the strata being black or dark grey, it is not easy to assign the beds to their different divisions; though they all probably belong to 2, 3, and 4 of division B. In this part the whole development of rock on the north side of the anticlinal axis does not exceed between 300 and 500 yards in breadth. In this there appear to be one or two minor undulations; and although the white limestones, both of A 2 and B 1, are exposed in it near Blood's Corners, it has not yet been found practicable to trace out their respective connections in detail. In one of these exposures, which is quarried, toward the west end of the second lot of the ninth range, not far from the house of Mr. Schneider, a white limestone supposed to belong to B 1, presents on the surface a narrow wedge-shaped mass, upward of a quarter of a mile long, dipping on both sides southeastward at high angles. The small end of the wedge points to the northeast, and the whole mass presents a sharp overturn anticlinal form; the true character of which would never be suspected, were it not for the presence of a yellow-weathering magnesian bed of about a foot thick, which flanks it on both sides, and folds over it at the extremity.

Blood's Corners.

Overturn anticlinal.

Across the seventh range, the rocks on the immediate axis of the main anticlinal are concealed by drift; but there are exposures on the Bedford road, which runs about 300 or 400 yards northwest of the axis, and these extend in one place as much as three quarters of a mile beyond the road. This locality is on the land of Mr. Corey, on the sixth and seventh lots of the seventh and eighth ranges of Stanbridge; where there is a great display

Bedford road.

of the limestones, 1 of division C, which are extensively quarried and burned in the neighborhood. The largest exposure is on the seventh lot of the eighth range, showing a breadth of about 350 yards, dipping S. 78° E. < 16°–20°. From this the strata run into the sixth lot of this range; and then apparently sweeping round the extremity of a trough, having a subordinate undulation dividing it into two parts, they gain the adjacent portions of the sixth and seventh lots in the seventh range. From the southwest corner, they appear to traverse the latter lot obliquely, and then to cross the southeastern corner of the eighth lot; but here, proportionally reduced in breadth by an increase in slope, they dip N. 42° W. < 55° – 70°; thus proving their synclinal arrangement. Near the northern extremity of the first and largest exposure mentioned, after an interval of about 130 yards, leaving room for part 2 of division C, these limestones are followed by the lowest band of the black limestone conglomerate belonging to part 1 of division D. The exposure showing this is near the northwest corner of the seventh lot just mentioned; and the same succession occurs on the southern side of the synclinal, where the limestones, C 1, cross the southeast corner of the same lot; while there are two intermediate exposures of conglomerate, the one at the bottom and the other at the top of D 1, with thin limestones and slaty conglomerates between them. Corey's limestone. Synclinal. Limestone conglomerates.

The strata which come from beneath the massive limestones, 1 of division C, and are exposed on the Bedford road, where it crosses the seventh range of the township, are black limestones, many of them thin bedded, and appear to belong to the upper part of division B. In conformity with this, we should expect the limestones, C 1, and the succeeding conglomerates of D to assume a place on the south side of the anticlinal, which runs parallel with the road. The limestones of the upper part of division B enter a little way into the eighth range, and the lowest band of conglomerate accompanies them, leaving space between for the strata of division C; which however are here concealed. Slaty conglomerates are met with about half a mile farther on, in the town of Bedford, on the Pike River.* These are similar to some of the slaty strata associated with the stronger conglomerates, and probably belong to division D; but the fossils occurring in the enclosed calcareous masses do not appear to include any of the thick-shelled species so characteristic of the stronger bands. The fossils met with are *Orthis*, an *Ophileta* like *O. uniangulata*, with new species of *Agnostus*, *Ampyx*, *Asaphus*, and *Illænus*. Bedford.

Black slates are seen both below and above this mass of slaty conglomerate; and about half a mile somewhat westward of north from it, there occurs an exposure of limestone conglomerate, which is supposed to belong

* By inadvertence, Bedford was stated, on page 276, to be on the Yamaska, instead of on the Pike River.

to the summit of division D. Neither the massive limestones of C, nor any of the succeeding conglomerates, have yet been observed on the axis of the anticlinal, in what may be considered its prolongation from the eighth range, the country being very much covered with drift. The same may be said of the area on the southeast side of the anticlinal, between Bedford and the north line of St. Armand, and a mile farther to the southwest. The presence, and the course of the rocks of C and D under the drift, are however pretty conclusively proved by well characterized exposures of conglomerates on the twenty-ninth lot of St. Armand. These occur on the north side of the lot, and nearly in mid-length of it. They are two in number, and may probably belong to the two bands in part 1 of division D. The beds dip S. 70° E. $< 28°$, and are comprised in a breadth of about 140 yards; giving, with the uncertain interval which separates them, a thickness of about 190 feet. They present many very large blocks of black limestone, in which are found *Murchisonia*, *Pleurotomaria Laurentina*, *Ecculiomphalus spiralis*, *Maclurea ponderosa*, *M. matutina*, and *Orthoceras*. The nearest underlying rocks, exposed to the west of them, apparently belong to the summit of division B. They occur at a distance of about 700 yards, and their slope is about fifteen degrees. This interval would give a vertical thickness of about 500 feet, which is more than sufficient to include the strata of division C.

St. Armand.

Conglomerates.

It was stated on pages 279 and 280, that on the east side of the synclinal axis which crosses the province line on the hill west of Rock River, the outcrop of one of the beds of part 4 of division B, had been traced northeastward, in a nearly vertical attitude, for about three quarters of a mile; but that the turn of the higher divisions of the group on the axis had not been ascertained. Dips have since been observed, inducing the supposition that the axis is not removed more than 250 yards to the northwestward of the nearly vertical bed above alluded to, so far as this has been traced; that it occurs at a somewhat less distance westward of Moore's Corners, and that northward of this place it nearly coincides, for three quarters of a mile, with the road to Blood's Corners; leaving it where the road makes a turn to the northwestward, on the twenty-sixth lot of St. Armand, and where the strata of the upper portions of divisions B are exposed, dipping westward at an angle of three or four degrees. This general course, continued about a mile farther, would bring the axis to the immediate vicinity of the conglomerate masses of D 1, on the twenty-ninth lot. About 200 yards eastward of these masses, there appears in the side of a rising ground, a series of thin bedded slaty limestones, dipping about S. 87° E. $< 30°$, and occasionally becoming magnesian. These are followed by beds in which pure grey limestones predominate, containing many specimens of *Stromatopora*, *Ophileta*, and *Orthoceras*. These pure limestones are penetrated and surrounded by a yellowish dolomite, giving to sections of

Synclinal axis.

Moore's Corners.

the rock a broadly and irregularly mottled surface, which does not however appear to be due to a conglomerate structure. The whole exposure has a breadth of about 150 yards, and with the rise in the ground, would give a thickness of about 250 feet. These strata, probably belonging to the upper part of division B, appear to present the southwestern termination of a trough, one side of which runs about north, and the other about N. 50° E.; while the synclinal axis may have a course of N. 30° E. On this axis, about half a mile from the end of the trough, there is another exposure of conglomerate, between which and the sides there would be room for the massive limestones of division C. This exposure, holding *Eospongia*, *Maclurea matutina*, *Holopea*, and *Orthoceras*, occurs near the east end of the thirtieth lot, and there is little doubt that it is equivalent to one of those of D 1, on the twenty-ninth; but to account for their relative positions, there must run between them either an anticlinal or a dislocation. The attitude of the conglomerates on the twenty-ninth lot, and of the thin bedded limestones to the east of them, with the narrowness of the space between, make it probable that there is a break.

Dolomites.

Synclinal.

Fault.

On the southeast side of the trough just described, the section above mentioned is augmented by an addition of strata at the base, and presents a more precipitous slope; the dip of the lowest beds, which consist of thin bedded limestones, being about N. 40° W. < 55°-75°. Strata belonging to the Potsdam group come up behind these, at a distance of between eighty and ninety yards. They consist of a mixture of pure limestone and dolomite, somewhat like that of division B just described, but interstratified with layers of slate, and many beds of white sandstone, all without observed fossils. These strata have the same strike as the thin bedded black limestones above them, and they slope in the same direction, but at a more moderate angle, their dip being about N. 40° W. < 30°-40°. The exposures of these beds are seen on the land of the Hon. Mr. Moore, between 300 and 400 yards north of his residence; and with another exposure occurring a little way southward, on the adjoining parts of the twenty-seventh and twenty-eighth lots, near the house of Mr. G. Carruthers, they show pretty clearly that the apparent arrangement of the Phillipsburgh and Potsdam rocks is due to a fault. On the southeast side of the road, in the latter locality, the Potsdam beds show extensive surfaces of white sandstone and of brown-weathering sandy magnesian limestone, interstratified with one another and dipping at a very low angle eastward of north. Approaching the road, they bend over a little toward it; and from fifty to sixty yards on the northwest side of it, they come into contact with the Philipsburgh strata, which stand in a nearly vertical attitude against the terminal edges of the Potsdam beds. The two formations are seen in contact for about 600 yards. At the northeastern end of the exposure, the Phillipsburgh strata, of which there may be altogether

Potsdam group.

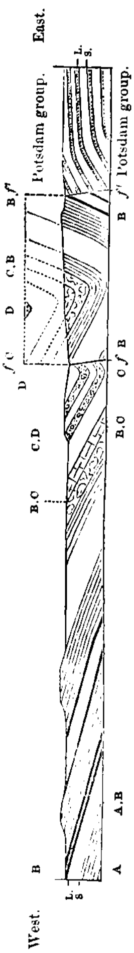
White sandstones.

Great fault.

a thickness of between 300 and 400 feet, are thin bedded black limestones and nodular shaly limestones ; their dip being N. 60° E.< 75° – 90°. But proceeding southwestwardly, a band of pure whitish limestone, mixed with brown-weathering light grey dolomite, becomes gradually interposed between the thin slaty limestones and the Potsdam beds ; and the dip of the former at the same time becoming gradually overturned, ultimately overhangs the perpendicular as much as sixty degrees. Along the junction of the two formations, broken masses of strata are thrust in irregular attitudes between them, and the whole exposure presents the aspect of a well-marked dislocation. In the diagram 443, showing a section across the conglomerates on the twenty-ninth lot, the band exposed on the thirtieth lot is introduced in the position which it would occupy were it continued far enough southward. This diagram also sufficiently illustrates the contact of the Phillipsburgh strata with those of the Potsdam group, as just described. In this neighborhood, both of these groups become concealed by drift about a mile northeastward of the exposures which have been described on the land of the Hon. Mr. Moore, on the twenty-ninth lot of St. Armand; and they have not as yet been traced much beyond the house of Mr. J. Rosenberger, on the one hundred and thirtieth lot of St. Armand, which is the one abutting against the thirtieth lot.

Contact of Phillipsburgh and Potsdam rocks.

443.—SECTION ON THE TWENTY-NINTH LOT OF ST. ARMAND.



Horizontal and vertical scale, three inches to a mile.

L L, level of Lake Champlain; S S, sea level. The letters A, B, C, D refer to the divisions of the Quebec group, given on page 844; f f and f' f' mark two faults or dislocations, the latter bringing up the Potsdam group.

Returning to the northwest side of the whole mass of rocks belonging to the Quebec group, which we have been investigating, there is still something to be added in regard to the distribution of the limestone conglomerates in Stanbridge. From the seventh lot of the seventh range of the township, where, as already stated, there is an exposure of the conglomerates at the base of division D, they are traceable to the northeastward, by an exposure which crosses the Henryville road, about a mile westward of Bedford, and extends to the left bank of the Pike River. The length of this exposure is somewhat under half a mile, and it exhibits both of the

Stanbridge conglomerates.

bands of conglomerate of D 1. To the right of the Pike River, there is a drift-covered interval of about three quarters of a mile; beyond which the conglomerates again appear on the twelfth lot, and can be followed thence with facility to the north side of the eighteenth lot, the distance being about two miles. In this, they gradually pass from the seventh to the sixth range, and in the latter half of their course keep close upon the line dividing these ranges. The general dip is about S. 75° E. < 40°–45°; but irregularities occur in some parts, occasioned by transverse dislocations. There appears to be one of these on the thirteenth lot, another on the line between the fourteenth and fifteenth lots, and a third probably occurs at the Wallbridge mills, on the fifteenth lot, where the Beaver Brook finds a passage across the bands. The strata are concealed across the nineteenth lot; but the conglomerates again appear for 300 or 400 yards on the twentieth, and finally gain the twenty-first lot. Their course across this lot is about N. 40° E.; and gaining the north side of the lot, toward the east end, the upper band is seen to make a turn in folding over an anticlinal axis, on the north side of which it returns in a course about S. 70° W., for 600 yards; showing a high dip to the westward of north.

Pike River.

Transverse faults.

Anticlinal

None of the strata belonging to part 2 of division D have been observed in connection with this run of the division from the seventh lot of the seventh range, before reaching the fourteenth lot of the sixth range of Stanbridge. Here the conglomerate band at the top of D 2, is exposed for about 300 yards along the Farnham road, showing a breadth of about fifty yards. Indications of it are seen again on the Beaver Brook, on the fifteenth lot; and it is said to have been struck in sinking a well, on the east side of the road in the seventeenth lot. On the west side of the road there occurs a band of brown-weathering black dolomitic slates, which underlies the conglomerate. The most northern, and the only other observed exposure of this conglomerate band 2 of D, occurs on the twenty-second lot of the fifth range; where it dips northward at an angle of from forty to fifty degrees, and is evidently on the north side of the anticlinal axis over which the lower conglomerate 1 of D, folds in the next range.

Farnham road.

The only examinations which have yet been made of the strata of part 3 of division D, are upon a road running eastward from the Farnham road between the eighteenth and nineteenth lots, and upon another road running eastward from the Wallbridge mills, on the fifteenth lot. The strata seen on both of these roads are chiefly brown-weathering dolomitic slates. On the more northern one they show a breadth of about two miles, extending about 700 yards into the fourth range; on the other road, with a breadth of a mile and a quarter, they have been observed to about the middle of the fifth range. About nine chains west of the line between the fifth and sixth ranges, the dolomitic slates are interstratified with a ten-

Dolomitic slates.

Anticlinal. feet band of black limestone conglomerate; and about eleven chains east of the line, they fold over the axis of an anticlinal, which is probably a continuation of the one passing near Blood's Corners. What effect this anticlinal, in its farther prolongation, may have upon the distribution of the rocks of the division D has not yet been ascertained.

Hudson River formation. Immediately to the northwest of the mass of rocks belonging to the Quebec group, which have thus been followed from Vermont to the twenty-first lot of the sixth range of Stanbridge, there runs the whole way, a depression, occupied partly by Lake Champlain, and partly by low flat land, often covered with swamp. Beyond this, at a variable but moderate distance, there is a ridge of black slates resembling those of the Hudson River formation, and considered equivalent to them, between which and the Phillipsburgh series, there is supposed to be a great break. These slates are seen within 500 yards of the exposure of the conglomerates of D 1, already mentioned as occurring on the twentieth lot of the township; and dip in the same southeastward direction, with a slope of forty-five degrees. They are seen also on the twenty-first lot; and here their strike would bring them to within 250 yards of the conglomerate band, where it is doubled over, very probably by the effect of the dislocation, to a precipitous dip westward of north. On the road between the eighteenth and nineteenth lots, the distance would be about 700 yards, and on the road west of Bedford, about half a mile. On a road in the sixth lot the black slates would be about half a mile west from the massive limestones of the division C; but about half a mile southwestward of these, there start up from the intermediate flat ground two isolated masses of strata dipping westward of north, at high angles, and showing in ascending succession about seventy feet of dove-grey limestone, fifty feet of white-weathering sandstone, and twenty feet of thin bedded slaty black limestone. These rocks, which are distinct from and higher than any of the divisions first described, may for convenience be designated as division E. They resemble in sequence and lithological character the lower part of the strata of St. Dominique, and of Highgate Springs; to which they are still farther assimilated by the occurrence in the thin bedded limestone of *Stenopora fibrosa*, a fossil which is not met with lower than the Chazy formation in the undisturbed outcrop of the Lower Silurian series at the base of the Laurentian hills. These two isolated masses of strata stand one behind the other, at a distance of about 250 yards; and in the more northern one, following a small twist, there is a fault running parallel with the general trend of the black slates, and producing a displacement of about fifty yards. This carries a part of the northern mass nearer to the southern, and it is probable that there may be other breaks or twists between them. It would seem that a part of the Chazy has here been brought up from beneath the Hudson River formation; and there would be quite room enough

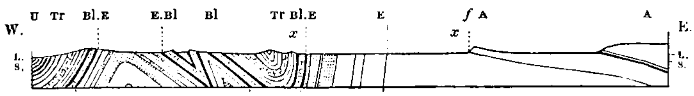
Division E.

Chazy formation.

under the concealed space between the isolated masses of the former, and the black Hudson River slates, for the Birdseye and Black River, as well as the Trenton formation.

At Phillipsburgh these black slates come against the strata of part 1 of division A. The relation of the strata on the western and eastern sides of the great fault which there runs between them, as well as of those on the opposite sides of its continuation at Highgate Springs, has already been *Highgate Springs*

444.—SECTION AT HIGHGATE SPRINGS, VERMONT.

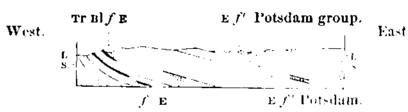


Horizontal and vertical scale, three inches to a mile.

L L, level of lake; S S, sea level; A A, lowest division of the Quebec group in the Phillipsburgh series, page 844; E E, the Chazy formation, with the dove-grey limestones at its base, page 854; Bl, Black River formation; Tr, Trenton formation; U, Utica formation; *f*, proximate place of fault. The portion from *x* to *x* is concealed.

given on pages 273–275. The strata on the west side of the fault, at the latter place, belong to the Chazy, the Birdseye and Black River, the Trenton, and the Utica formations, and the accompanying diagram, 444, shows their arrangement. The Trenton at its final outcrop, has a western dip, and there would be room in the covered space between it and the Quebec group for the Birdseye and Black River formation, as well as for the Chazy, and the dove-grey limestone which may be a part of it. In the diagram these formations are introduced in the position which they probably occupy to the eastward of the strata exposed. At Smith's lime-works, about eight miles *Smith's lime-works*

445.—SECTION AT SMITH'S LIME-WORKS.



Horizontal and vertical scale, three inches to a mile.

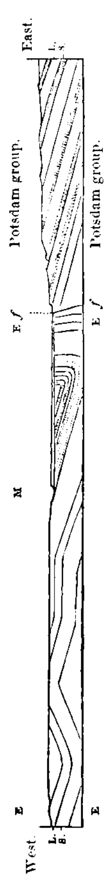
L L, level of Lake Champlain; S S, sea level; E E, Chazy formation, with lower dove-grey limestones, as above; Bl, Black River formation; Tr, Trenton formation; *f f*, fault; *f′ f′*, break or overlap bringing up the Potsdam group.

southward of Highgate Springs, these formations (probably on the east side of another synclinal) become inverted, as described on page 280, and a wood-cut, 445, is now given to illustrate their attitude. In this a line is introduced, showing the position of the great break that must here occur;

beds on the west side of this position do not run conformably under those to the east. Both to the north and the south of the lime-works there have been observed some additional facts in connection with the rocks involved in this inversion, which deserve to be noticed.

Between the high road and the railway from St. Alban's to Swanton, and about a mile and a half northward from Smith's lime-works, there occurs another exposure of the rocks of division E. The dove-grey limestone approaches to within 240 yards of the high road, and shows a breadth of about the same measure, with a dip E. $< 30°–80°$. The west side of this mass, in its strike to the south, would come close upon the east side of an exposure of the sandstone; which, with a dip in the same direction as that of the limestone, has a breadth of 220 yards, with an inclination of from thirty-five to fifty-five degrees. This would give it a greater thickness than where seen elsewhere, but its apparent volume may possibly be increased by disturbances. On the west side it becomes interstratified with the black limestone, which terminates the exposure, and approaches to within about 120 yards of the railway. These masses are precisely in the strike of those at the lime-works, and a continuation of the strata in the same direction would carry them, in less than a mile, across the road over the flat land between the red strata of the Potsdam group (page 281), and the Missisquoi bridge

Swanton. southeast of Swanton. Less than another mile in the same direction would bring us to a development of the dove-grey limestone about a mile east from Swanton, on the road to Highgate Falls. The strata of this exposure, which has a length of about 400 yards, and a breadth of about 200, are arranged in the form of a trough converging northward; the dip on the west side being about S. 72° E. $< 55°–80°$, and on the east S. 60° W. $< 40°–85°$. But to the southwest of this there is another and a very considerable exposure of dove-grey limestone between Swanton and the Missisquoi bridge already mentioned. The area which it occupies has a length transverse to the measures of about 1200 yards, terminating southeastwardly at the margin of the river, and a breadth, with the measures, of about 700 yards. The general strike of this mass appears to be about N. 15° W.; which would carry it a little to the westward of the exposure on the road to Highgate Falls. The general dip of the strata is to the eastward: the angles of inclination, as ascertained on the east and west sides of it, vary from thirteen to twenty-five degrees; but in the intermediate part, there occur one or two undulations, which serve to diminish the average rate. This area has very probably a farther extension northward, and may join the west side of the one just described as occurring more to the north; the strike of that side of the more northern exposure being directed towards it. Its position and attitude would seem to indicate that it is on the western side of a trough, of which the exposures of dove-grey limestone farther south are on the eastern, and more precipitous or overturn side, and that these masses have above them in the middle, a conforming mass of the sandstone and black limestone. The diagram 446, represents a section running east and west across the Missisquoi River, at the bridge southeast of Swanton. It illustrates the relation of the dove-grey limestone which is west of the bridge, to the strata of division E to the south of it, and to those of the Potsdam group to the eastward.



446.—SECTION NEAR SWANTON, VERMONT.

Horizontal and vertical scale, three inches to a mile.

L L, level of Lake Champlain; S S, sea level; E E, Chazy formation, with underlying strata, as on page 855; f f, break or overlap, bringing up the Potsdam group; M, the Missisquoi River.

To the southward of Smith's lime-works the same series of strata occur at the lime-works of Mr. Rich. They still present the same inverted attitude, and Professor Emmons states that *Orthoceras* is here met with in the dove-grey limestone. Still farther southward, about a mile beyond Stephen's Brook, the dove-grey limestone is seen close against the red strata of the Potsdam group; and about a quarter of a mile to the west of it there is a small exposure of the black limestones, the sandstone being probably concealed in the interval. The dove-grey limestone continues along the cliff in a narrow band for about a mile. There is then an interval of about half a mile from which it is absent, but it again becomes exposed in the vicinity of St. Alban's Bay, at the mouth of the ravine leading up to St. Alban's, and on the opposite sides of it. On the north side it runs along the escarpment of the Potsdam strata for nearly half a mile, approaching to within twenty yards of it. Both rocks dip about S. 80° E.; but while the Potsdam beds present a pretty uniform inclination of from fifteen to twenty degrees, the inclination of the dove-grey limestone varies from fifteen to sixty-five degrees. The breadth of the limestone is here about 180 yards, and on the western side of it, which would be the top, there occurs a *Pleurotomaria* very like *P. Quebecensis*. The dove-grey limestone here, as farther north, is succeeded by the sandstone, the two being seen in contact, and the black limestone follows. On the south side of the ravine there are two exposures of the dove-grey limestone, one nearly touching the red strata of the Potsdam group, and the other about a quarter of a mile to the north-

Rich's lime-works.

St. Alban's Bay.

The mass near to the Potsdam strata dips in the same direction with them, about S. 70° E., but at a higher angle; the inclination of the latter being from seven to fifteen degrees, while that of the former is from twenty to forty-five degrees. The more western exposure of the dove-grey limestone is followed by the sandstone; which becomes interstratified with thin beds of black limestone, and is limited by a thick bed of this rock, studded with nodules of black chert. This is seen where the rivulet flowing from the ravine falls over the escarpment formed by the limestone. In its strike, nearly half a mile to the south, a limestone of the same color occurs, holding *Strophomena alternata*, a *Maclurea* like *M. Atlantica* of the Chazy, with a *Pleurotomaria*, (these two being seen in section,) together with an *Asaphus* like *A. platycephalus*. The first and last of these species ascend to the Hudson River formation. Opposite to the ravine, and in a position which is westward of the northward strike of the black limestones, there occur two exposures of dove-grey limestone, constituting two mounds or hillocks, belonging probably to one mass of rock, with a length of about 500 yards, and a breadth of 150. In the arrangement of this mass, there appears to be a curve, the dip at the west end being about S. 55° E. $<58°$, while on the southwest side it is about N. 35° E. $< 50°$–$60°$. The mass appears to be underlaid by black slates similar to those at the Missisquoi bridge, west of Swanton; and it may belong to the west side of the same synclinal as the dove-grey limestone at the east bridge, and have a concealed outcrop connection with it. It is probable that there may be a transverse dislocation running up the ravine at St. Alban's Bay, throwing the measures on the south side of it to the westward. This would apparently pass between the rivulet which falls over the cherty limestone, and the two hillocks which have been mentioned, and would keep to the north of the road to St. Alban's. On this road, about a mile west of St. Alban's, there is a band of limestone conglomerate, holding large masses of grey pure limestone, imbedded in a brown-weathering calcareo-magnesian paste; which is traceable for upwards of a quarter of a mile north of the road before it disappears: the place of the fault would probably be a little north of this. About a quarter of a mile farther west, on the road, this conglomerate is followed by a mass of whitish sandstone, weathering brown; at the base of which there is another band of conglomerate, with fewer and smaller masses of pure limestone. Immediately beneath this occurs a band of dark grey slightly micaceous slate, with *Obollela cingulata*. Its position is about 1200 yards from the escarpment of the Potsdam red strata, where these come in contact with the dove-grey limestone on the south side of the ravine. The average inclination of these strata is about eleven degrees, which would give a thickness of about 680 feet. The thickness in the Potsdam section to the east of Swanton (page 281), from the white and red dolomites to the top of the Paradoxides bed, is 650 feet; and the

Trenton fossils.

Obollela slates.

slates in the two localities so closely resemble one another that there is not much doubt of their equivalency.

It will be seen from what has been said, that between St. Alban's Bay and the middle of Stanbridge, there are two great dislocations connected with the Quebec overlap; the western one running from the outside of the hillocks of St. Alban's Bay, by Swanton, Highgate Springs, and Phillipsburgh, to the twenty-first lot of the sixth range of Stanbridge; and the eastern from the mouth of the ravine at St. Alban's Bay, by Smith's lime-works, the Missisiquoi valley southeast of Swanton, the Rock River on the province line, and the house of Mr. J. Carruthers, to the one hundred and twenty-ninth lot of St. Armand. It was stated as probable, on page 283, that these two faults would join one another somewhere in the neighborhood of Smith's lime-works. This statement must now be modified. The junction is evidently south of St. Alban's Bay, and it would require farther examination to know how near it may approach to Burlington. From the position of the highest dove-grey limestone on the Highgate Falls road, east of Swanton, and of the lowest, near Mr. Robey's residence, it is evident that a dislocation must pass between them, from the eastern to the western fault. To determine the position from which this starts from the eastern fault, will require additional facts; but about a mile south from Robey's, there is an exposure of grey pure limestone, and about half a mile east from this another; the former showing *Ophileta*, and the latter in one or two of its beds almost made up of *Stromatopora compacta*, a species hitherto not found lower than the horizon of the Chazy formation. Possibly some evidence may hereafter be obtained near these exposures, to elucidate the matter. In the meantime, it is probable that this intermediate break joins the western fault somewhere not far from the mouth of the Rock River; and it would appear that included between the east and west faults, from the intermediate break southwards, we have an area composed of a mass of conformable deposits, of which the Trenton formation is at the summit; while between the same faults, from the intermediate break northward, are included deposits belonging wholly to the Quebec group. The strata in each area are arranged in the form of a trough, with a comparatively gentle dip on the west, and a precipitous or overturn dip on the east side; and as the strata of the more northern area approach the west fault, it is seen in some parts that they become precipitously bent over toward it. The northern trough-like area, as has been shown, is divided into two subordinate forms of the same character, by an anticlinal with a gentle dip on the east, and a precipitous, occasionally overturn dip on the west. Were this anticlinal to pass into a fault by the disruption of the strata on the west side, it would represent the probable character of the greater disturbances to the east and west of it; the one to the west being

Two dislocations.

General structure

Between Stanbridge and Quebec no fossiliferous strata have been met with similar to those of the divisions A, B, and C of the Phillipsburgh series. The nearest approach to the material of any of these beds occurs in some of the lighter colored masses of limestone enclosed in the Point Lévis conglomerates. The strata accompanying these closely resemble those associated with the conglomerates of division D in Stanbridge, particularly the brown-weathering magnesian limestones and magnesian slates; the latter of which in both localities are characterized by the same fucoid in similar abundance. The limestone masses in the Stanbridge conglomerates, in as far as these have been examined, appear however to be chiefly derived, as has already been stated, from the dark colored limestone of division C. If with these there were mingled any considerable proportion of the ruins of the lighter colored limestones of A and B, the general lithological resemblance of the Stanbridge and Point Lévis conglomerates would be sufficiently close to leave little doubt of their equivalency. With the exception of the locality at Bedford, the Stanbridge conglomerates have however yielded scarcely any fossils other than those which characterise the dark colored limestone of C. None of the species belonging to this division have ever been met with in the Point Lévis conglomerates, and the only fossils common to these, and to the Stanbridge conglomerates are *Ophileta uniangulata*, which occurs in the latter in one of the exposures on the Henryville road: and two specimens from Bedford. One of these strongly resembles *Agnostus Orion*, and the other is the hypostoma of an *Asaphus*, identical with a specimen from the island of Orleans. Eight of the most characteristic species of the divisions A and B of the Phillipsburgh series occur in the conglomerates of Point Lévis. These are *Camerella calcifera*, *Holopea dilucula*, *Ecculiomphalus Canadensis*, *E. intortus*, *Bathyurus Saffordi*, *B. Cordai*, *Chierurus Eryx*, and *Menocephalus globosus?* The occurrence of these fossils, and the general structure of the Point Lévis conglomerates, seem to support the opinion that some of the rounded masses enclosed in these may be derived from the ruins of limestones equivalent to those of A and B of Phillipsburgh, in the same way as the masses of the Stanbridge conglomerates are derived from C. This would place the two series of conglomerates on the same horizon; and although the difference in time might not be great, it would make the Point Lévis rocks somewhat younger than the lower divisions of Phillipsburg. At the same time however, some of the fossiliferous portions of the Point Lévis bands, having the same color and texture as the supposed boulders, possess the character of original sediments or concretionary masses, and it is difficult to separate the fossils of these from those of the rolled masses.

Point Lévis conglomerates.

Stanbridge conglomerates.

It is not yet certain how many of these conglomerate bands there may be in succession at Point Lévis, but it will be seen from a plan in the Atlas accompanying this Report, that there are supposed to be at least nine.

On this plan, the heavy black bands represent the known exposures of the limestone conglomerates, while the dotted lines between different exposures represent their supposed connection. Some of the geographical undulations are shown by what are designated on the plan as the Coast Ridge, and the North, Middle, and South Ridges. The main feature of the Coast Ridge is a thick band of limestone conglomerate, extending in a hill and precipice, which overlook the beach from Patton's wharf to the neighborhood of the Lower Ferry; beyond which it gives place to the cliff which is immediately behind the houses near the Lower, Middle, and Upper Ferries. The North Ridge is a hill, which rises up from and runs parallel with the road passing in front of the Temperance Monument or Cross, and attains its greatest height in a band of limestone conglomerate, about 300 yards southeastward. The Middle and South Ridges are respectively about a quarter and three quarters of a mile to the southeast of this. Ridges at Point Lévis

Southeastward from the St. Lawrence, the limestone conglomerates of Point Lévis are distributed over a breadth of more than two miles. In the Middle and South Ridges they are arranged in two well marked anticlinal forms; and the axis of a third anticlinal is suspected to run along the road on the north side of the North Ridge. In the North Ridge there are four bands, numbered 1, 2, 3, 4, on the plan; on which is represented, in addition, a long lenticular bed, 4^a, subordinate to 4, but separated from it by slate. This lenticular bed is composed of brown-weathering magnesian limestone, but appears to contain few or none of the included masses of pure limestone which characterize the conglomerates. On the north side of the Middle Ridge are exposed five additional bands, numbered 5, 6, 7, 8, and 9 on the plan. From the dotted lines on this the relation of the whole will be understood. Distribution of bands

The distribution of the fossils in these bands is shown in the following catalogue, in which there is a column for each of the nine bands mentioned, and also for each of three bands marked D, G, and A on the plan. The first of these three occurs at the margin of the St. Lawrence, in front of the Coast Ridge, and the other two along the cliff to the southwest. To these three bands no certain stratigraphical place is assigned; but should an anticlinal form really exist on the north side of the North Ridge, they would probably be a repetition of some of the lower bands in the series from 1 to 9, which is in ascending order. With the exception of those otherwise marked, all the determined species have been described by the palæontologist of the Survey. Fossils

LIST OF FOSSILS FROM THE VARIOUS BANDS AT POINT LEVIS.

	D	G	A	1	2	3	4	5	6	7	8	9
Tetradium ?		*										
Graptolitidæ, several sub-genera (Hall),		*					*					
Lingula Mantelli,						*	*					
" Irene,		*										
" Quebecensis,			*									
Obolella Ida,						*	*					
" desiderata,			*									
Acrotreta, undescribed,						*						
Leptæna decipiens,								*	*	*	*	*
" sordida,								*				
" undescribed 1,								*				
" " 2,						*						
" " 3,							*					
Strophomena, undescribed,			*									
Orthis gemmicula,								*				
" Tritonia,								*				
" orthambonites (Pander),								*				
" Euryone,								*				
" Electra,								*				
" Hippolyte,								*				
" Evadne,								*				
" Mycale,								*				
" Eudocia,								*				
" Quebecensis,			*									
" undescribed 1,						*						
" " 2,							*					
" " 3,							*					
" " 4,												*
Camerella calcifera,						*	*					
Stricklandia ? Arachne,								*				
" Arethusa,								*				
Cyrtodonta ? undescribed,								*				
Ecculiomphalus Canadensis,							*	*				
" intortus,							*					
Pleurotomaria vagrans,							*					
" Postumia,							*					
" Quebecensis,							*					
" undescribed 1,							*	*				
" " 2,							*					
" " 3,											*	
" " 4,											*	
Murchisonia, undescribed 1,							*					
" " 2,							*					
" " 3,							*					
" " 4,											*	
Helicotoma perstriata,							*					
Ophileta uniangulata (Hall),							*					
" undescribed 1,							*					

FOSSILS FROM POINT LEVIS.—*Continued.*

	D	G	A	1	2	3	4	5	6	7	8	9
Ophileta undescribed 2,							*					
Maclurea Atlantica,											*	
Holopea dilucula (Hall),							*					
" undescribed,							*					
Metoptoma Melissa,							*					
" Hyrie,							*					
" Orphyne,							*					
" Venillia,						*	*					
" anomala,							*					
" Augusta,							*					
" superba,						*	*					
Orthoceras Autolycus,							*					
" undescribed 1,							*					
" " 2,							*					
" " 3,							*					
" " 4,							*					
" " 5,							*					
" " 6,												*
Cyrtoceras Metellus,							*					
" Dictys,							*					
" Alethes,							*					
" Mercurius,							*					
" Syphax,							*					
" undescribed,											*	
Nautilus, "												*
Agnostus Americanus,						*	*					
" Orion,						*	*					
" Canadensis,						*	*					
Amphion Cayleyi,						*	*					
Ampyx, undescribed,							*					
Arionellus cylindricus,						*						
" subclavatus,						*						
Asaphus Illænoides,						*						
" goniurus,						*						
Bathyurus capax,						*						
" dubius,						*						
" bituberculatus,						*						
" armatus,												
" Saffordi,							*					
" oblongus,							*					
" Cordai,						*						
" quadratus,					*		*					
Cheirurus Apollo,							*					
" Eryx,							*					
Conocephalites Zenkeri,							*					
Dikelocephalus magnificus,						*	*					
" planifrons,						*	*					
" Oweni,						*						

FOSSILS FROM POINT LEVIS.—*Concluded.*

	D	G	A	1	2	3	4	5	6	7	8	9
Dikelocephalus Belli,	..	..	..	..	..	*	*					
" megalops,	..	..	..	..	..	*						
" cristatus,	..	..	..	..	..	*						
" undescribed,	*											
" (Olenus) Logani (Devine),	..	..	..	..	..	..	*					
Endymion Meeki,	..	..	..	..	..	..	..	..	..	..	*	
Holometopus Angelini,	..	..	..	..	..	..	..	..	..	..	*	
Illœnus, undescribed,	..	..	..	..	..	..	..	..	..	..	*	
Leperditia,	..	..	..	..	..	..	..	..	..	..	*	
Menocephalus globosus,	..	..	..	..	..	..	*					
" Sedgwicki,	..	..	..	..	..	..	*					
" Salteri (Devine),	..	..	..	..	..	..	*					
Nileus, undescribed,	..	..	..	..	..	..	*					
Shumardia granulosa,	..	..	..	*								

Strait of Belle Isle

Newfoundland

In describing the rocks on the strait of Belle Isle, it was stated on pages 287–292 that the strata on the north side, belonging to the Potsdam group, descend to the water at an inclination of about sixty feet in a mile ; and that those immediately opposite, on the south side, apparently belonging to the Calciferous formation, rise from the water at an angle so small that it was nearly impossible to distinguish it by the eye. The beds under the strait thus appeared to form a shallow trough ; and the strata along the coast, southward from Anchor Point, showing a very small slope to the southwest, seemed, along the water-line, to be turning from the extremity to the side of the trough in question. An examination of the coast of the island from Anchor Point northward to Cape Norman, has shown that the same strata descend with a very gentle slope all the way in that direction also. It is inferred therefore that in neither direction is this small inclination at right angles to the strike, and that the true dip must be between them, or toward the southeast. The scarcely appreciable rise mentioned as occurring on the southwest side of the strait must probably therefore be only local, and there is consequently no reason for supposing that the beds under the strait are arranged in the form of a trough; although it is possible, as will be seen farther on, that they may be on the north side of a synclinal form, of which the axis would be at some distance to the southeast. If, in this case, it be assumed that the dip of the beds under the strait is southeastward all the way across, it would be necessary to assign to them a much greater thickness than that given to division 3 of the section on page 289. Instead of 250 feet, their volume would probably be between 800 and 900 feet. This would better accord with the thickness which has since been found by direct measurement to belong to their supposed equivalents in Bonne Bay.

In the ascending section of the Labrador and Newfoundland rocks given on pages 288–290, the divisions were arranged under the numerals 1 to 16. Some of these divisions have since been re-measured in greater detail than before ; while with respect to others, the examination of their equivalents in other localities has shown that these divisions include additional strata. In giving these farther results, it will be convenient to designate the divisions by letters, and to indicate the subordinate parts of each by numerals. To facilitate a comparison of the present results with those stated in the previous chapter, a summary of the section already referred to is here given, with the former numerals, but having the letters now to be used, prefixed. The thickness formerly assigned to these divisions, and the localities in which they were observed, are also appended. Section.

POTSDAM GROUP.

				Feet.	Feet.	
A.	1.	Red and grey sandstones,	Ance au Loup,	231		Potsdam group.
B.	2.	Grey, reddish, and green limestones,	" "	143		
C.	3.	White sandstones, concealed,	Strait of Belle Isle,	250		
				——	624	

QUEBEC GROUP.

D.	4.	Grey and reddish magnesian limestones,	St. Barbe Bay,	150		Quebec group.
E.	5.	Dark grey limestones,	" "	400		
F.	6.	Dark grey geodiferous limestones,	Port au Choix,	400		
G.	7.	Dark grey limestones,	" "	130		
H.	8.	Greyish-blue limestones,	" "	340		
I.	9.	Light yellowish-grey magnesian limestones,	" "	150		
K.	10.	Grey and whitish magnesian limestones,	Point Rich,	130		
L.	11.	Light bluish-grey limestones,	"	130		
M.	12.	Light bluish-grey limestones,	Table Head,	550		
N.	13.	Black bituminous limestones,	"	200		
				——	2580	
O.	14.	Grey calcareous sandstones and black shales,	Cow Head,	700		
P.	15.	Grey and white limestone conglomerates,	"	700		
				——	1400	
Q.	16.	Greenish sandstones and red shales,	Bonne Bay,		2000	
					6604	

Between one and two miles inland from the northeast side of the East Arm of Bonne Bay (page 292), there arises a range of hills of Laurentian gneiss, 2,000 or 3,000 feet in height, on the flank of which is exposed the following measured section: Bonne Bay.

A.	Feet.	Feet.	
1. Blackish-blue fine grained slate, with a cleavage independent of the bedding. Of this slate only 105 feet of the upper part are seen ; the lower part is concealed in the space between the upper portion and the gneiss, and may comprise a thickness of about 230 feet,	335		Division A.
2. Blackish-blue slate interstratified with grey quartzites, in beds of from six inches to three and four feet. In the eighty feet at the bottom, the quartzites greatly predominate, and they constitute fifteen feet at the top, while the intermediate 175 feet consist chiefly of slate,	270		
	——	605	

B.

		Feet.	Feet.
Division B.	1. Light grey yellow-weathering limestone, in beds of from one to three inches thick, interstratified with blackish-blue slightly calcareous slate, both containing small specks of silver-white mica, which are more abundant in the limestone than in the slate. The limestones hold in abundance fragments of trilobites, chiefly belonging to three or four species. Among them is *Paradoxides* (*Olenellus*) *Vermontana*, a new species of *Bathyurus*, and the pygidium of a species so closely resembling *B. extans* of the Birdseye and Black River formation, that it can scarcely be distinguished from it, and may possibly be the same,	80	
	2. Greyish-green micaceo-arenaceous shale, interstratified with a few beds of greyish quartzite weathering slightly yellow,	80	
	3. Strata concealed,	30	
	4. Reddish granular quartzite in thick beds, with numerous parallel joints in two directions, dividing the beds into rhomboids,	105	
	5. Grey and greyish-green micaceo-arenaceous shale in beds from a quarter of an inch to an inch thick, interstratified with a few beds of grey very ferruginous, sandy dolomite, and fewer of grey quartzite,	127	
	6. Reddish quartzite, in beds of from one to two feet thick,	34	
	7. Grey arenaceous dolomite, weathering yellowish-brown, interstratified with reddish quartzite, in beds of from one inch to one foot thick, and with reddish and greyish micaceo-arenaceous shale, predominating toward the top. The beds of dolomite and shale contain fossils, among which are *Obolella chromatica?* *Obolus Labradoricus*, *Paradoxides Vermontana*, *Conocephalites*, a new species of *Bathyurus*, and one or more undetermined species of *Salterella*,	27	
			483

C.

		Feet.	Feet.
Division C.	1. Whitish quartzite in beds of from six inches to two feet, interstratified with light grey micaceo-arenaceous shale, in layers of from six inches to one foot, which occur at intervals of from five to ten feet,	150	
	2. White and reddish quartzite, in beds of from one to three feet thick, interstratified toward the bottom with a grey arenaceous dolomite, weathering yellowish-brown,	160	
	3. White and reddish quartzite, in beds of from one to three feet thick, interstratified with greenish micaceo-arenaceous shale, constituting about one half the amount,	90	
	4. Grey pure limestone, in beds of from one to three feet thick, marked with a few reticulating strings of yellowish-weathering dolomite. The rock is a mass of comminuted organic remains, among which are *Paradoxides Vermontana*, and undetermined species of *Bathyurus* and *Salterella*, as before,	20	
	5. Blackish-blue soft shale, interstratified with grey yellow-weathering limestone, probably magnesian, in beds of one or two inches thick. The quantities of shale and limestone are about equal, and the whole is intersected by reticulating strings of calc-spar,	35	
	6. Grey pure limestone, composed of comminuted organic remains, belonging to *Paradoxides*, *Bathyurus*, and *Salterella*, as before,	27	
	7. Bluish-black soft shale, interstratified with grey yellow-weathering dolomitic bands as before,	60	

	Feet.	Feet.
8. Grey pure limestone, probably composed of comminuted organic remains as before; underlaid by bluish-black shale enclosing nodules of blue compact limestone; some of which weather yellowish-brown, and are probably magnesian,	13	
9. Bluish-black soft shale of the same character as before, interstratified with a few beds of quartzite,	68	
		623
		1711

The summit of the above section occurs on the east side of Deer Brook Bay on the East Arm of Bonne Bay, and its base about six or seven miles up the East Arm from the mouth of Deer Brook. All of the beds can be seen coming to the coast in succession, with a westward dip, and an inclination of from twenty to sixty degrees. Where the beds of the base were observed, the measures appear to fold over an anticlinal axis, and for about 100 yards they dip to the eastward. For two miles beyond this, along the east side of East Bay, the greatest confusion prevails, and nothing reliable in regard to the sequence can be obtained from the exposures. East Bay and West Bay are two deep southward parallel indentations of the coast, which form the extremity of the East Arm. The area between them is from one to two miles wide, and the strata in it appear to lie in the form of a synclinal. The axis of this synclinal would run about north and south, and in the former direction it would strike to the eastward of the anticlinal just mentioned as occurring on the north side of the East Arm, while the axis of this anticlinal would strike into West Bay. The distance across the East Arm, on the axis of the synclinal, from the position where the lowest beds of the section above given would come upon it, to the position where it would be crossed by the lowest beds between East and West Bays, would be about the same as that occupied by the whole section between the Laurentian gneiss and the coast of Deer Brook Bay. On the west side of this bay there occur some limestones of a peculiar color and character, whose stratigraphical place would be a few hundred feet above the highest beds in the section just given. About the same distance above the base of the strata between East and West Bays, similar limestones occur; and there is therefore not much doubt that the strata between these bays come in immediate or proximate sequence to those already given in the section C. These additional strata are as follows: East Arm

C.—*Continued.*

	Feet.	Feet.
10. White quartzite, in beds of from two to three feet thick, interstratified with striped olive-drab and black compact arenaceous magnesian brown-weathering limestone, which constitutes one fourth of the mass, and holds small disseminated masses of iron pyrites,	58	
11. Strata concealed,	150	

Division C.

	Feet.	Feet.
12. Blackish-grey limestone; it is divided into beds of from two to eight inches, and under the influence of the weather breaks up into thin scales,	54	
13. Smoke-grey compact pure limestone, striped with ochre-yellow arenaceo-ferruginous limestone, passing into brick-red. The grey and yellow alternate in lenticular layers, varying in thickness from a quarter to half an inch, and the rock presents a very peculiar and striking aspect. The yellow and red colors may be the effect of weathering, but in breaking up the rock the same alternation of these with the grey limestone was apparent in the interior. Rock of the same character occurs on the west side of Deer Brook Bay,	30	
14. Olive-grey brown-weathering ferruginous sandy dolomite, containing thin lenticular patches and thin beds of pure smoke-grey limestone, with disseminated cubes and small masses of iron pyrites,	17	
		309
D.		
Division D. 1. Greenish-white and yellowish-white magnesian limestone, in massive beds, some of which are ferruginous and weather buff, while others remain unchanged in color. They are interstratified with beds of ash-grey limestone, weathering yellowish, and near the middle with two bands of grey calcareo-arenaceous shale, one of two, and the other of three feet thick. These massive limestones terminate in a four-feet bed of smoke-grey pure limestone in thin layers, interstratified with thin layers of probably magnesian limestone, weathering ochre-yellow. The bed, for the thickness of a foot, is arranged, on the strike, in a series of curves or arches, which span from two to three feet, separated by straight intervals, varying from one to two feet. The curved portions appear to hold a greater number of the yellow-weathering layers than the straight parts, and these layers have in general a lenticular form. The top and bottom of the bed are arranged in even layers, which fill up the inequalities of the intermediate part,		174
		483

The surface between East and West Bays rises into a mountain of 500 or 600 feet in height, in which the strata dip in directions conforming to their synclinal arrangement, at angles varying from twelve to twenty-five degrees. Proceeding southward along the east side of West Bay, they are seen to accumulate above one another to the amount of 1400 feet, in addition to the preceding section. These higher strata consist almost entirely of limestone of various shades of grey, with two or three bands of black, the latter usually thin bedded. Of the lowest 200 feet, about two fifths weather to various shades of yellow and brown; of the succeeding 300 feet the proportion of yellow-weathering beds is about one sixth, and in the remaining 900 feet they are but few. If these yellow-weathering beds are, like the similar ones in the detailed section just given, magnesian, it would appear that the proportion of magnesia gradually diminishes in ascending this portion of the series. In the whole of these 1400 feet,

West Bay.

Divisions E, F, and G.

which are supposed to represent the divisions E, F, G, referred to on page 865, the only strata in which fossils were observed occur at about 400 feet from the top; where the surfaces of various beds, in a thickness of between ten and twenty feet, are marked by the weathered-out forms of silicified fossils, consisting of undetermined species of *Pleurotomaria* and *Ophileta*.

From West Bay, the strata strike, in a general way, along the coast to the westward: they are much contorted, and it is difficult to make out any true continuous succession of the beds. At the west horn of the bay, however, the whitish massive magnesian limestones of division D occur; and in the contorted strata for a couple of miles beyond, the peculiarly striped smoke-grey and ochre-yellow thin bedded limestones of C 13 are occasionally seen. At the promontory which faces the west horn of Deer Brook Bay, the strata become vertical, or nearly so, but somewhat more regular; and the absence of any beds weathering yellow or brown appears to indicate a proximity to the horizon of the silicified fossils above mentioned. About 800 feet of dark grey limestones are here exposed, at the summit of which there occurs a bed holding *Maclurea*, *Orthoceras piscator*, and *Leperditia*. Of the genus *Maclurea*, the opercula were the only parts observed, and these are silicified; but the bed is supposed to be higher in the series than the band with silicified fossils between East and West Bays, inasmuch as it is immediately followed, not by the dark-grey limestones, but by about 200 feet of light grey limestone; a good deal of which, although it does not weather yellow, is magnesian. The summit of these 200 feet is fossiliferous, and contains undetermined or undescribed species of *Orthis*, *Ophileta*, *Maclurea*, *Nautilus*, *Amphion*, *Asaphus*, and *Leperditia*. The 800 feet are probably comprised in the divisions F and G, while the 200 feet may constitute a part of H.

The divisions M and N of the Newfoundland rocks have been, in a general way, described from exposures occurring at Table Head. The total thickness was here estimated from measurements by pacing, but few details were ascertained; and the fossils collected having been lost, from the necessity of abandoning them on the coast through stress of weather, it was considered expedient to re-examine the locality. The following detailed ascending section is the result. It commences between 600 and 700 feet lower than the strata comprised in the division M, or 12, as previously given on page 284, and the lowest part of these additional strata are considered equivalent to some of those at Point Rich.

Table Head.

Section.

H.	Feet.	Feet.
1. Bluish-grey limestone in beds of from one to two inches, interstratified with grey sub-crystalline yellow-weathering magnesian limestone in beds of from three to six inches thick. The beds are fossiliferous, containing the genera *Orthis*, *Ophileta*, *Maclurea*, *Pleurotomaria*, *Murchisonia*, *Orthoceras*, and *Bathyurus*. The described species are *Orthis electra ?*, *Maclurea matutina ?*, and *Orthoceras piscator*,..	100	
2. Strata concealed,..	165	
		265

Division H.

I.

Feet. Feet.

Division I.

1. Light yellowish-grey mottled and sub-crystalline magnesian limestone, with geodes of calc-spar. The limestone is divided into beds of from six inches to one foot, and shows occasional fossils, the only recognizable species being *Maclurea matutina*,.................... 65
2. Light yellowish-grey mottled magnesian limestone as before, interstratified with greyish-black limestone in beds of from three inches to one foot. The magnesian beds contain *Maclurea matutina*,........ 70

135

K.

Division K.

1. Light grey sub-crystalline limestone, with greyish-black limestone, both in beds of from two to six inches, and associated with a few bands of greyish-white dolomite, from six to nine inches thick; the whole interstratified at intervals of from ten to twenty feet with black and greyish-green shales. The light grey limestone and whitish dolomite are fossiliferous, containing the genera *Orthis*, *Ctenodonta*, *Ophileta*, *Maclurea*, *Pleurotomaria*, *Murchisonia*, and *Orthoceras*. The described species are *Orthis electra*, *Maclurea matutina*, and *Orthoceras piscator*, ... 100

L.

Division L.

1. Greyish-white dolomite and greenish-grey compact limestone, both in beds of from two to six inches thick, interstratified with about three per cent. of black and greyish-green shale, all without observed fossils, ... 104
2. Light reddish-grey magnesian limestone, in beds varying from fifteen inches to two feet in thickness. The rock breaks from the cliff in which it is exposed, in rectangular blocks of several feet long and wide, and would make an excellent building stone. No fossils were observed,.. 16
3. Brownish-grey hard limestone, in beds of from six inches to two feet; Fossils occur at the base, among which are the genera *Stenopora*, *Orthis*, *Murchisonia*, *Asaphus*, and *Leperditia*, ... 65
4. Reddish-grey magnesian limestone, in beds of from two to six inches, without observed fossils, ... 6

191

M.

Division M.

1. Brownish-grey limestone in beds, varying in thickness from six inches to six or seven feet; interstratified at distant intervals with reddish-grey dolomite in beds of from three to nine inches, which constitute one or two per cent. of the whole. Both the limestone and the dolomite are fossiliferous throughout; the organic forms however are obscure in the whole, with the exception of about a foot of the limestone at the base, and six feet at the top, including a bed of the dolomite, in the whole of which the fossils are silicified. The genera at the base are *Eospongia*, *Orthis*, *Ophileta*, *Pleurotomaria*, *Murchisonia*, *Orthoceras*, and *Asaphus*. At the top the same genera occur, but there is a greater number of species, and it is probable that the fossils of these two parts represent those of the whole mass,........ 350

In the fossiliferous beds of divisions K and L, and in part 1 of M, there are several species of each genus, and the same species seem to range through the whole. The described species are *Orthis electra*,

	Feet.	Feet.
Maclurea matutina, and *Orthoceras piscator ;* but the chief part of the species of the remaining gasteropods and cephalopods are so closely allied to some of the common forms of the Trenton group, that it scarcely appears doubtful that they are the same. The most striking resemblances are to *Orthoceras Bigsbyi*, and *O. Allumettense* of the Birdseye and Black River, and to *Murchisonia gracilis*, *M. bellicinta*, and *M. perangulata* of the Trenton formation.		
2. Bluish-grey limestone, in beds varying from six inches to ten feet in thickness, the thicker beds being made up of layers of one or two inches, distinguishable in section by slight differences in color, but without any tendency to separate. Some of the beds are nodular, and crumble under atmospheric influences. Fossils are abundant in all the beds, but are not readily separated. They consist chiefly of *Stenopora fibrosa*, *Orthis*, like *O. Platys*, *Rhynchonella* allied to *R. plena*, *Camerella varians*, new species of *Maclurea*, and *Orthoceras ;* with *O. piscator*, *O. Allumettense ?*, *O. Bigsbyi ?*, *Amphion*, *Ampyx*, *Asaphus*, *Illænus*, and *Leperditia*,......................................	308	
		658

N.

Division N

	Feet.	Feet.
1. Blackish-grey nodular fossiliferous limestone, in beds of from one to three inches thick, becoming bituminous toward the top. The fossils are *Orthis*, *Strophomena*, *Rhynchonella* allied to *R. plena*, a new species of *Camerella*, *Orthoceras piscator*, *O. Allumettense ?* *Amphion*, *Asaphus*, *Holometopus Angelini*, *Illænus*, and *Leperditia*, ...	81	
2. Black bituminous limestones, in beds of from one to three inches thick, interstratified with fine brittle black bituminous shale in layers varying from a quarter of an inch to three inches. The prevailing fossils are *Stenopora fibrosa*, *Lingula* allied to *L. Philomela*, *Orthis*, *Strophomena*, *Rhynchonella* allied to *R. plena*, a new species of *Camerella*, with *C. varians*, *Orthoceras*, *Agnostus*, *Amphion*, *Ampyx*, *Asaphus*, *Endymion Meeki*, *Holometopus Angelini*, *Illænus*, *Nileus scrutator*, and *Leperditia*,..	174	
3. Black bituminous shale, with *Graptolithus*, *Lingula*, *Orthoceras*, and *Paradoxides* or *Olenellus*, ...	22	
		277
		1626

The grey, yellowish, and greenish-white magnesian limestones of division D of the Newfoundland section, occur at Bay St. Barbe. The dark grey limestones, interstratified with yellow-weathering magnesian beds, of division E (5 on page 289), which succeed, occupy a valley which runs obliquely into the land in a direction about N. E. This is the bearing of the strike, and in it a similar valley comes out upon the coast, about twenty miles from Anchor Point, just beyond West Point. From this point to Cape Norman, and to the east side of Pistolet Bay farther on, the chief part of the coast was examined in detail. A thin bedded argillaceous limestone occurs in the bay, at West Point, holding a small *Lingula ;* but in the thirty miles between this and Cape Norman, no organic remains were observed. The rocks consist of dark grey limestone, interstratified with grey yellow-weathering magnesian bands, and present a series of low escarpments along

Bay St. Barbe.

Pistolet Bay

the coast. The dip of the strata is about S. 45° E. < 1°–4° and the bearing of the coast about N. 60° E. In this bearing the strata accumulate above one another, all the way, and the thickness is estimated to be between 400 and 600 feet. At Cape Norman the bearing of the coast changes to one more nearly transverse to the measures, which, after a short distance become affected by undulations. Southeastward from the strike of the beds of Cape Norman there are accumulated between 300 and 400 feet of strata above the preceding, consisting of dark grey limestones, without observed fossils ; but at the summit of these there occur about twenty feet of dark grey and light reddish-grey limestones, interstratified with one another, which are marked by the occurrence of the genera *Ophileta*, *Maclurea*, *Pleurotomaria*, *Murchisonia*, *Orthoceras*, *Piloceras*, *Nautilus*, and *Bathyurus ;* the only described species being *Piloceras Canadense*. Many of the species are identical with, and others strongly resemble, those of division H of the Port au Choix rocks. In lithological character and paucity of fossils the strata from West Point to Cape Norman resemble those of divisions E and F of Bay St. Barbe, and there seems little doubt that the whole series is an unbroken repetition of the four divisions E, F, G, and H.

Cape Norman.

The position of the fossiliferous strata just mentioned is about 100 feet over the level of the sea, and they appear to strike for about the south corner of Norman Cove. They dip at a small angle to the northwestward ; and for about three quarters of a mile to the southeast of them, the strata exposed are either flat, or dip at about the same rate and in the same direction as the fossiliferous beds, until reaching the next cove southeastward of Norman Cove. Here, after a short interval of concealment, there occurs an exposure of about ten feet of black bituminous shales. These beds contain the genera *Graptolithus*, *Orthis*, *Lingula*, *Agnostus*, *Ampyx*, *Triarthus*, *Holometopus*, *Endymion*, *Cheirurus?*, and *Paradoxides* or *Olenellus*. The described species are *Holometopus Angelini*, and *Endymion Meeki*. In most of their species, and in their lithological characters, these beds strongly resemble those of parts 2 and 3 in division N of the Table Head section ; and there is not much doubt that the two series are on the same horizon. Such being the case, there must be a dislocation between the north and south sides of the cove, throwing the measures down about 1400 or 1500 feet on the southeast side.

Norman Cove.

The visible breadth of the black limestones and shales is about twenty yards ; and on the southeastward side they are overlapped by bluish-grey limestone, between which and the black beds there appears to be a fault, with an underlie to the southeastward at an angle of ten degrees. This limestone presents a confused and ragged surface, on which no evidences of stratification were observed for a breadth of three quarters of a mile, and only occasional obscure indications of stratigraphical divisions for a quarter of a mile farther. These obscurely marked beds dip at angles varying from sixty to ninety degrees, and sometimes on one side and sometimes on the other of the strike; which, with many irregularities, is, on the average, about N. E. In the obscurely stratified part of the rock, fossils are met with in three or four spots: the genera are *Orthis*, *Ophileta*, *Maclurea*, *Pleurotomaria*, *Murchisonia*, *Orthoceras*, *Amphion*, and *Leperditia*. All of the species are identical with those occurring in division M of the Table Head section, the most characteristic having the peculiarity of an identity or close alliance with forms of the Trenton group. The *Orthis* resembles *O. platys*, and this, at Table Head, is not found lower than part 2 of the division M.

This rock forms the whole of the west coast of Pistolet Bay, and the fossiliferous part observed is opposite to Schooner Island, from which it is distant about a mile. At the southwest point of this island, between high and low water mark, there is a small exposure of black graptolitic slates, following grey slate interstratified with grey sandy limestone; and there may probably be a run of these rocks along the northwest side of the island. They are succeeded by dark grey limestone, which occupies the whole of the island, with a southeast breadth of three quarters of a mile. In the northwest half of this the rocks present a confused and ragged surface, without any indication of bedding; but in the remainder the stratification is sufficiently distinct. The beds are from an inch to a foot in thickness, and they dip irregularly to the southeast at angles varying from two to twenty degrees. Fossils occur in the rock on the southeast side of the island, the genera being *Eospongia*, *Ophileta*, *Maclurea*, *Pleurotomaria*, *Orthoceras*, *Nautilus*, and *Piloceras*. They resemble those of the neighborhood of Norman Cove, and the rock is probably a repetition of the divisions H and I (8 and 9 on pages 289 and 290) of the Port au Choix beds, brought up by a great fault on the northwest side of the island. **Schooner Island.**

The same rock occurs on the peninsula at Burnt Cape, on the opposite side of Pistolet Bay, the distance across being about four miles. On the west side of the peninsula between high and low water mark, there is a breadth of between forty and fifty yards of grey and greenish slates, interstratified with dark grey brown-weathering sandy magnesian limestone in beds of from one to four inches, and occasionally a foot in thickness. They dip about S. 70° E. $<$ 32°. They are followed by a mass of grey limestone, which rises into a cliff of about 100 feet high, and for a breadth of about a quarter of a mile shows a ragged surface, with no divisions into beds. The limestone weathers to a mottled black and white. The black parts, although holding more lime, yield more slowly to the atmosphere than the white, which appear to owe their color to the presence of grains of white sand. This mass is followed by about an equal breadth of bluish-grey limestone, which rises over the last in an escarpment of about fifty feet. It is divided into beds varying in thickness from six inches to several feet, and **Burnt Cape.**

dips about S. 70° E. < 5°–10°. Both of these limestones are characterized by fossils. Those in the western mass are few and obscure; they consist of *Orthoceras*, and *Piloceras Canadense:* while those in the eastern are well defined, and more numerous; the genera being *Orthis*, *Ophileta*, *Maclurea*, *Pleurotomaria*, *Murchisonia*, and *Orthoceras*. The latter show the peculiar species belonging to M 2, of Table Head; while the former are similar to those of divisions H and I of Port au Choix.

On the narrow isthmus joining the Burnt Cape peninsula with the west shore of Pistolet Bay, and separating the waters of this from those of Ha-ha Bay, the limestones, M 2, on the east side of the peninsula, become covered over by black and dark grey slates, interstratified with dark brown-weathering very sandy magnesian limestones, resembling the strata on the west side of the peninsula, and those on the west side of Schooner Island. These strata line the east side of Pistolet Bay for upwards of two miles to the southward of the isthmus. Their dip is irregular: its direction varies from N. E. to S. E., but on the average it may be about S. 80° E. < 2°–50°. About 200 feet above the limestone of the peninsula there appear on the surface of one of the beds impressions of graptolites. From the recurrence of these slates in this position, it seems probable that between their equivalents, and the limestone on the west side of the peninsula, there is a great upthrow fault. Whether there is any dislocation coincident with the escarpment which runs along the middle of the peninsula, is uncertain. The breadth of these slates is upwards of a mile: they have a well-marked and regular cleavage, but the dip of the stratification, though sufficiently distinct, is very irregular both in direction and inclination; the former varying from N. E. to S. E., and the latter from five to thirty degrees. It is in consequence difficult to estimate their thickness, but it can scarcely be much under from 750 to 1000 feet; and they may represent the strata of division O, which are numbered 14 in the section given on page 290, and were there described as consisting of grey calcareous sandstones, interstratified with greenish and black slates, which predominate toward the top.

Pistolet Bay.

The slates on the east side of Pistolet Bay are dark grey, sometimes greenish, and are striped with thin bands of black. They are silicious rather than argillaceous, and have a considerable degree of hardness. Resting upon them in conformable stratification, and thus apparently occupying the place of division P (15 of page 291), is the following succession of beds, in ascending order:

Section.

	Feet.
1. Olive-green fine grained calcareous diorite, traversed by seams of white quartz, and distinctly marked on the transverse surfaces by numerous small waved lines, which show the stratification. These are due to laminæ of a dark green chlorite-like mineral, resembling that in the diorite of Upton (page 604), to which portions of this mass bear a close resemblance, ...	30

	Feet.
2. Greyish-green diorite, gneissoid in structure, with numerous transverse joints, which are filled with white quartz. It cleaves readily with the elemental layers into thin plates, which are coated with films of a dark green chloritic mineral. Some of the layers are chiefly composed of a greenish-white compact feldspar, while others have a porphyritic aspect from the presence of uncleavable feldspar grains in a blackish-green base, ...	20
3. Fine grained feldspathic rock, striped with narrow bands of black and greyish-green. The former portions are sub-translucent, with a scaly fracture, a feeble waxy lustre, and weather opaque white. Interstratified with this mass are bands of from one to two inches of a similar feldspathic rock, greyish-white, sub-translucent, impalpable, and with a conchoidal fracture. Like the greenish portions, it weathers opaque white, and has the aspect of an amorphous triclinic feldspar, ...	15
4. Fine grained black slate, with thin dark grey bands. It resembles the slates at the base of this section, but has nearly the hardness of quartz, and besides its slaty structure, has a conchoidal fracture. It is interstratified with bands of from one to six inches of granular diorite, in which the feldspar greatly predominates. Their color is greyish, with greenish layers which resemble the lighter colored portions of 2. Thin bands of serpentine, like those of 6, are also interstratified with these slates. Along the outcrop, numerous graptolites were found in loose masses of a black slate apparently identical with that of the band,..	30
5. Fine grained greenish feldspathic rock, with blackish-grey streaks and clouds. It much resembles 3, but encloses flattened pebbles of an apparently unaltered bluish-grey limestone, which are sometimes two inches in length, ...	6
6. Dark olive-green or blackish-green serpentine in layers, from a few lines to more than two inches in thickness, interstratified with similar bands of greenish-white diorite. The serpentine contains small plates of diallage, in addition to which, thin layers, composed chiefly of small crystalline grains of black hornblende, are occasionally interposed between the serpentine and the greenish-white material, and in some parts forms bands of half an inch in thickness. The serpentine is cut by transverse joints, which are lined with films of what appears to be chlorite, ...	20
	121

Diorite. Black slate. Conglomerate. Serpentine.

These rocks are immediately succeeded by a mass estimated at about 1000 feet in thickness, consisting in part of a blackish-green serpentine, holding diallage, and in part of a fine grained dark olive-green diorite; which is traversed by thin irregular seams of carbonate of lime, and resembles somewhat the parts 1, 3, and 5 of the above section. The serpentine of this mass, like that of the Quebec group in Eastern Canada, contains small portions both of chrome and nickel; and these metals were also detected by analysis in two of the thin bands of serpentine from part 6 of the section.* The white layers interstratified with this are, unlike the

Chrome and nickel.

* In addition to the chrome and nickel which these serpentines have in common with similar rocks of the same age in Eastern Canada, it is worthy of remark that copper ores, with specular iron, have been found associated with the serpentines of Newfound-

serpentine, but partially decomposed by sulphuric acid, which however takes up a large amount of alumina, with some protoxyd of iron, a little lime, and much magnesia, leaving an undecomposed granular silicate.

Succeeding to these serpentines and diorites, there is a great development of massive greenish chloritic sandstones, which often become sufficiently coarse grained to constitute conglomerates, with white quartz pebbles attaining occasionally half an inch in diameter. The thickness of this mass, though not determined, must be considerable, as the rock occupies a breadth of several miles, and there is not much doubt that it represents the Sillery division of the Quebec group.

Dislocations. Of the four dislocations on Pistolet Bay, one, as already stated, is a downthrow, while the other three are upthrows to the southeast. The absence of stratification in each of the masses of limestone on the upthrow side of these three faults, is probably occasioned by the grinding of the strata in the movements occurring at the time of displacement, and by the subsequent cementing of the mass by the infiltration of carbonate of lime. In one of the faults it is very evident that the unstratified limestone overlaps the black shales in contact with it, at an angle of five degrees to the plane of the lower beds, or of ten degrees to the horizon; and something analogous may occur in connection with the other faults. In this, the dislocations would resemble those of Quebec and of Phillipsburgh. All of these faults have a southwest bearing, and run with the general strike; and it appears not improbable that some of them may have a connection with the faults which are noticed on page 292 as occurring between St. John's Island and Bonne Bay. These dislocations are there described as probably transverse to the measures; but farther investigation induces the supposition that they run with the strike, or nearly so. They are all upthrows on the southeast side.

The most northerly of the disturbances in this part appears to be an

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land, and resembling the ores of the Quebec group in the Eastern Townships. A beautiful variety of steatite, holding traces of nickel, and colored emerald-green by oxyd of nickel, occurs with these serpentines. In this connection it may be noticed that in addition to the copper, lead, cobalt, nickel, arsenic, chrome, silver, and gold, already Antimony. described, antimony is now to be added to the mineral wealth of the Quebec group. A deposit of this metal has lately been discovered in the township of South Ham, on the twenty-eighth lot of the range east of the Gosford road. It is described as occurring in a vein or bed, of from six to sixteen inches in thickness, in argillite, which is penetrated by numerous smaller veins of the ore. The greater portion of the antimony is in the metallic state, as lamellar, or more rarely, as finely granular native antimony; but the sulphuret, antimony glance, also occurs in small radiating prismatic crystallizations. Besides these, the white oxyd of antimony, both massive and fibrous, is found in this locality, associated with small crystalline tufts of the red oxysulphuret of antimony, kermesite. These latter ores are probably only the results of superficial oxydation. From the specimens already obtained from this locality, it would appear probable that antimony exists here in workable quantity. It is accompanied by quartz and a little brown-spar.

undulation in the measures, rather than a fault, the axis of which would run on the inside of St. John's Island, and through Point Rich. The influence of this undulation is visible in the turn of the strata between Port au Choix and Point Rich, and in the attitude of the limestone composing a small island about 100 yards southeast of that of St. John, where for a breadth of 275 feet the beds are turned up to the dip N. 40° W. < 33°. This undulation gives to the area between it and the north shore of the Strait of Belle Isle the form of a trough, the axis of which would run through the Island of St. John. The second disturbance occurs at Port Saunders, near the entrance to Hawke's Bay; and as it brings the division F, on the southeast, against L on the northwest, it would appear to be a break of about 1200 feet. What is supposed to be a continuation of this break occurs about a mile and a half inland, opposite St. John's Island; where the division G, on the northwest, is brought against some of the quartzites in the upper part of the Potsdam group, on the southeast. The relation of the two points at which the break has been observed would give to it a bearing not far removed from northeast. The third disturbance has already been alluded to as occurring on the shore, a little southeast of Table Head. Its continuance is seen near the head of Hawke's Bay, where the division E, on the northwest side, comes against the white quartzites of the Potsdam group on the southeast; and again about six miles inland opposite St. John's Island. Here the quartzites of the Potsdam group are exposed in nearly horizontal strata on both sides of the fault: but on the southeast they show an escarpment rising quickly to a height of a thousand feet, and maintaining for ten miles a straight course in the bearing of the fault, which seems to be nearly if not quite parallel with the previous one. The upthrow is estimated to be about 1300 feet. A fourth disturbance has already been mentioned as occurring at Portland Creek, but no especial facts have been ascertained to determine its bearing. A fifth is the anticlinal seventeen miles south of Portland Creek, mentioned on page 292 as affecting the limestone conglomerates of division P, and as running between Steering Island and Cow Head.

Hawke's Bay.

On a further examination of the strata of Cow Head, *Cheirurus* and *Lichas* were added to the genera previously met with in the limestones; and in the black shales were obtained several additional species of Graptolitidæ, among them *Phyllograptus typus* and *P. angustifolius*. Between Cow Head and Bay St. Paul, a distance of three miles, no rocks are exposed on the coast; but the limestone conglomerates appear again about a mile and a half within the bay, on the north side. Here in a small anticlinal hillock, a band of the conglomerate is associated with black and greenish shales, in which graptolites are obscurely seen. About a mile farther in, the bay is divided into two parts by a strait called the Narrows; and while the outer part is about two and a half miles long,

Cow Head.

and shallow, the inner is five miles long, from one to two wide, and very deep. On both sides, at the Narrows, there are exposures of conglomerate, interstratified with thin bedded light grey limestones, and black calcareous shales. In the limestones occur obscure specimens of *Graptolithus*, with better preserved specimens of *Orthis*, *Lingula*, *Ophileta*, and *Leperditia;* while in the shale the graptolites are abundant and well preserved. Among them are *Graptolithus bryonoides*, and several other species, with *Dictyonema*. South of the Narrows, on the inner bay, there are several exposures of limestone conglomerate, interstratified with red and green shales, and greenish-grey sandstones, in beds varying in thickness from six inches to a foot. With the red shales are associated a few beds of red limestone, and others of a greyish limestone, weathering yellow, and probably magnesian. The conglomerates run along the shore from Bay St. Paul to Broom Point and beyond. They are said to compose Martin's Point and Green Point; and being found farther on running along the north shore of Bonne Bay, from the mouth to the entrance of the East Arm, it appears probable that their strike coincides with the coast the whole way.

Graptolites.

St. Paul's Bay.

About a mile and a half from the head of St. Paul's Bay, on the south side, there occurs an exposure of thick bedded grey limestone running nearly north and south, in an almost vertical attitude. It has a breadth of about 400 feet, and comes in contact, on its east side, with Laurentian gneiss. Of this there is an exposed breadth of about 100 yards, which is followed by a mass of brownish limestone, weathering yellow. This limestone has a breadth of about 140 yards, and presents a rough jagged surface, without any indications of bedding. On the east side it is succeeded by the gneiss, which rapidly rises into a mountain, attaining a height of probably 2000 feet in the distance of a mile. This mountain belongs to a range, which, southwardly, attains the position where it has already been mentioned in Bonne Bay; and in an opposite direction it holds a course which brings it to a point about sixteen miles east of Table Head; the whole distance along which it is seen being about seventy miles. In the grey limestone which is at the foot of the range in Bay St. Paul there are a few obscure fossils, the genera of which appear to be *Ophileta* and *Ecculiomphalus*. The limestone here in contact with the gneiss is supposed to belong to division E; while on Deer Brook, about sixteen miles to the south, the whole thickness of the Potsdam rocks (about 2000 feet) intervenes between the two. This would appear to indicate a fault, but no facts were observed on the coast to correspond with such a break. The position where such a fault, if it should run parallel with the others, would come upon the coast, was however but imperfectly examined.

Laurentian gneiss.

If the thickness of the strata under the strait of Belle Isle be assumed to be 800, instead of 250 feet, agreeably to what has already been proposed, a comparison between the vertical sections of the fossiliferous rocks of this region, as ascertained in 1861 and in 1862, will be as given in the following table. In this the letters already used are prefixed to those portions which are supposed to be approximately equivalent, and the localities in which the strata have been measured, are designated. The two vertical black lines show, by the breaks in them, the interruptions in the continuity of the different parts of the series. The upper part of the Table Head portion, and the whole of that at Cow Head, are common to the two sections.

Two sections compared.

	1861.	Feet.	Feet.	1862.	Feet.	Feet.
A	Anse au Loup,..	231		Bonne Bay,......	605	
B	" ..	143		"	483	
C	Belle Isle Strait,	800		"	932	
			1174			2020 = POTSDAM GROUP.
D	St. Barbe Bay, ..	150		"	174	
E	" ..	400		"	500	
F	Port au Choix,..	400		"	500	
G	" ..	130		"	400	
H	" ..	340		Table Head, ...	265	
I	" ..	150		"	135	
K	Point Rich, ...	130		"	100	
L	"	130		"	191	
M	Table Head, ...	550		"	658	
N	"	200		"	277	
O	Cow Head, ...	700		Cow Head, ...	700	
P	" ..	700		"	700	
			3980			4600 = QUEBEC GROUP.
			5154			6620

The *Paradoxides* in the divisions A, B, and C of this series, and many of the lithological characters of these divisions, leave little doubt that this part belongs to the same horizon as the Red sandrock of Vermont (page 281). The graptolites, both simple and compound, of O and P, with the general structural aspect of these divisions, leave as little doubt that this portion is equivalent to the strata of Point Lévis ; while at the same time it contains in some abundance *Maclurea ponderosa*, one of the thick-shelled and peculiar gasteropods which so strongly mark the conglomerates of Stanbridge. Though the organic remains of the intermediate part, including divisions from D to N, are different from those of the Phillipsburgh limestones, yet the latter agree with this middle portion of the Newfoundland rocks in containing fossils of the Calciferous formation; those of Newfoundland belonging to the base, and those of Phillipsburgh to the summit of this formation. It is thus evident that we have in the Newfoundland series, the Potsdam and the Quebec groups, and that the latter there overlies the former. This might be considered sufficient to establish that the Phillipsburgh and Stanbridge series is younger than the Red sandrock of Vermont; and it has been shown by the details already given

Calciferous formation

in regard to the structural arrangement in the neighborhood of Phillipsburgh, that there is no stratigraphical evidence to contradict this conclusion.

The horizon of the Point Lévis rocks is that assigned to the diorites and serpentines of the Eastern Townships; and this appears to be the stratigraphical place of the diorites and serpentines of Pistolet Bay, where the metamorphic strata show evidences of association with the graptolitic slates of the Newfoundland series. The sandstones which succeed to the serpentines of Pistolet Bay would thus appear to occupy the horizon which has been provisionally assigned to those of the Sillery formation near Quebec. Farther research however is yet required to establish the true relation of this formation to the Quebec group.

Sillery formation.

GASPÉ LIMESTONES AND SANDSTONES.

The additional information which has been obtained during the past season in regard to these rocks, refers to their distribution in an area eastward of a line running southward up the Magdalen, and its tributary the Cold Water Brook, and extending to the valley of the Douglastown River. Their distribution in this area is already partially described on pages 406–410; where it has been stated that three anticlinal axes run from the coast into the interior; the most northern starting from Cape Haldimand, the second from Tar Point, and the third from Point Peter; while a fourth was ascertained to coincide with the valley of the Douglastown River for twenty-five miles of its course, and to reach within thirteen miles of its mouth. It was further stated on page 409 that the Haldimand anticlinal was probably continued in one occurring near the source of the Cold Water; and on page 410, that the axis of the Tar Point anticlinal would probably coincide with the valley of the York River for fifteen miles above Silver Brook. In each of these cases the course of the axis of the anticlinal, as will be shown presently, is more northward than that which was assigned to it.

Four anticlinals.

It has been shown on page 406 that the Gaspé limestones are traceable from Little Gaspé Cove, on the north side of the Northwest Arm, and its tributary the Dartmouth River, for twenty-four miles, to a north turn in the upward course of this stream, not far from Serpentine Mountain. The bearing of the limestones in this distance is about N. 30° W., and they have now been followed upwards of sixteen miles farther in the same direction, along the south side of the valley of the Dartmouth; where they form the flank and crest of a conspicuous mountain range. At the extremity of this distance the mountain range is intersected by a deep transverse valley, which holds the upper part of the Dartmouth River; and the limestones have been traced between one and two miles on the west side of this transverse

Dartmouth River.

valley, where they continue in the same bearing as before. They here constitute a mountain, divided into two parallel ridges, in the northern one of which the limestones dip to the south: while in the southern they appear to be nearly vertical, with a probable dip to the north. On this part of the Dartmouth, the northern outcrop of the limestones is about three miles north of the strike of the south-dipping limestones of Terrace Mountain; and as the Two-ridged Mountain dies down before reaching the Magdalen, and its limestones disappear in this direction, it is inferred that they first fold upon a synclinal, and then upon an anticlinal axis, before joining those of Terrace Mountain. The anticlinal appears to be a continuation of that of Cape Haldimand: the effect of which, in the intermediate distance, is seen in several places. Between Gaspé Basin and Mount Serpentine, it brings up the limestones through the sandstones in three or four mountain-tops along the range which flanks the south side of the Dartmouth. Mount Serpentine, which presents an area of between two and three miles belonging to the Quebec group, is flanked on the south by a margin of the limestones, and on the north by the sandstones. Its presence in this place seems to be due partly to the effect of the anticlinal, and partly to the inequalities of the ancient sea-bottom on which the limestones were deposited. The limestones have been observed a short distance to the west of this area, and it is possible that they may be brought to the surface on the crown of the anticlinal all the way to its intersection by the Dartmouth. The measured thickness of the Gaspé limestones at the falls in the north turn of the Dartmouth, north of Mount Serpentine, is about 2000 feet. At this place, and along the Dartmouth, the strata at the base are of a somewhat soft and arenaceous character, and occasionally pass into flaggy calcareous sandstones fit for scythe stones. Both varieties are different shades of bluish-grey, and weather to a brownish-grey. In the arenaceous limestones of the neighborhood of the falls, some of which are nodular, fossils occur. Among them are undetermined or new species of *Orthis*, *Strophomena*, and *Murchisonia*, with a branching coral. In a band of arenaceous limestone at about the same horizon, on Eden's Brook, between seven and eight miles higher up the valley, two undetermined species of lamellibranchiate shells occur in a good state of preservation; and in a similar but finer grained and softer bed at the bend near the Two-ridged Mountain, *Strophomena rhomboidalis* is found in abundance, associated with an undetermined coral. Above the arenaceous limestones, the escarpment is composed of dark grey hard flaggy limestones and shales, with several hundred feet of hard limestone toward the top; but in these parts no fossils were observed.

Mount Serpentine.

Limestone.

The sandstones on the north side of Mount Serpentine, are a continuation of those occupying the Gaspé Bay synclinal (pages 396 and 406); and like them, are characterized by a multitude of carbonized fragmentary remains of land-plants, among which *Psilophyton princeps* is the most abun-

Gaspe Bay synclinal.

dant. From the presence of fragments of the sandstones in the channels of various north-flowing brooks, intersecting the limestone on the south side of the Dartmouth, and joining this river, it appears probable that these rocks are continued in this synclinal some thirteen miles farther. A brook flowing parallel with the others, and joining the Dartmouth about three miles below the Two-ridged Mountain, is free from these fragments of sandstone, and may therefore mark the northwestern limit of the Gaspé sandstones in this synclinal. In the valley of the Dartmouth, for the sixteen miles below the Two-ridged Mountain, the limestones are underlaid by rocks resembling those of the Quebec group. They consist in the lower part of the distance of one or two exposures of sandstone like that of the Sillery series, and in the upper part, of limestone conglomerates resembling those of Point Lévis. Black slates accompany the conglomerates, and in these are occasionally interstratified thin lenticular bands of fibrous limestone like those of the Chatte River (page 420). These may belong to the lower black slates, which are supposed to underlie the Quebec group (page 266). In one of these bands there was met with an imperfect trilobite, very much resembling *Paradoxides Harlani*. It shows the glabella, part of the right cheek, and nine segments of the thorax, and would, if complete, be about four inches long. The imperfection of the specimen however is such, that it may possibly be a *Dalmanites* instead of a *Paradoxides*.

Quebec group.

Black slates.

Haldimand anticlinal.

The Cape Haldimand anticlinal having thus been shown to run between the Two-ridged Mountain and Terrace Mountain, the Tar Point anticlinal, which is the next to the southward, would be the one corresponding with that near the source of Cold Water Brook. Its course between Tar Point and this brook, would carry it obliquely across the mouth of the Douglastown River, and that of the York River. It would come upon Silver Brook about two miles from the junction of this tributary with the York River, and at this place the Gaspé sandstones present an anticlinal arrangement which serves to confirm the course given to the axis. This position is about a mile north of the oil-spring mentioned on pages 403 and 789. The Gaspé limestones and sandstones on the Cold Water, on the north side of this anticlinal, and the corresponding limestones on the south side, on York River, have been mentioned on page 408. The breadth of the latter is about a mile and a half, and they are visibly limited to the south by the overlying sandstones; which occupy a breadth of about two miles on a south-flowing part of the river, and display a synclinal arrangement between the limestones just mentioned, and another development of the same series, brought up by the next anticlinal, which is that of Point Peter. The position where the Gaspé limestones of this part would sink beneath the overlying sandstones to the eastward, on the axis of the Tar Point anticlinal, has not been ascertained. Exposures of the limestone occur on the upper part of the Dartmouth River, between eight and nine miles to the eastward

Tar Point anticlinal.

York River

of the most southern exposures on the Cold Water, and others about three miles a little south of east from those just mentioned on the Dartmouth. The limestones on the York River, subordinate to the Tar Point anticlinal, are exposed on the strike for upwards of three miles; and combining the bearings thus ascertained on the opposite sides of this anticlinal, it seems probable that the limestones would meet somewhere about six miles to the westward of the sandstones on Silver Brook.

Point Peter anticlinal.

Assuming that the Point Peter anticlinal runs from the coast in a course nearly parallel with that of Tar Point, it would cross the Douglastown River about two miles west of the western limit of the township of York; and in this bearing it would reach the York River about five miles above the northwest corner of the same township. On the south side of the river at this place, a mass belonging to the Gaspé limestones comes to **Limestones** the surface, presenting a sharp anticlinal form. The rock is strongly bituminous, giving indications of petroleum, and measures 167 feet across. It is flanked on each side by the sandstones of the Gaspé series, and probably shows a position on the crown of the Point Peter anticlinal, between which and the exposures already alluded to as brought up by this anticlinal on the York River, there is a distance of about sixteen miles. The transverse breadth of these exposures on the York River is nearly two miles, **York River.** in which the strata are arranged in the form of an anticlinal, with the opposite sides converging toward the west at such a rate as to make it probable, that in this direction, the limestones will become covered by the overlying sandstones at the distance of about two miles from the river. From one to two miles to the east of these exposures on the York River, Keg Brook, a tributary of this stream, crosses the anticlinal in a deep **Keg Brook** ravine, and exposes the limestones in many places for two miles. In this distance several tributary streamlets flow in deep gullies in the strike. All the timber has been burnt off the declivities, and the surface is covered with small bleached angular fragments of silicious limestone and shale. A high bare ridge, known as Jack Mountain, lies in the form of a wedge between Keg Brook and its lowest branch on the right. A mile up this branch the strata dip S. 5° W. $<$ 65°, and consist of black petroleum-bearing limestone in beds from one to six inches thick, with occasional partings of shale. A short distance farther down, the dip is S. 28° W. $<$ 26°, and the limestone beds are from three to seven inches thick. The anticlinal bringing up these limestones, like most of the anticlinals in Gaspé, is more precipitous on its north than on its south slope; its axis is therefore not in the middle of its breadth, and on Keg Brook it may be about a mile and a quarter from the southern boundary of the limestone. In the York River, just above this brook, the limestone at the summit of the formation is divided into thick beds, of which some are dark grey, weathering reddish-brown, and containing petroleum; while others are nearly black, and hold **Petroleum** disseminated masses of chert. The dip is here S. 25° W. < 9°, but the average inclination on the south side of the anticlinal axis appears to be about twenty degrees; giving in the mile and a quarter, which the south side occupies, a total thickness of about 2200 feet. Between six and seven miles to the east of Keg Brook, and between two and three miles north of the York River, there occurs in the bed and banks of a branch of the Mississippi, a brook tributary to this river, an exposure of about 1600 feet of the upper portion of the formation. The exposure has a breadth of forty-five chains, with a dip S. 4° W. < 34°, and consists toward the top of dark grey hard limestone, in uneven surfaced beds from six to eleven inches thick, with drusy veins holding petroleum; but the greater part of the section is thinner bedded, and is interstratified with drab brownish-weathering shale. How far the formation continues exposed to the eastward of this is uncertain, but it is supposed that it may be covered by the succeeding sandstones for between three and four miles before reaching the exposure already mentioned as occurring on the axis of the anticlinal, five miles above the township of York.

Mississippi Brook.

Between this spot and the mouth of Keg Brook, the Gaspé sandstones are displayed almost continuously in the bed and on the banks of the York River, at the most southern bend of which they are removed about four miles, across the measures, from the summit of the limestones. At this part they have a northern dip, and rise into a prominent hill called Becharvaise Mountain; which presents a long straight east and west ridge on the south side of the river, about four miles to the north of the limestones brought up on the succeeding anticlinal in the valley of the Douglastown.

Becharvaise Mountain.

Sandstones.

The sandstones of York River are all greenish-grey in color, and interstratified with frequent bands of greenish crumbling arenaceous shale. The only observed exceptions to these prevailing strata consist of the resinous beds described on page 792, and two thin layers of red shale occurring between six and seven miles above the lowest exposure of limestone, besides occasional bands of conglomerate. The sandstone beds vary from half an inch to ten feet in thickness, and are uniformly of a moderately hard and rather coarse even grained character. They frequently split into smooth surfaced slabs of suitable thicknesses for flagstones, owing to the presence of thin partings, with mica or carbonized remains of plants. The thicker beds are sometimes made up of very regular thin oblique layers, constituting false bedding; while at other times they are massive, and fit for building purposes. The greenish arenaceous shales are most prevalent near the base of the formation. They constitute about one half of the strata in a thickness of several hundred feet overlying the limestones above Keg Brook; and they are also largely interstratified with the sandstones at all other points on the river, where these approach the underlying limestones. Small rounded pebbles are often seen disseminated through the sand-

Red shale.

stones, especially in the higher parts of the formation, sometimes in such numbers as to constitute conglomerates. These pebbly strata however do not appear to be of such frequent occurrence as in Gaspé Bay.

Calcareous bands, containing abundance of shells, are met with in some places near the base of the sandstones. At the mouth of the Patawegia Brook, joining the York River on the left bank, about three miles above the lowest exposure of limestone, a six-feet band of this kind occurs in a great thickness of crumbling arenaceous shale, also holding fossils. Among those which characterize the whole exposure are *Zaphrentis*, *Orthis*, *Strophomena*, *Chonetes*, *Rensselaeria ovoides*, *Leptocoelia flabellites*, *Avicula*, several species of acephala of undetermined genera, *Orthoceras* and *Dalmanites*. Undetermined species of *Spirifer* and *Cyrtodonta* are common in similar strata on Silver Brook; and loose fragments of calcareous sandstone, containing some of the above fossils, are found on the surface between the York and Douglastown Rivers, south of the lowest exposure of limestone. Carbonized remains of land plants are abundantly disseminated through the sandstones of York River, as far as examined; and in many places they compose innumerable thin laminæ or partings between the arenaceous strata. Among these plants, as determined by Dr. Dawson, *Psilophyton princeps* is the most abundant, and it is accompanied in some places by *Leptophleum rhombicum*, a species occurring in the Devonian sandstones of Perry in Maine, and *Didymiphyllum reniforme*, found in the Hamilton group of New York. There occur in some beds two species of fossil wood, resembling *Prototaxites*, but destitute of lines of growth and medullary rays. These Dr. Dawson proposes to describe under the provisional generic name of *Nematoxylon*, as *N. simplex* and *N. minus*. Among many fragments not sufficiently distinct to be described, there are some apparently of a *Lycopodites*, resembling *L. Milleri* of Salter; and others are stems pitted, or marked with raised points, in the manner of certain roots described by Salter from the Old Red sandstone of Caithness.

Patawegia Brook.

Fossil plants

It was stated on page 410 that the axis of the anticlinal on the Douglastown, leaving the river about five miles above the west side line of the township of York, appears to bear towards Point Peter. It is now however considered more probable, that, gradually curving to the southeast, it will come upon the coast at the village of Percé. No facts, however, in regard to what is supposed to be its course, have yet been ascertained between the Douglastown and Malbay Rivers, in a distance of fifteen miles. The Malbay River, for three miles from its mouth, is occupied by strata belonging to the Bonaventure formation, and for between six and seven miles farther by the sandstones of the Gaspé series. In these, about a mile above the west side-line of the township of Malbay, there are evidences of an anticlinal arrangement, and this structure is supposed to mark a point in the axis of the anticlinal in question. From this there appears to be a trend in the

Percé anticlinal.

ridges of the hills towards Percé, which may indicate the farther course of the anticlinal.

Four anticlinals. On a line a little westward of south from Cape Haldimand, the axes of the four anticlinals which have been described are comprised in a distance of between ten and eleven miles; but on a line south from the mouth of the Magdalen they occupy a distance of twenty-five miles, and while they thus separate from one another, they all gradually curve round from a northwestward to a westward bearing.

Grand River. On page 442 it is shown that the rocks of the Grand River, which enters the Bay of Chaleur about eight miles west of Cape d'Espoir, consist, for six miles up from its mouth, of dark grey slates, and dark grey limestones, with arenaceous layers. The slates are partially calcareous, and the same rocks have been ascertained to prevail on the river for twelve miles beyond the distance above mentioned. The upward course of the river appears to coincide, in a general way, with the strike of the slates, which is about N. 40° W., while the dip is northeastward. These slates very much resemble some of those of the Patapedia (page 417), and of Lake Temiscouata (page 424); but no fossils have yet been obtained to determine their exact horizon.

BONAVENTURE FORMATION.

The only additional information obtained in respect to the rocks of this formation, relates to their distribution in the interior, between Point Peter and the Grand River. **Malbay River.** Their occurrence on the Malbay River, for three miles up from its mouth, makes it probable that the base of the formation keeps about a mile north of the north side of Malbay, and continuing westward, curves round and crosses the Malbay River as indicated. From its intersection with this river the strike would bring the base to within about a mile of the southwest angle of Malbay; from which it would appear to run southwest, inside of the north line of the township of Percé, nearly to the Grand River; where its proximity is indicated by fragments of the conglomerates and red sandstones belonging to this formation, brought down by a brook joining the Grand River on the left, about five miles from its mouth. From this point it is probable that the base recedes, in the form of a bay, toward Cape d'Espoir, leaving only a narrow border of the rock along the coast to the mouth of the Grand River.

SUPERFICIAL GEOLOGY.

No solid stratified rocks newer than the palæozoic formations already described are known in Canada. These last are however in many parts covered over with an accumulation of loose materials, constituting what is often called diluvium or drift; which rests upon a very uneven surface, left by the great and irregular denudation of the earlier rocks. These superficial deposits have as yet been but imperfectly studied: the principal facts known in their history will however be given in the following pages; and advantage will be taken of the published observations of persons not connected with the Survey, to whom due credit will be given in the course of the description.

Classification.

These deposits, so far as yet known, may be considered in three groups, which are shown in the following table. The order in which the examples under each are placed must not be understood to imply any difference in the age of these local deposits, which are in many cases equivalents. The numbered groups, however, represent the order and succession of the three great divisions of these superficial deposits, and in group II, the subdivisions which are included under part 1 underlie those of part 2 in western and eastern Canada respectively. The relations of these subdivisions will be considered in their proper places. The Erie and Saugeen clays and sands of western Canada, apparently belong to a distinct basin, and are in part at least, of fresh-water origin; so that their relations to the lower and upper divisions of the stratified drift of eastern Canada and Vermont cannot yet be determined.

III.

Shell-marl, calcareous tufa, peat.
Ochres, bog iron and manganese ores.
Modern alluvions.

II.

	WESTERN CANADA.		EASTERN CANADA.
2.	Algoma sand. Artemisia gravel. Saugeen fresh-water clay and sand.	2.	St. Maurice and Sorel sands. Saxicava sand of Montreal. Upper sand and gravel of Beauport. Upper Champlain clay and sand of Vermont.
1.	Erie clay.	1.	Leda clay of the St. Lawrence and Ottawa. Lower shell-sand of Beauport. Lower Champlain clay of Vermont.

I.

Boulder formation, or glacial drift.
Auriferous drift of Eastern Canada.

As a preliminary to the history of the boulder formation, the grooving, polishing, and rounding of the older rocks will first be mentioned; after which will be given the characteristics of the glacial or unstratified drift, as seen both in eastern and western Canada. In describing the second group, which corresponds to the lower and upper divisions of the stratified drift, the deposits of western Canada, which exhibit peculiar local differences, will be first considered. The two corresponding divisions in eastern Canada will next be described, and will be followed by a notice of the auriferous drift of southeastern Canada, and of the older tertiary deposits in the adjoining state of Vermont.

ROUNDED ROCKS AND ICE GROOVES.

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Rounded, grooved, and polished surfaces are often found on the older rocks where these are naturally exposed, and are met with in still greater perfection wherever the ancient superficial deposits which cover them are artificially removed. The process which produced these results must therefore have been contemporaneous with the transport of the drift over the surface, or anterior to it. These phenomena have by geologists been attributed to various agencies, but the evidences afforded in Canada appear to favor the supposition that they have been caused by the action of glaciers. Along the whole of the southern boundary of the Huronian and Laurentian hills, from Lake Superior to Labrador, the rounded rocks, or "roches moutonnées," are very conspicuous, and the ordinarily rounded outline of these hills may be due to glacial action. On Lake Superior the general direction of the striæ is southward; but it varies slightly in different localities, and not far from Fort William, Professor Agassiz observed them running about due

grooves.

east, in a valley. The grooves are not always parallel, but frequently intersect one another at small angles: the greatest is about forty-five degrees, but in general the angle is very much less. The rocks along the north shore of Lake Huron, and on the multitude of small islands adjoining it, are rounded and grooved in a very striking manner. As on Lake Superior, the general direction of the striæ is south, varying only a few degrees to the east or west. Some of the small grooved islets, quite destitute of soil, rise above the surface of the water like segments of spheroids, while others are barely submerged, and render navigation very dangerous. The grooves are also well shown along the rivers of the north shore, and around many of the lakes in the interior. At one place, near the Bruce Mines, the grooves were observed to run under an overhanging mass of rock, and to mark both the wall and the roof. These, it would seem, must have been caused by fragments imbedded in the yielding ice of a glacier. On Lake Temiscamang also, a long narrow expansion of the Ottawa, the rocks are furrowed in such a manner as to suggest that it is the result of glacial action. Along this lake, as well as along the Rivière Rouge, north of the Ottawa. the furrows conform in a general way to the directions of the river-valleys, the limits of which appear to have guided the moving masses producing the present grooves. In some places on the Rouge, beds of quartzite, interstratified with the crystalline limestone, and having furrowed surfaces, stand out boldly and abruptly from six to nine inches above the latter rock; which has been probably slowly dissolved away by the subsequent action of water. Glacial action.

On page 6 it is stated that the distribution of the innumerable lakes, which appear scattered as if at random over the Laurentian region, is often well explained by the peculiar geographical distribution of the strata, resulting from their very corrugated condition, combined with the unequal wear dependant upon the hardness and toughness of some parts of the deposits, and the softness of others. The rock which is most characteristic of the depressions is the comparatively soft crystalline limestone of the series, and it appears probable that one of the main erosive forces has been glacial action. Not only the lake-basins, but many of the river-valleys, in which the lake-basins are only deeper parts, run on the bands of limestone, and may be due to the same cause. It has been shown on page 17 that the arrangement of the great western lakes of Canada is traceable to the arrangement of two parallel zones of strata, the softer members of which have yielded with comparative facility to the wearing agency, producing the excavations which hold the water. These great lake-basins are depressions, not of geological structure, but of denudation; and the grooves on the surfaces of the rocks, which descend under their waters, appear to point to glacial action as one of the great causes which have produced these depressions.* The following list of ice-grooves, with the latitudes and longitudes of the places where they occur, will show some of the directions in which glacial action has been exerted in different parts of the province. The directions are all referred to the true meridian. Origin of lake-basins.

* Prof. A. C. Ramsay has lately endeavored to show that the lakes of Europe have been produced by the action of great glaciers, which, by their slow grinding action, formed those depressions in the rocky strata which are now the basins of the lakes. The facts above mentioned, and especially the glacial grooves continued beneath the waters of the lakes, go far to show that the fresh-water basins of North America have had a similar origin. This hypothesis points to a glacial period, when the whole region was elevated far above its present level, and when the Laurentides, the Adirondacks, and the Green Mountains were lofty Alpine ranges covered with perpetual snow, from which great frozen rivers or glaciers extended far over the plains below; producing by their movements the glacial drift, and scooping out the river-valleys, and the basins of the lakes. Dr. J. S. Newberry has pointed out in a very clear manner the evidences of this former extensive glacial action in North America. (*Annual of Scientific Discovery*, 1863, page 252.)

LIST OF GLACIAL GROOVES.

No.	Locality.	Latitude.	Longitude	Direction.
		° ′	° ′	°
1	Goulais Bay, ...	46 46	84 29	S. 30 E.
2	Batchehwahnung Bay; north side,............	46 56	84 27	S. 23 W.
3	" " east angle,............	46 54	84 22	S. 23 W.
4	" " east point,............	46 52	84 22	S. 2 E.
5	Macdonald Township; southern boundary, ...	46 26	84 00	S. 40 W.
6	" " " "	46 26	83 59	S. 25 W.
7	Echo Lake; island,..........................	46 33	83 58	S. 55 W.
8	" shore, ...	46 33	83 58	S. 70 W.
9	Walker's Lake; hill north shore,..............	46 24	83 55	S. 10 W.
10	Raft Lake; eastern island, ...	46 31	83 54	S. 9 W.
11	Thessalon Lake; western island,.............	46 26	83 49	S. 17 W.
12	" " southern shore,.............	46 25	83 48	S. 17 W.
13	" River, above Rock Lake, ...	46 27	83 46	S. 25 W.
14	Rock Lake, west and south sides,.............	46 26	83 46	S. 15 W.
15	" southwest shore,.................	46 25	83 45	S. 15 W.
16	Bruce Mines, ...	46 18	83 44	S.
17	Palladeau Islands; one of the group,..........	46 16	83 39	S. 20 W.
18	" " "	46 15	83 39	S. 15 W.
19	Thessalon River, mouth,.....................	46 16	83 31	S. 18 W.
20	Wabiquekobingsing Lake, N. W. end, ...	46 19	83 25	S.
21	" " S. E. end, ...	46 18	83 24	S. 12 W.
22	Pakowagaming Lake, S. W. shore,............	46 15	83 17	S. 25 W.
23	Katigamaigouska Lake, ...	46 32	83 24	S. 15 W.
24	" "	46 31	83 22	S. 7 W.
25	Wahcomatagaming Lake,.....................	46 35	83 19	S. 17 W.
26	" "	46 34	83 17	S. 32 W.
27	Little White River, ...	46 25	83 15	S. 43 W.
28	" " "	46 28	83 13	S. 19 W.
29	" " " ...(other grooves S. 70° E.)	46 28	83 10	S. 46 W.
30	Mahcomang Lake, ...	46 23	83 7	S. 21 W.
31	" "	46 22	83 4	S. 15 W.
32	" " on an island, ...	46 22	83 4	S. 25 W.
33	Blind River, on Cataract Lake,...............	46 17	83 1	S. 8 W.
34	" " below " "	46 16	82 59	S. 5 E.
35	" " mouth,.........................	46 11	82 57	S. 20 W.
36	" " Lake of the Mountains,...........	46 16	82 53	S. 17 W.
37	" " " " "	46 16	82 55	S. 3 W.
38	Lake Huron, north shore,....................	46 14	83 20	S. 22 W.
39	" " " "	46 12	83 13	S. 15 W.
40	Mississagui River, mouth,....................	46 16	83 13	S. 10 W.
41	" " island at its mouth,.........	46 11	83 2	S. 12 W.
42	" " " "	46 12	83 2	S. 12 W.
43	Lake Huron, north shore, Luzon's mills, ...	46 10	82 53	S. 13 W.
44	White-fish River, Round Lake, east side, ...	46 19	81 9	S. 45 W.
45	" " " " south side, ...	46 18	81 11	S. 41 W.
46	" " Long Lake, ...	46 8	81 39	S. 49 W.
47	Maskanongiwagaming Lake, north end, ...	46 49	80 26	S. 23 W.

LIST OF GLACIAL GROOVES.—*Continued.*

No.	LOCALITY.	LATITUDE. ° ′	LONGITUDE. ° ′	DIRECTION. °
48	Wahnapitaeping Lake, ...	46 42	80 38	S. 23 W.
49	" "	46 41	80 38	S. 23 W.
50	Maskanongi River, ...	46 40	80 26	S. 37 W.
51	Georgian Bay, western outlet of French River,	45 55	80 56	S. 37 W.
52	" " " " " "	45 55	80 55	S. 45 W.
53	Nipissing Lake, S. E. Bay, ...	46 10	79 33	S. 35 W.
54	Nahmanitigong River, ...	46 1	79 26	S. 35 W.
55	Derby, at Owen Sound, ...	44 34	80 57	S. 41 W.
56	Brant, ...	44 12	81 13	S. 10 W.
57	Sydenham, ...	44 35	80 52	S. 12 W.
58	"	44 32	80 55	S. 23 W.
59	Sullivan, ...	44 28	80 54	S. 5 E.
60	St. Vincent, ...	44 32	80 35	S. 10 E.
61	Collingwood, Blue Mountains, (*Prof. Chapman,*)	44 30	80 20	S. 22 E.
62	" " (*Mr. J. Irving,*)	44 29	80 19	S. 69 E.
63	Eramosa, at Rockwood, ...	43 38	80 8	S. 38 E.
64	Blanchard, at St. Mary's, ...	43 16	81 11	S. 45 E.
65	Beverley, ...	43 19	80 14	S. 46 E.
66	" near Sheffield, ...	43 20	80 13	S. 72 E.
67	" " Troy, ...	43 15	80 12	S. 76 E.
68	"	43 18	80 13	S. 59 E.
69	"	43 19	80 10	S. 79 E.
70	West Flamborough, ...	43 21	80 2	S. 49 E.
71	" " .. (other grooves S. 69° W.)	43 16	80 1	S. 74 W.
72	" "	43 16	80 1	S. 24 W.
73	Ancaster, ...	43 15	79 56	S. 71 W.
74	"	43 15	79 59	S. 59 W.
75	York, Grand River, ...	43 2	79 54	S. 68 E.
76	Niagara Falls, ... (other grooves S. 8° W.)	43 7	79 4	S. 28 W.
77	Shannonville, (*Prof. Chapman,*)	44 13	77 12	S. 45 E.
78	Battersea, ...	44 25	76 24	S. 10 W.
79	Kingston, ... (other grooves S. 85° E.)	44 14	76 29	S. 45 W.
80	Kingston Mills, ...	44 19	76 25	S. 45 W.
81	Prescott, ...	44 43	75 30	S. 22 W.
82	Newborough, (*Dr. Geo. Lawson,*)	44 39	76 19	S. 68 W.
83	Lake Temiscamang, East Bay, ...	47 36	79 30	S. 53 E.
84	" " "	47 33	79 28	S. 78 E.
85	" " West Bay ....(also S. 36° W.)	47 31	79 37	S. 15 E.
86	" " east shore, ...	47 30	79 29	S. 38 E.
87	" " " "	47 24	79 26	S. 18 E.
88	" " west shore, ...	47 21	79 28	S. 18 E.
89	" " H. B Co.'s post, ...(also S. 13° W.)	47 19	79 25	S. 35 E.
90	" " west shore, ...	47 18	79 26	S. 14 E.
91	" " " "	47 13	79 25	S. 1 E.
92	" " " "	47 9	79 26	S. 7 W.
93	" " " "	47 7	79 27	S. 18 E.
94	Allumettes Lake, Montgomery's, ...	45 51	77 12	S. 25 E.
95	Horton, near Renfrew village, ...	45 25	76 37	S. 45 E.
96	Pakenham, ...	45 19	76 17	S.

LIST OF GLACIAL GROOVES.—*Concluded.*

No.	Locality.	Latitude.	Longitude	Direction.
		° ′	° ′	°
97	Rideau River, Stegman's Rapids, ...	45 22	75 42	S. 45 E.
98	Hull, ...	45 26	75 44	S. 45 E.
99	Gatineau River, below Blasdell's Mills, ...	45 28	75 44	S. 37 E.
100	Ottawa City, Barrack Hill, ...	45 26	75 42	S. 45 E.
101	Kemptville, ...(other grooves S. 5° E.)	45 1	75 38	S. 10 E.
102	Trembling Lake, Grandison, ...	46 14	74 37	S. 25 E.
103	Rouge River, ...	46 10	74 42	S. 12 E.
104	" " .... (other grooves S.)	46 5	74 41	S. 5 W.
105	" "	46 3	74 39	S. 30 E.
106	" "	46 2	74 37	S. 10 W.
107	" "	45 58	74 37	S. 20 E.
108	" "	45 55	74 40	S. 25 W.
109	" "	45 51	74 39	S. 7 W.
110	" "	45 48	74 42	S. 15 W.
111	Grenville, ...(other grooves S. 10° W.)	45 41	74 35	S. 20 W.
112	"	45 42	74 33	S. 7 W.
113	"	45 41	74 33	S. 5 W.
114	"	45 40	74 36	S. 13 E.
115	Wentworth, ...	45 46	74 25	S. 20 W.
116	Isle Perrot, ...	45 25	73 58	S. 45 W.
117	New Glasgow, ...	45 50	73 53	S. 14 W.
118	Ste. Rose, ...	45 37	73 47	S. 19 W.
119	Montreal, Mile-end quarries, ...(also S. 47° W.)	45 32	73 35	S. 67 W.
120	" E. of Papineau Road, ...	45 32	73 34	S. 40 W.
121	" W. " "	45 32	73 34½	S. 44 W.
122	" N. of Mile-end, ...(also S. 51° W.)	45 31	73 36	S. 61 W.
123	St. Armand, ...	45 4	72 42	S. 61 E.
124	Sutton, ...	45 7	72 40	S. 36 E.
125	Orford, ...	45 24	72 13	S 43 E.
126	Sherbrooke, ...	45 24	71 53	S. 43 E.
147	Temiscouata Road, ...	47 44	69 12	S. 64 E.
128	" "	47 43	69 11	S. 49 E.
129	" "	47 43	69 2	S. 64 E.
130	" "	47 41	68 58	S. 64 E.
131	" "	47 41	68 57	S. 44 E.
132	Temiscouata Lake, west shore, ...	47 39	68 49	S. 54 E.
133	" " south shore, ...	47 36	68 43	S. 52 E.
134	" " ....(also S. 55° E.)	47 36	68 42	S. 66 E.
135	" "	47 36	68 41	S. 48 E.
136	" "	47 35	68 39	S. 27 E.
137	Madawaska River, Little Falls, ...	47 22	68 19	S. 60 E.
138	Trois Pistoles, ...	48 7	69 8	S. 32 E.
139	Kempt Road, near Matapedia Lake, ...	48 32	67 43	S. 80 E.
140	Mingan River Falls, ...	50 19	64 2	S. 27 W.
141	Moutange Island, Mingans, ...	50 17	63 49	S. 7 W.
142	Pointe aux Morts, ...	50 16	63 40	S. 27 W.
143	Clear Water Point, ...	50 14	63 27	S. 17 W.
144	Ste. Geneviève Harbor, opposite the island, ...	50 17	63 3	S. 12 W.
145	Island near Whale Head, ...	50 36	59 12	S. 32 E.

At the Pointe aux Morts, an ice-grooved surface, comprising many acres, is exposed between high and low water mark. The main bearing of the grooves, as stated in the list (142), is S. 27° W. Grooves in several other directions however occur, and, from the manner in which they cross one another, the following appears to be the succession of directions, from the oldest to the newest: S. 27° W., S. 37° W., S. 47° W., and S. 31° W. Toward the east side of the exposure there is a shoulder of rock eight or ten feet high. Approaching this, a group of grooves, which are very distinctly marked, and can be followed for fifty yards, is observed to turn gradually from S. 37° W. to S. 10° W.; and two of the grooves, which were about six inches apart and very deep, run into one.

BOULDER FORMATION AND SURFACE BOULDERS.

The boulders or erratic blocks, which are found irregularly distributed over the surface of the province, appear to have been left by the washing away of the lighter material from the formations in which they were once imbedded, and to have been, for the most part, derived from the glacial drift, in which they abound. These blocks are met with alike in valleys and on hill-tops. In the former, they are found in great abundance in many places where the boulder formation has been extensively denuded by the action of water, and its lighter materials swept away. On elevations, they are often seen resting upon the unstratified drift, which in the adjacent depressions of the surface is covered over by stratified sand and clay. The boulders in any locality always present a greater or less admixture of various kinds of rocks; although some one species, either of local or remote origin, often greatly predominates over the others. The blocks appear, in almost all cases, to have travelled southward. A few exceptions to this have however been noted. Thus in the county of Rimouski, in the valley of the Neigette River, there are found on the surface, several large boulders of limestone, one of them forty feet in diameter, belonging to the Gaspé series, which have been moved several miles northward or northeastward. Farther down the valley of the St. Lawrence, blocks of trachytic granite have been carried northeastward from the Table-topped Mountain down the valley of the Magdalen. Dr. Dawson has described similar instances of the northward transportation of boulders in Nova Scotia. Erratic blocks.

On the north shore of Lake Superior, mingled with the ruins of the rocks immediately near, there are found numerous blocks of Upper Silurian fossiliferous limestone, which have been brought from the northward. On Lake Huron, the surface of Sugar Island, and of the flat land between it and the Huronian hills to the north, is strewn with boulders of the Silurian sandstone of the region, of Laurentian gneiss, and of the

Lake Huron. Huronian rocks, including some of the characteristic jasper conglomerate. Rounded blocks, mostly of Huronian age, are very abundant along the whole north shore of Lake Huron. At one place, about thirteen miles east of the Thessalon, the shore is so encumbered with them as to impede the landing with boats. Here also blocks of the jasper conglomerate are met with. On Lacloche, and the neighboring islands, rounded boulders of a black trap are common; and the ringing sound which they give when struck is said to have been the origin of the name of Lacloche. Huronian rocks. Huronian boulders are abundant on the French River, and around Lake Nipissing; and they become more numerous as we ascend the Sturgeon and Wahnapitae Rivers, where they are sometimes seen perched on the bare Laurentian gneiss, as much as a hundred feet above the water. Boulders of the jasper conglomerate occur on Lacloche Island, and on the Fox Islands, thirteen miles west of the French River, but have not yet been observed on the coast to the east of this river. According to Dr. Bigsby, the south and west sides of the island called the Giant's Tomb, four and a half miles from the Christian Islands, are covered with boulders of labradorite and other Laurentian rocks; while they are absent from the north and east sides. Boulders, most probably of Laurentian origin, have been observed by Mr. Sanford Fleming to be abundant on the hills skirting Lake Huron, from Penetanguishine to Nottawasaga; and boulders of Laurentian rocks are Laurentian rocks. found in considerable numbers scattered over the high table land of western Canada, south of Georgian Bay. A portion of this region attains an elevation of 1700 feet above the sea, and much of it is higher than the Laurentide hills to the north, from which the boulders have been derived. These blocks are generally more angular than those from a similar source found at lower levels, and are associated with many others of local origin.

In the counties of Grey and Wellington, the erratic blocks of local origin are largely mingled with others, both of Laurentian and Huronian age, and the boulder formation is in many places seen beneath the stratified gravel. In the south half of the county of Bruce, boulders are comparatively rare, and consist for the most part of Huronian rocks. On the twenty-third lot of the seventh range of Goderich, is a group of very large flat angular blocks of unfossiliferous sandstone, which have been quarried for building purposes; and angular blocks of a similar sandstone, of which the origin is uncertain, are scattered over the whole country between Goderich and Woodstock. Boulders and pebbles of Huronian rocks are found along the Detroit River, and the western part of the north shore of Lake Erie. It is remarked by Mr. De Cew that in the southwest corner Devonian rocks. of Windham, and along the east side of Middleton, very large boulders of Devonian limestone, probably belonging to the Corniferous formation, are of frequent occurrence, associated with others of Laurentian origin. In the latter township, the limestone masses are not found on the west side of

Big Creek, while those of Laurentian rock continue to be as abundant as before. To the north of Brantford, Huronian rocks are abundant among the erratic masses ; but boulders of Laurentian gneiss are unusually large and numerous about Galt, and many buildings in the town are constructed of this rock ; while in the Niagara district it is observed that, with the exception of those of local origin, the blocks are chiefly Laurentian.

Boulders are abundant along the west side of Cook's Bay on Lake Simcoe, and the Holland River, where they present mixtures of Laurentian, Huronian, and Silurian rocks. Similar boulders are met with on the high land south of Holland Landing, in Whitechurch and King ; and Prof. Chapman notes the occurrence of a very large block of Black River limestone in Albion, on the highest part of the Oak Ridge. Through Vaughan and Markham, and along Yonge Street south to Toronto, boulders are somewhat rare. Laurentian blocks occur everywhere along the north shore of Lake Ontario, and the shore of the Bay of Quinté, and are frequently found on eminences back from the lake. In Darlington and Clarke, according to Dr. Bigsby, the Silurian boulders generally occur in groups, and not scattered like those of Laurentian origin. The latter are very numerous throughout the counties of Hastings, Addington, and Frontenac, and are often largest and most abundant on the highest ridges. One of these ridges, which occurs on the twelfth lot of the third range of Sheffield, presents, among other boulders, one of Laurentian crystalline limestone, containing about 6500 cubic feet. Lake Ontario.

The glacial drift, with its boulders, forms the surface of the country over much of the triangular area included by the St. Lawrence and Ottawa Rivers, and the meridian of Kingston, especially in the southwestern portion of this region. Stratified clays and sands however fill up depressions of greater or less extent over this surface, and upon these parts erratic blocks are of somewhat rare occurrence. Along the Ottawa River, ridges of glacial drift or of boulders, running north and south, and resembling moraines, are observed in very many places, and often produce contractions in the channel of the river. One of these occurs at the Hudson Bay Company's post about eighteen miles from the head of Lake Temiscamang. At the Long Sault, just below this lake, an accumulation of Laurentian boulders obstructs the passage of the river, and is greatly instrumental in producing the rapids ; another is met with at the mouth of the Maganasippi, or River of Round Stones, about twenty miles above the Mattawa, where the well rounded boulders, which evenly pave the bed of the stream, are remarkable for being very uniform in size, with a diameter of ten or twelve inches. At the rapids of Roche Capitaine a great accumulation of boulders rises into a ridge between the present channel of the Ottawa, and a ravine, which is probably an old bed of the river. A little above the mouth of Green's Creek, between nine and ten Ottawa River. Moraines.

miles below the city of Ottawa, a line of boulders runs quite across the river, greatly obstructing its navigation. Near L'Orignal, six of these ridges, or lines, occur in the distance of a mile. Numerous large boulders of Laurentian gneiss and labradorite are strewed on the surface of the Lower Silurian rocks at Grenville, where the finer detritus which probably once accompanied them has been washed away.

Rigaud Mountain.

On Rigaud Mountain, there is met with a series of plains, destitute of vegetation, and covered with boulders. These plains, which extend over a large area, filling depressions in the surface of the mountain, begin on the north side, about two hundred feet above the Lake of Two Mountains, and rise gradually toward the south, until they attain a height of two hundred and eighty feet, beyond which they slope away gradually to the south. On the north side, near the summit, these rolled masses are arranged in parallel ridges, from five to six feet high, twenty or thirty paces asunder, and running about northwest. The boulders consist, in great part, of the trap of the mountain, mixed with a few of sandstone. They are generally very well rounded, and vary from three to eighteen inches in diameter. At a depth of seven or eight feet from the surface, the same boulders are still found, without admixture. The upper portions of the mountain, its southern flank, and a considerable extent of country to the south of it, were found to be thickly strewn with similar trap boulders, derived from the rock of the mountain. On its northern flank however, and on the plain between the mountain and the Ottawa River, the erratic blocks consist, for the most part, of Laurentian boulders, and of large angular masses of a sandstone, apparently belonging to the Potsdam formation. A linear distribution of boulders is in some places observed around Mount Royal, where many of the blocks are striated in a similar manner to those of Alpine moraines.

Boulders are very often found imbedded in the stratified clays and sands throughout eastern Canada; and some of the blocks which are here and there met with on the surface of these deposits, may have been left by partial denudation, while others may have dropped from floating icebergs. The facts known with regard to the unstratified drift of eastern Canada will be given farther on, in describing the stratified deposits of that region.

ERIE AND SAUGEEN CLAYS.

Two divisions have already been indicated in the stratified clays of western Canada, the lower of which had been partially worn away before the deposition of the upper division, so that this rests unconformably upon it, adapting itself to the irregularities of the denuded surface. The latter is sometimes associated with beds of gravel and sand; a layer of which, clay, is, when moist,* of a blue color, with thin grey bands. It is commonly more or less calcareous, and always holds boulders and pebbles in greater or less abundance. These, when of palæozoic rocks, though partially worn smooth, are generally somewhat angular, but are rounded when from the Laurentian or the Huronian series. They are frequently scratched; and in some localities few of them are found without striæ, which are best preserved on the pebbles of limestone. These lower clays have as yet yielded no fossils. Erie clay.

The upper division of these deposits, which is largely developed and well exposed along the Saugeen River, may be called the Saugeen clay. With the exception of a yellow band sometimes found at the top, it consists of a thinly bedded brown calcareous clay, generally containing but few boulders or pebbles. The layers of clay, seldom exceeding an inch in thickness, are separated by thin partings of a drab or olive color. This division is sometimes underlaid by beds of sand, which separates it from the Erie clay; and in certain parts of its distribution it is also interstratified with sands and gravels. The thickness of the lower clay has in no one place been ascertained to be more than 200 feet; but clays apparently belonging to this division occur at various levels, from sixty feet below the surface of Lake Ontario, to a height of perhaps one hundred feet above Lake Huron; showing differences in level of about 500 feet. In like manner, clays having the characters of the upper or Saugeen division, are found from the level of Lake Ontario to at least 100 feet above Lake Huron, showing differences of level nearly or quite equal to that of the lower clay. The interstratified gravels and sands of the upper division occur principally in the deposits on the higher levels. Fresh-water shells have in two or three instances been found in beds apparently belonging to this division. Saugeen clay

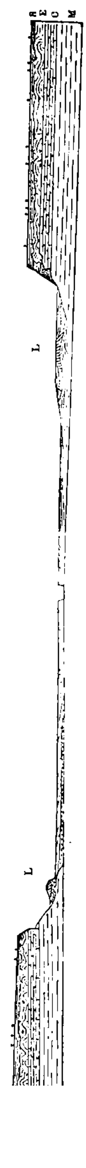
The Erie clay, with few interruptions, runs along the north shore of Lake Erie, from Long Point westward to the Detroit River, and appears to underlie the whole country between this part of the lake and the main body of Lake Huron. It is again found at Owen Sound, and along the Nottawasaga River; and it occurs along the shores of Lake Ontario, and as far east as Brockville. This clay appears to be more calcareous in the northwestern part of its distribution than elsewhere A specimen from the shore of Lake Huron, near Goderich, contained thirty per cent. of carbonate of lime; and similar clays from Walkerton in Brant, Owen Sound, and Linwood in Wellesley, are equally calcareous, and in many places unfit for the manufacture of bricks. They are in such cases a blue marl, which readily disintegrates, and might be used with advantage as an application to sandy soils. Erie clay

When less calcareous, the clays of this division are much esteemed for

* The color ascribed to any clay in these pages is always to be understood as applying to it in an undried state.

White bricks. the manufacture of bricks, which are white, with a yellowish, or more rarely, a greenish tinge when burned; while the clays of the upper division appear in every case to yield red bricks. Clays fitted for the manufacture of white bricks are wrought at St. Mary's, London, Woodstock, Dundas, Toronto, Cobourg, Belleville, Frankville in Kitley, and Easton's Corners in Wolford. In all of these localities the lower clay has the characteristic blue color, and is overlaid by the unconformable brown clays. The boulders and pebbles which are constantly present in it, are not in sufficient numbers to interfere much with its use for brick-making. These lower clays exhibit in many instances a distinctly jointed structure, which appears to be wanting in those of the upper division.

Owen Sound. The principal facts known with regard to the relations and the distribution of these two divisions will now be given, beginning to the westward. At Owen Sound, recent road-cuttings in the terraces on each side of the town exhibit, in a beautiful manner, the relations of the two clays, which are shown in the accompanying section, 447. The bedding of the lower deposit, which is readily distinguished by its grey stripes, is remarkably corrugated, while its denuded surface slopes, on either side, to the valley between the two terraces. In the terrace on the west side, the blue clay, at the thickest part in the cutting, measures eighteen feet, and is mingled with sand, with fragments of rock from the Hudson River and Clinton formations, and with pebbles and boulders of gneiss. The overlying brown Saugeen clay lies in nearly horizontal beds, abutting unconformably against the sloping surface of the Erie clay, and is largely interstratified with beds of fine sand and loam, which are also brown. This upper deposit extends over the whole terrace between the west side of the Sydenham River and the escarpment of the Niagara formation, which rises half a mile to the westward. On the opposite side of the river, at the same horizon, brown clay is met with, from which red bricks are made; and in the south-east corner of the township of Sydenham, beds of tenacious brown clay, interstratified with brown sand



447.—SECTION AT OWEN SOUND ACROSS THE VALLEY OF THE SYDENHAM RIVER.

Horizontal scale 1000 feet, and vertical scale 400 feet, to an inch.

Medina formation; c c, Clinton formation; E E, Erie clay; S S, Saugeen clay with boulders; L L, lacustrine sand and gravel.

High banks of brown sand, capped with a thin bed of brown clay, are seen in several places on the Saugeen, between Hanover and Walkerton; and the blue Erie clay is observed in the bank of the river, about two and a half miles below the former place. In this neighborhood the upper clay in some places appears as if pressed into the underlying sand, in mammillary masses of various sizes. At Walkerton, a fine section of these deposits is seen, at a bend of the river, on the twenty-eighth lot of the first range north of the Durham road. Here, a bank rises one hundred feet over the water, and displays bands of laminated brown clay, interstratified with thick beds of fine sand, the whole resting on the blue clay at the foot of the bank. In Brant, on the twenty-fifth lot of the second range south of the Durham road, and about a mile south of Walkerton, two terraces occur at Mr. McVicar's brick-yard. On the lower of these, an excavation shows a section of about twenty feet of brown laminated loamy clay, interstratified with beds of sand. A little to the south of this, rises the second terrace, consisting of nine feet of brown clay. A grey calcareous sand underlies these clays, and has been penetrated to a depth of twenty-one feet. A bed of hard cemented gravel and sand, three inches in thickness, and with a ripple-marked surface, was found between this sand and the overlying sandy clay. In the bed of the Saugeen, and in its west bank in South Brant, layers of coarse cemented gravel were observed, which appeared to pass under a fine loamy yellow sand occurring higher up in the bank. The banks of this river, in many places between Walkerton and its mouth, exhibit alternations of clay and sand. In the seventh and eighth ranges of Brant, the east bank is more than one hundred feet high, and is, for a considerable part, composed of brown clay. On the opposite side of the river, on higher ground, about half a mile from the bank, a well was sunk through eleven feet of brown clay. This was underlaid by twelve feet of a gravelly light blue clay; on penetrating which a sandy layer was reached, supplying abundance of water. In the northwest corner of Brant, on the forty-first lot of range B, another well was sunk, which gave, in descending, twelve feet of alternating layers of brown clay, and brown and white sand. This was followed by thirteen feet of stiff clay, composed of alternate layers of brown and dark olive colors, with thin partings of fine white calcareous sand; the whole being underlaid by a soft tenacious blue clay, which was penetrated to a depth of twenty feet.

Saugeen River.

Brant.

At the intersection of the Teeswater with the town-line between Elderslie and Brant, the brown clay is underlaid by the blue clay, the latter containing pebbles, with an occasional boulder; and in the village of Paisley, at the junction of the Teeswater with the Saugeen, six feet of reddish-brown clay, holding a few boulders and pebbles of Laurentian and Huronian rocks, and interstratified near the base with layers of fine sand, rest upon an unknown thickness of fine yellowish-white sand. The blue clay appears

Teeswater.

beneath the brown on the east side of the Saugeen, a little below Paisley; but the latter forms the surface on either side of this river, from the north line of Brant to within three miles of its mouth. Its breadth here has not been ascertained, but it probably overlies the blue clay throughout the greater part of the country between the Saugeen and Lake Huron, and may form part of the steep and high clay bank which overlooks the lake the whole way from Clark Point to Port Frank, in Stephen, a distance of fifty miles. It is said to occupy the valley of the Rivière aux Sables (du nord), and is probably continuous between this and the Saugeen. On the twenty-third lot of the seventh range of the township of Goderich, yellow clay was observed, supporting boulders of Devonian and of northern metamorphic rocks. In this region, it is to be remarked, that among the boulders of metamorphic rock, those of Huronian age prevail to the westward, but toward the east are gradually replaced by those from the Laurentian series.

Normanby. In Normanby, near to Neustadt, in the banks of the South Saugeen River, are seen about seventeen feet of hard gritty bluish clay, filled with pebbles, and overlaid by the same thickness of loose gravel. Striated boulders of dolomite, which appear to have been washed out of the clay, are found here. Again, on the west bank of this river, on the ninth lot of the twelfth range of Normanby, beneath a few feet of yellow clay and fine brown sand, are found about twenty-five feet of a similar sandy bluish clay, holding pebbles. Wells sunk in the southern part of the township have penetrated from twelve to twenty-four feet in a like deposit. The west bank of this river, where it crosses the town line of Minto and Normanby, exhibits about fifteen feet of fine yellow clay, which, like the overlying clays and sands just named, apparently belongs to the Saugeen division. The underlying material is here concealed. On the south side of the same river, in the village of Mount Forest, at the corners of Normanby, Egremont, Arthur, and Minto, there is a hill covered with gravel, beneath which appears a fine blue clay. The surface of this appears to be deeply worn by denudation, and the overlying gravel fills up the inequalities. Beneath the gravel, clay is also observed in several other hills in the vicinity. Along the river Canistoga, in Maryborough, Peel, Wellesley, and Woolwich, a very hard bluish-drab pebbly clay, locally known as hard-pan, forms the subsoil. In sinking a well at Linwood, in Wellesley, there were found eight feet of alternating sand, and yellow and drab clay, followed by forty-two feet of the hard-pan; beneath which was found a bed of sand, affording a good supply of water. The pebbles of this lower clayey deposit were generally small and well rounded: one of nem contained fossils of the Trenton formation. Throughout the town-greenstone, are generally distributed over the surface, which presents a broadly undulating aspect. It is not certain whether the underlying bluish pebbly clays of this region represent the Erie division: in some cases they may belong to the more ancient unstratified drift.

Clays of different kinds may be said to predominate throughout all the townships bordering on Lakes Huron and Erie, and the waters connecting them, from the mouth of the Saugeen on the one hand, to the mouth of the Grand River on the other. The prevailing subsoil of the great triangular area between these coast lines, so far as it has yet been examined, is likewise of clay. Although the steep bank of clay, often more than 100 feet in height, already mentioned as stretching from Clark Point to Port Frank, is the only part of the deposit which is actually washed by the waters of Lake Huron, a continuation of the same bank is traceable, at a short distance back from the lake, both north and south from these points. Northward from Clark Point, it recedes very gradually from the shore for a few miles, and thence continues to the Saugeen, at an average distance of two miles from the lake; the extreme variations being about one mile at its nearest, and three miles at its greatest distance from it. The space between this ancient lake margin (thirty-five miles in length) and the present shore, is occupied by drifting sands. Southward from Port Frank, the continuation of the clay terrace, which is sometimes visibly underlaid by strata of the Devonian series, is seen at a short distance from the lake, for about thirty miles, beyond which it appears to run farther inland. The intervening area, on which the township of Sarnia is partly situated, is occupied by loose sand. In the bank of the St. Clair, near the village of Sarnia, the clay again makes its appearance, and continues thence southward to Lake Erie. In the township of Plympton, the clay of this terrace was found to contain fragments of the Corniferous limestone. Lake Huron. Sarnia.

At the oil wells, on the thirteenth and fourteenth lots of the tenth range of Enniskillen, two beds of gravel, of four and five feet respectively, have been met with in the clay, at depths of ten and forty-four feet from the surface, making a total section of clay and gravel of forty-nine feet. *Unio circulus*, *U. gibbosus*, and several valves of a *Cyclas*, were obtained in the upper bed of gravel; and in this bed a deer's bone was also said to have been found. Between the gravel and the overlying ten feet of clay, a thin layer of impure mineral pitch, or half-dried petroleum, intervenes, enclosing leaves of land-plants, and occasionally insects (page 524). Prof. Mather has also noted the occurrence of fresh-water shells in the clay along the Detroit River. Enniskillen.

On the shore of Lake Erie, the two divisions of the clays are well exposed in cliffs, which, in the neighborhood of Port Talbot and Port Stanley, attain an elevation of one hundred and fifty feet. The lower, or Erie clay, which is bluish and somewhat calcareous, frequently holds angular fragments of Lake Erie.

limestone, and small rounded boulders of the northern crystalline rocks. This is overlaid by another deposit of clay, which is light brown above and buff or yellowish toward the summit. This upper clay, generally brownish in color, covers a considerable area in the townships bordering the east side of the Grand River, below Brantford, and those on the lake between the mouth of this river and the Niagara. The townships of Rainham and Walpole are covered in many parts with a reddish-brown clay, of no great thickness, which rests directly on the palæozoic rocks. Similar clays are said to continue through Woodhouse, Charlotteville, and Walsingham. A cliff of reddish clay, holding angular fragments of Corniferous limestone, and worn boulders of crystalline rocks, commences on the shore of Lake Erie, three miles east of the Grand River, and extends about a mile and a half farther eastward. At Niagara Falls the Silurian limestone is covered by 120 feet of sandy loam, holding striated pebbles and small boulders, and containing near the middle the shells of a species of *Cyclas*. It is overlaid by fifteen feet of thinly bedded reddish-brown clay, containing similar pebbles and angular fragments. This deposit, whose summit is sixty feet above the level of Lake Erie, forms a bank which continues up to Chippawa.

Beneath the upper clays of the region just indicated, blue clays belonging to the lower division are met with in several places. In a brick-yard, a mile to the south of Brantford, there is exposed a section of twenty-four feet of blue clay, beautifully stratified in horizontal bands of a few inches, with grey layers. These are less tenacious than the rest, and present various corrugations and contortions, which are subordinate to even beds composing the mass. This clay, which is used for the manufacture of white bricks, abounds in pebbles and rounded boulders, which latter appear to be chiefly of northern metamorphic rocks. From the aspect of the bank below the section, it is probable that the blue clay has here a thickness of seventy or eighty feet. A similar clay has been met with in sinking wells in several parts of the township of Seneca. Much of the flat country between the Niagara escarpment and the southern shore of Lake Ontario appears to be underlaid by clay. In the township of Niagara, it is exposed along the river and the lake, often covered with sand. At Thorold the clays appear to belong partly to the upper, and partly to the lower division; while at St. Catherine's, a clay, which is supposed to belong for the most part to the former, has been penetrated to a depth of forty feet. At Jordan in Louth, both clays are met with, and together form a bank of seventy feet in height. From Grimsby westward, the upper clay diminishes in thickness, and at Hamilton it entirely disappears.

Brantford.

St. Catherine's.

The area between the Desjardins Canal and the limestone escarpment

The surface of the clay is here somewhat uneven, and the depressions are filled with sand and gravel holding fragments of rocks from the Hudson River formation, and pebbles of Laurentian gneiss; the whole being sometimes overlaid by a thin stratum of fine sand. In the valley in which Dundas is situated, the blue clay has been penetrated to a depth of seventy-eight feet, being about sixty feet below the level of Lake Ontario; while on the plateau to the south of the town, its height above the valley is probably over one hundred feet; so that if the clay of the valley runs under that of the plateau, the entire ascertained thickness of the formation would be about two hundred feet. An uneven covering of loamy gravel and rounded fragments of limestone, with an occasional boulder of gneiss, is spread over the blue clay at Dundas; while to the westward, the valley is literally filled with irregular hillocks and broken ridges, composed of sand, and blue and brown clays, which rise confusedly over one another to the summit of the Niagara escarpment at Copetown, in the townships of Ancaster and Beverley. Dundas.

At Copetown station on the Great Western railway, near Dundas, eighteen feet of brownish clay belonging to the upper division, are seen to rest upon a considerable thickness of sand; and farther to the westward, at Harrisburg in South Dumfries, the same clay has been ascertained to be at least thirty feet thick. In sinking a well at Paris, one hundred feet of clay holding boulders, and said to be for the most part brownish in color, were met with. At Princeton, and at Ingersoll, twenty feet of this clay were found resting on gravel; and at Woodstock thirty feet of a similar clay repose upon a clay belonging to the lower division. In sinking a well at the Great Western railway station at London, Mr. Robb, on whose authority the facts in the last four localities are stated, found a section in descending order, of twenty-two feet of loam and sand, followed by sixty-eight feet of hard-pan, with boulders, and two layers of four and five feet of soft sandy clay; the whole underlaid by beds of sand and clay, with boulders, to a depth of at least fifteen feet. The hard-pan, which, as already stated, is a hard bluish-drab pebbly clay, may belong to the unstratified drift; but in another place near the town a section of fourteen feet of clay is exposed, the upper part of which yields red bricks, while the lower portions burn to a white or greenish-white color. London.

In the second range of York, in the rear of Toronto, the lower or Erie clay is extensively wrought for the manufacture of white bricks. It is bluish when moist, but ash-colored when dry. It has a distinctly jointed structure and contains pebbles and boulders sparingly distributed. Over the irregular denuded surface of this horizontally stratified clay is spread a coating of yellow clay and sand, which conforms to the undulations of Toronto.

to red bricks, was three feet in thickness. Beneath this was found, in the two sections, from five to nine feet of yellow sand, interstratified with yellowish and bluish clays, both burning white. Under these was the solid jointed blue clay; which has been penetrated to the depth of sixty feet, and in wells near by, to seventy or eighty feet, without any apparent change in its characters. In digging wells in Toronto, according to Prof. Hind, trunks and branches of trees have been found imbedded in the overlying yellow clay at depths of from ten to twenty feet from the surface.

To the east of Toronto, clays, generally overlaid by sand, continue through the southern parts of York and Scarborough. At Port Hope, and for a few miles to the eastward, banks of stratified clay capped by sand, rise from ten to forty feet above the level of Lake Ontario. Between Cobourg and Napanee, the stratified clays are found in many localities, and are of two colours, bluish below and yellowish above. These appear, as at Toronto, to represent respectively the Erie and Saugeen divisions, In Belleville, an excavation made near the court-house showed at the top four feet of very fine yellow sand, followed by three feet of a mixture of brown clay and sand, to which succeeded eight feet of stratified drab clay. This rests upon the uneven surface of the boulder formation.

Belleville.

Near Kingston, between the city and the Grand Trunk railway station, a narrow belt of what appears to be the upper clay occurs along the west side of the Cataraqui River. The railway cutting exposes a thickness of about fifteen feet, which is in thin slightly undulating layers, and is thickly studded with very rough irregular calcareous nodules, generally of small size. In one of these, a valve of *Cyclas* was met with. Annular and tubular concretions, from a quarter of an inch to an inch in diameter, are very abundant in some parts of this deposit. In the townships in the rear of Kingston, a similar brown clay often occupies the level portions between the rocky ridges. Dr. Lawson has observed the leaves of a plant resembling a *Vaccinium* in a laminated brownish clay at Newborough. He also found near Frankville, in the township of Kitley, brown clay with nodules, like that of Kingston, lying upon a blue clay, which yields white bricks, and probably belongs to the lower division. At Easton's Corners, in Wolford, also, a hard jointed clay, yielding white bricks, is said to be unconformably overlaid by a soft drab clay, which becomes red by burning. In the cutting for the Brockville and Ottawa railway, at Brockville, a bluish clay holding boulders is overlaid by several feet of brownish clay. The plane of contact of these two clays slopes toward the St. Lawrence. On the south side of Lake Ontario, in New York, clays belonging to the two divisions are again met with.

Kingston.

In the metamorphic region north of Lakes Superior and Huron, and between the latter lake and the Ottawa, thinly bedded clays have been found in the valleys of many of the rivers. Between McKay's Mountain and the Grand or Kakabeka Falls of the Kaministiquia, the banks of the river often consist of laminated buff-colored clays, covered by yellow sand, which together attain the height of sixty feet. Nodules, which have been washed from the clay, are found in abundance on the edge of the river. Red clay is seen on the bank of the Batchehwahnung, under a high cliff of sand and gravel, at the distance of a mile and a half in a straight line from the mouth of the river. On the Schibwah River, red and drab clays, in very thin alternating layers, are found about two miles from its mouth, in a direct line from the bay. One bed contains an abundance of thin flattened nodules; and some of the clay at the surface was found to be thickly perforated with small tubular holes filled with sand, which, though they recall the *Scolithus* of the Potsdam formation, are probably the burrows of the larva of some insect. At thirteen miles up the Goulais River, in a straight line from its mouth, a deposit of similar clay, resting on solid rock, and running under a bed of sand, has a thickness of upward of sixty feet. Numbers of large and curiously formed nodules were found in the clay at this place, but none of them contained organic remains. Lake Superior.

At the upper termination of the town plot, on the right bank of the Goulais River, there is a deposit of the roots and limbs of trees, imbedded in a bluish scaly material, apparently a mass of compressed leaves and moss, which rests upon a bed of clay, and is overlaid by a mixture of clay and sand: the whole, with a stratum of sand at the top, constitutes a bank of from twenty to twenty-four feet high. The bed of vegetable matter, which is from one to three feet thick, and about ten feet over the river at the western end of the exposure, dips gently and evenly up the stream; while a thin bed of reddish clay, intervening between the overlying arenaceous clay and the stratum of sand which forms the surface, seems to be perfectly horizontal. Goulais River. Fossil wood.

On the south side of Lake Superior, between White-fish Point and the Painted Rocks, a great deposit of sand, interstratified with gravel, is spread over the surface of the country. At the Grand Sable, a short distance west from the Grand Marais, it rises here and there almost vertically from the lake to a height of 300 feet. At the parts most exposed to the winds of the lake, such as at White-fish Point, the sand is piled up in dunes or sub-conical hillocks; but in more sheltered parts, where covered by vegetation, it is arranged in a series of terraces, which rise one above another with considerable regularity, attaining in the highest terrace an elevation of more than 150 feet above the water. Along the coast, a bluish-drab clay occasionally crops out from below the sand, which west from Two Heart River is in several parts overlaid by an accumulation of roots and Grand Sable.

the bed on Goulais River, except that it sometimes presents a thickness of twelve or fourteen feet. The bed of vegetable matter at the Grand Sable is covered by a layer of mixed sand and clay, above which the hill of interstratified sand and gravel, which may belong to the Algoma division, rises abruptly to the height already stated. The vegetable remains are of recent species, among which are the stems and branches of what appear to be the white cedar, *Thuja occidentalis*, the white birch, *Betula paperacea*, and the balsam poplar, *Populus balsamifera*, occur. The bark of the birch is only partially decayed.

St Mary River. Behind the Sault Ste. Marie, a terrace, varying in its height, but averaging perhaps one hundred and fifty feet above Lake Superior, and often composed of clay in red and drab layers, stretches from the Laurentide hills southward toward the St. Mary River. About a mile below, and again about four miles above the foot of the Sault, this terrace comes near the edge of the river, and recedes in sweeping curves in both directions from each of these points. A bay, two miles and a half in depth, is thus left between them, and is occupied by a barren plain of no great elevation above the river, partly covered with coarse brown sand, and partly strewn with boulders of northern metamorphic rocks, and angular fragments of Silurian sandstone, which are sometimes arranged in small bare ridges parallel to the present direction of the river. The surface has thus the appearance of having formerly been covered with swiftly flowing water.

Thinly stratified red and drab clays, with beds containing nodules in great numbers, occur in several places in the lower part of the Garden River. Many of the nodules were broken, and found to be devoid of organic remains. A considerable depth of brownish-drab thin bedded clay, holding nodules, is also seen in the banks of the Thessalon and Mississagui Rivers. Mississagui. The sections met with farthest up the Mississagui, and its tributary the Little White River, exhibit near their summits thin seams of yellow sand interstratified with the clay, and the whole deposit is overlaid by the same kind of sand. On the Little White River, the clay is fifty feet thick; and at one place a bed was observed to be curiously contorted, while those above and below it were even and undisturbed. A similar structure occurring in the palæozoic shales of Gaspé, has been figured on page 392. The clay deposits of the Mississagui and Little White Rivers do not attain an elevation of more than 160 feet over Lake Huron, or 738 feet above the sea. A similar clay is often seen under the sand in the banks of the Spanish River, below the White-fish branch; and a portion of the same kind of clay exists on a small island near the north shore, six and a half miles east of the Hudson Bay Company's post at Lacloche, and directly opposite the highest mountain in the neighborhood. At the elbow of the Nahmanitigon or Red Clay River, which enters the southeast corner of Lake Nipissing, stratified red, blue, and buff clays, holding spherical nodules, occur at an estimated elevation of 710 feet above the sea. Laminated brownish-drab clay has been found in three places in the upper part of the Meganatawan River. The highest of these has an elevation of about 1000 feet above the sea. Drab clay of the same character was found between Ox-tongue Lake and the Lake of Bays, on the upper part of the Muskoka River. Clay, probably similar to these just noticed, is also met with among the hills in the townships between Georgian Bay and Lake Simcoe.

Muskoka.

It will be perceived that the clays just described, in this northwestern part of the province, although occurring in isolated patches of no great extent, are all of the same general character, and appear to belong to one age, supposed to be that of the Saugeen clay; with which, in the absence of any evidence to the contrary, they may for the present be classed.

ALGOMA SAND.

To the north of Lake Huron, and between Georgian Bay and the Ottawa River, part of the surface of the country consists of bare rock, but where any superficial covering exists, it is almost invariably a yellow sand. This also overlies the clays of this region, which have just been described, and are exposed only in river cuttings. This sand is most largely developed along the principal rivers of the district, and it also covers St. Joseph's Island, and part of the Grand Manitoulin; while to the westward of Lake Huron, the sands already alluded to on the south side of Lake Superior probably belong to the formation. It is largely developed on the Dog and Kaministiquia Rivers, and spreads over a considerable tract below the Great Falls of the Michipicoten, as well as over a smaller area on the Batchehwahnung River. The Goulais River, in its lower stretch, flows in a very tortuous course between mountain ranges, through a wide and fertile valley, which has yellow sand as a subsoil over a great part of its area. This yellow sand also extends far and wide over the higher table-lands of the Thessalon and Mississagui Rivers. On either side of the Spanish River, below the great bend, it forms an extensive plain, bearing a heavy growth of pines, and it is also found in large patches north of that part of the coast lying between the mouths of the Mississagui and Spanish Rivers. About Grand Portage on the Mississagui, gravel takes the place of the clay and sand which are found farther down in the valley, and becomes coarser and more prevalent in ascending the river. At its intersection with Salter's base line, the Mississagui is 830 feet over the level of the sea; and farther up, the banks and flats of the river are covered with coarse shingle and boulders. The sand is widely spread almost all along the valleys of the White-fish and Sturgeon Rivers, the upper reach of the Wahnapitae, and

Yellow sand.

Thessalon.

Lake Nipissing. deposit surrounds Lake Nipissing, with a varying breadth, on all sides except the south, and appears to be extensively developed between this lake and the Ottawa. It is reported to be pretty continuous over the whole district between the line of the Mattawa and Lake Nipissing on the north, and the head waters of the Meganatawan and Muskoka to the south. Below Cedar Lake the Petewahweh is flanked on either side by a wide plateau formed of yellow sand, which is again largely developed on the Bonnechère, above the third chute, and covers much of the country between this river and the Madawaska. It likewise occupies a considerable area around Lake Kamaniskaik, and between Muskrat Lake and the Bonnechère.

Much of the region thus covered, lies within the district of Algoma, and this great arenaceous deposit may hence be conveniently designated as the Algoma sand. It has hitherto proved unfossiliferous, and it is uncertain what relation it bears to the fossiliferous sands farther down the Ottawa, which will be described in the sequel.

Algoma sand.

ARTEMISIA GRAVEL.

Gravel. A belt of loose gravel, remarkable for its great extent, stretches in a southward direction across the peninsula of western Canada, from near Owen Sound to Brantford, a distance of 100 miles. Its average breadth, not including that of the extreme points, is twenty-three miles, and its total area more than 2,000 square miles. The limits of this great gravel deposit are approximately as follows. Its northern extremity is in the southwest corner of Sydenham, and from this point its western boundary runs nearly straight to the west side of Bentinck. Proceeding thence with a slight curve to the eastward, it intersects the east half of the south line of Normanby. The curve is now reversed, and takes in the northeast corner of Minto, and the northern half of Arthur. Entering Luther, it again curves to the east, and includes the southwest part of that township. From the centre of the south line of Luther it proceeds in a direct course to the north side of Wilmot, thence to the northern part of East Oxford, where it turns eastward, and comes to the Grand River near Brantford.

Again, starting from the southwest corner of Sydenham, its eastern boundary is traced across Holland to about the centre of the west line of Euphrasia, and, after forming a northward spur in that township, it reaches the Beaver River in the north of Artemisia. From this point, it proceeds northeastward, and curves round, making a promontory which includes a small portion of Collingwood, and the greater part of Osprey. It forms a westward sinus in Melancthon, continues thence into Mono, and runs out in a long spur between Albion and Ajala, in the direction of the Oak Ridge. Leaving the south side of this spur, it continues from the southwest line of

Caledon, with a gentle curve to the eastward, till it reaches the centre of Puslinch; bisects the north line of Beverley, and after forming a spur in that township, returns nearly to its northwest angle, and follows its western line for several miles, and then crosses the southeast corner of South Dumfries, and reaches the Grand River just below Brantford. Within the above limits the gravel is continuous over almost the whole surface.

This great belt of gravel has a general parallelism with the Niagara escarpment, and follows the highest ground of the peninsula. The materials composing it consist principally of the ruins of the Guelph formation, Source of the gravel. on which the greater part of it lies, except toward the southern extremity, where the Niagara formation is largely represented. Pebbles of Laurentian and Huronian rocks are everywhere mixed with the others, and sometimes form a considerable proportion, while rounded fragments from the harder beds of the Hudson River formation occur locally in some abundance. The gravel is all well rounded, and generally coarse; it often constitutes what might properly be called shingle, being loose and free from any admixture of clay; and it is distinctly stratified. Well worn boulders of Guelph, Laurentian, and Huronian rocks are disseminated through the whole mass, and wherever the gravel has been dug for road-making, there may be found heaps of these, which have been thrown aside.

An extensive spur of gravel runs from this area to the northeast, constituting what is called the Oak Ridge, which has been described by Mr. The Oak Ridge. T. C. Keefer. It leaves the great Middle Silurian escarpment in the northern part of Albion, and runs eastward as far as Darlington, where it curves southward into Clarke. It thence runs almost straight to the great bend of the Trent in Sidney, and continues in the same course a short distance beyond it. The general course of the ridge thus presents a southward convexity, while the north shore of Lake Ontario curves in the opposite direction. The ridge appears to be composed wholly of sand and gravel; and its greatest elevation behind Toronto, where it is probably higher than at any other part, is 720 feet over Lake Ontario, or 950 feet above the sea. Near the summit of the ridge, in Sidney, there is a lake which has no visible inlet, but gives rise to a mill-stream. A similar lake is situated on the continuation of the ridge near the Pinnacle House, on Yonge Street, and not far from the summit of the water-shed.

The relations of this Artemisia gravel to the Algoma sand, and to the sands and clays of the upper or Saugeen division, have not yet been fully determined. Near Brantford, however, it is seen to overlie a blue clay, which belongs to the Erie division; and in the village of Mount Forest, as already stated, it rests unconformably upon a fine blue clay.

ANCIENT BEACHES, TERRACES, AND RIDGES.

Lacustrine sands. Besides the upper clays and sands already described in western Canada, there are several local accumulations of sands, often marked by fresh-water shells. These, together with various ridges and terraces, which are conspicuous features in the surface geology of this region, appear for the most part to have been formed by the waters of the great lakes, when their extent was much greater than at present. The most considerable deposit of this kind is probably the sandy tract in the county of Simcoe, which extends southeastward from the head of Nottawasaga Bay, and has an area of rather more than 300 square miles. It has been described by Mr. Sanford Fleming, and may be said to cover the whole of Sunnidale, the greater part of Vespra, the western quarter of Flos, the northeastern third of Nottawasaga, the northern half of Tossorontio, and the northern half of Essa. The sand, which is of a yellowish-grey color, appears to be of considerable depth. In Flos and Sunnidale, the Nottawasaga River flows for some distance between banks of sand, from seventy to eighty feet in height, holding fresh-water shells. These are also found in the sand all along the Nottawasaga River, from four miles south of its intersection with the Northern railway, to its mouth. At Angus station in Essa, on the west bank of this river, Professor Chapman collected the following species, which were in fine sand underlaid by gravel, and were met with from near the surface to a depth of eighteen feet: *Unio complanatus* (very abundant), *Cyclas similis*, *C. dubia*, *Amnicola porata*, *Valvata tricarinata*, *V. piscinalis*, *Planorbis trivolvis*, *P. campanulatus*, *P. bicarinatus*, *Limnæa palustris*, and *Physa ancillaria*. The general level at which these shells occur may be taken at from thirty to forty feet above Lake Huron, and the locality is distant above twenty miles in a straight line from the mouth of the river. Farther down the Nottawasaga, about twelve miles from its mouth, and at nineteen feet over Lake Huron, Dr. Bigsby found in the bank of the river two horizontal layers filled with shells of *Unio*. The layers are each from four to six inches thick, and from one to two feet apart, and are beneath from eighty to one hundred feet of sand. The shells are closely packed together, and some of them have their valves in contact. Shells of the genera *Planorbis*, *Physa*, *Limnæa*, *Melania* and *Paludina* are also met with in the same layers. All of the species found here are now living in great numbers in the Nottawasaga. The two layers above mentioned are continuous for three miles down the river, and are occasionally seen all the way to the lake, while numbers of shells are scattered through the sandy layers above them. The sand, which is uniformly stratified, holds occasional portions of gravel, and at one place three continuous layers of small pebbles occur half way up the bank. It is underlaid by clay, which is often seen in the bed of

Margin notes: Fresh-water shells. Nottawasaga.

the river, and sometimes rises twenty feet above it. The Nottawasaga River, before entering Lake Huron, runs for several miles parallel to the shore, being separated from it by a narrow peninsula of sand. Behind this, according to Mr. Sanford Fleming, a ridge of sand parallel to the present shore, rises to a height of about eighty feet above the lake, and appears to have formed a narrow neck of land reaching across the former extension of the Nottawasaga Bay. *Melania conica* and *M. Niagarensis* have been found in the sand, in a railway cutting near Collingwood, but Collingwood. at no great elevation above Lake Huron. *Planorbis trivolvis*, with three species of *Helix*, was found in sand and fine gravel in a road-cutting through a little ridge between seventy-five and seventy-eight feet above Lake Huron, about a mile south of Collingwood harbor. In the northern part of Collingwood, at the base of the Blue Mountains, there is another ridge of sand, the summit of which at Craigleith is not far from eighty feet above the lake. A beach-mark at about the same height is seen running from the northern extremity of Nottawasaga Bay into Essa, and another one at Penetanguishine. Near Meaford, at the mouth of the Bighead Meaford. River, a succession of ridges and terraces of sand and gravel rise above one another to about 150 feet above Lake Huron, and, winding along the bank of the river, come upon the shore three miles to the north of Meaford. Thence they are continued to Cape Rich. Fresh-water shells are found in one of these terraces at a height of seventeen feet above the lake, and are said to occur in another ridge at fifty feet. In sinking a well in Meaford, so many prostrate trunks of trees were met with, about ten feet under the surface, and about the same height over the lake, that the digging was abandoned. Trunks of cedar and other trees are found beneath about forty feet of sand near the river's mouth. Two miles to the west of Cape Rich worn fragments of bark and wood are said to have been met with in digging a cellar on a terrace 155 feet above the lake. One of the principal ridges leaves the Silurian escarpment, with a height of 160 feet, and, after running east for two miles nearly to Cape Rich and gradually losing its elevation, curves round and runs southward, parallel to the shore, with a height of only forty-five feet. In its east and west extension the ridge is very abrupt on the lake side, with a gentle fall to the south; but after rounding the cape it becomes steep on the landward side, and presents a gradual slope of 300 yards to the lake. This slope is thrown up into no fewer than fifteen regular parallel ridges of small flattened shingle, the summit of each rising three feet higher than that of the next below, or from four to five feet above the intervening depression. Still smaller secondary ridges frequently lie between these, and join them obliquely; in exactly the same manner as the little ridges of shingle, which are washed up by every storm, repose upon the slope of the lowest of the series. The contours of these clearly show that forces similar to those now in operation were acting at the time of their formation, and that the prevailing direction of the winds was the same then as now. This curved ridge encloses a marshy flat with a clay bottom, half a mile in breadth and thirty feet above the lake. After crossing this flat, on the road leading southwest from the cape, two other gravel ridges rise to sixty and eighty feet, respectively, above the lake. The higher of these ridges curves in the same manner as the ridge first described, and the other has probably a similar form. A terrace covered with large rounded gneiss boulders comes between the high Silurian escarpment and the highest ridge.

Owen Sound. Another deposit of sand and gravel extends, with a gradual rise, from the head of Owen Sound up the valley of the Sydenham River, for a distance of about three miles. In the town of Owen Sound, which stands upon this deposit, twelve species of recent fresh-water shells were collected in the sand, at elevations varying from nine to about fifteen feet above Lake Huron. They consist of *Limnæa umbrosa*, *Planorbis campanulatus*, *P. bicarinatus*, *P. parvus*, *Melania acuta*, *M. Niagarensis*, *M. conica*, *Paludina decisa*, *Valvata sincera*, *V. tricarinata*, *Amnicola porata*, and *Cyclas similis*. About a mile south of the mouth of the Sydenham River, some of the same species were found in the sand at forty feet above the lake. On the west side of this sandy plain, trunks of trees are seen at the edge of the river, projecting from the foot of a bank of gravel and sand about thirty-five feet in height; but their occurrence in this position may be accidental. Besides this lacustrine deposit on the shores of Owen Sound, there are several terraces of sand and gravel which occur at much higher levels, and correspond to ancient water-margins about 120, 150, and 200 feet above the present level of Lake Huron. Some of the higher terraces continue with great regularity several miles along the east side of the Sound. At Piette's Harbor, on the west side of the Sound, two ancient beaches are found; one at 149 feet, and another about 175 feet above the lake; besides others at lower levels.

Isthmus Bay. In Isthmus Bay, a set of small parallel ridges, composed of the debris of the Niagara dolomite, rises from the water's edge to a height of about twenty feet above it. Behind these, ridges of the same material succeed one another, attaining sixty or seventy feet above the lake. Human bones, much decayed and broken, are found in great numbers in one of these ridges between twenty-five and thirty feet over the water.

Cabot's Head. Wingfield Basin at Cabot's Head, is partly surrounded by ridges of shingle about twenty feet above the lake; but steps indicating former water-margins are found at greater elevations between the basin and the high cliffs in the rear. Dr. Bigsby notes the occurrence of a beach of rolled pebbles at about 100 feet above the lake, on a small island near St. Joseph's Island.

Lake Superior. Terraces and ancient beaches are found in many places upon Lake Superior, but no recent fossils have as yet been found in them. Three miles below the Petits Ecrits, seven terraces of sand and gravel rise above one another to a height of 931 feet above the sea-level. Their elevations are respectively 30, 40, 90, 224, 259, 267, and 331 feet above the lake. The third and fourth beaches are the best marked, and a marsh 500 yards in the rear, is on the same level as the fourth. Those already alluded to in the sands on the south side of the lake probably correspond with some of these. A few miles to the east of Black River (opposite the Slate Islands), four successive steps rise to a height of twenty feet over the lake, and are succeeded by another, twenty-five feet higher; while the sixth or uppermost is forty feet above this, making its elevation above the lake eighty-five feet. In the bays between the rocky points from the Montreal River to the Sault Ste. Marie, banks of sand and gravel are found at various heights, from the level of the lake up to thirty feet above it. On the north side of the lake, the ancient water-margins are frequently marked by the wearing of the solid rock (page 701), as well as of the loose materials. The latter sometimes hold pebbles, which contain organic remains belonging to rocks newer than the Niagara formation.

Petits Ecrits.

Black River

In the state of Ohio Mr. C. Whittlesey mentions a series of gravel ridges, rudely parallel with the southern shore of Lake Erie. The one nearest to the lake extends for a distance of 120 miles, and has an average height of 112 feet above the lake. The second, which is less continuous, has an average elevation of 145, and the third 186 feet above Lake Erie. The first and second of these are said to contain fresh-water shells. Similar ridges doubtless occur along the northern shores of this lake, but have not been much examined. A remarkable ridge of this kind is found in Raleigh.

Lake Erie

The sandy flats which are met with in many places along the river Thames, from St. Mary's to Chatham, contain land and river shells in great abundance. At London the fine fluviatile sand rests upon a mixture of coarse clay with sand and pebbles. Both the land and fresh-water shells, which comprise many species, are disseminated throughout the deposit, to a depth of seven feet, and perhaps more, but are most abundant in certain beds. It is observed that the proportion of land shells greatly increases toward the surface. Land and fresh-water shells are also abundant in the sandy alluvions along the Grand River, between Brantford and Dunville: and similar flats, full of the same kind of shells, occur at some of the bends of the Saugeen below Hanover. At the Falls of Niagara strata of fresh-water sand are found on Goat Island, where they rest upon the boulder formation, and in the ancient bed of the river, on each side of the gorge below the Falls. On the Canadian side, sixteen species of common fresh-water mollusca are found imbedded in the sand, evidently in the position in which they had lived. They are *Planorbis bicarinatus*, *Physa heterostropha*, *Limnœa caperata*, *L. stagnalis*, *Melania Niagarensis*, *M. conica*,

London

Niagara Falls.

M. acuta, *Paludina decisa*, *Amnicola porata*, *Unio gibbosus*, *U. complanatus*, *U. ellipsis*, *U. rectus*, *Margaritana marginata*, *Cyclas similis*, and *Pisidium dubium?*, with one land species, *Helix albolabris?* Prof. Hall states the occurrence of a mastodon's tooth in a similar deposit on the opposite side of the river. Fresh-water shells have also been met with in the bank of loose material on the north side of the whirlpool.

Burlington Bay.

Burlington Bay is separated from the western part of Lake Ontario by a low sandy beach running northwesterly; and five miles to the west of this is a nearly parallel ridge, which stretches with a westwardly curve across the marshes at the head of the bay, and constitutes Burlington Heights, which have an elevation of 107 feet above the lake. This ridge, which consists of alternate beds of sand, and of coarse and fine gravel, overlies the Medina formation in its continuation through the western part of the city of Hamilton. To the northward it terminates abruptly, and is separated from the escarpment of this formation by a deep and narrow ravine, which, until filled up by a railway embankment, served as the outlet of the streams which enter the Dundas valley from the westward. In making an excavation for the Desjardins Canal, the ridge was found to be underlaid by the Erie clay, near the level of the lake. Toward the top, many of the beds are cemented into a hard rock by infiltrated carbonate of lime. At a height of seventy feet above the lake were found several of the bones of the mammoth or fossil elephant, *Euelephas Jacksoni*, and in the same excavation, seven feet higher, the horns of the wapiti, *Cervus Canadensis*, and the jaw of a beaver, *Castor fiber*, were met with. To the west of the town of Dundas is an old water-margin, at an elevation which seems to coincide with that of Burlington Heights; while on the north side of the town another ridge of sand and gravel, attaining a height of 318 feet above the lake, occurs just under the escarpment of the Niagara formation, which is about 100 feet higher. In its eastward extension it recedes from the cliff, and, diminishing in height, disappears at the end of a mile. It approaches the face of the escarpment on the east side of Spencer's ravine, on the other side of which a still higher bank of sand and gravel conceals the escarpment; and was probably at one time connected with the gravel ridge, which would thus have formed a bar between the former outlet of Flamborough Creek and the waters which then filled the Dundas valley. This creek has now excavated the solid rock to a distance of half a mile back from the general line of the escarpment, and cut the bar of sand and gravel at the mouth of the gorge to its base.

Mammoth's remains.

Dundas.

On the north side of Lake Ontario fresh-water shells are found in the banks of the Don, beneath a considerable thickness of sand, at about thirty feet above the level of the lake. They also occur around Lake Simcoe, imbedded in sands from eighteen to thirty feet above the lake. Toronto Island, which is being constantly modified by the action of the lake, has been shown by Mr. Sandford Fleming to have resulted from the westward drifting of the materials derived from the wearing down of the Scarborough Heights, 320 feet high; and Long Point, in Lake Erie, appears to have been formed in the same way, by the gradual drifting of sand and gravel to the eastward. An exact counterpart of Toronto Island is presented by the Davenport ridge, described by Mr. Fleming. This ridge, which consists of fine rounded gravel, runs to the westward from the high ground behind Toronto, which is from 250 to 300 feet above Lake Ontario, in the same manner as Toronto Island extends from the Scarborough Heights. The gravel beds of this ridge all dip to the southward, and rounded lumps of fine clay are of common occurrence among them. Their presence is accounted for by supposing them to have been rolled, perhaps when in a frozen state, by the waves of the ancient lake. This ridge, the summit of which is about 170 feet above Lake Ontario, is about seven miles to the northwest of Toronto Island. In a paper presented to the Geological Society of London, in 1837, Mr. Thomas Roy states the occurrence of thirteen ancient water-margins between Toronto and Lake Simcoe, at the respective heights over the sea of 342, 442, 514, 542, 578, 634, 654, 734, 790, 858, 914, 966, and 996 feet. It is stated by Prof. Hall that on the south side of Lake Ontario, a conspicuous ridge runs eastward from Lewiston into Wayne County, a distance of 100 miles, with a general parallelism to the shore of the lake. The elevation of its summit varies a few feet, but it is supposed to have been thrown up when the water stood about 175 feet higher than the present surface of Lake Ontario, and in its elevation corresponds very well with the Davenport ridge. It holds no marine shells, but species of *Unio* are said to have been discovered in it.

Toronto Island

Wayne County.

STRATIFIED CLAYS AND SAND OF EASTERN CANADA.

The valleys of the St. Lawrence and the Richelieu, in Canada East, and a considerable portion of the region between the St. Lawrence and the Ottawa, to the east of the meridian of Kingston, are occupied by stratified clays; which, unlike those of western Canada, contain abundance of marine shells, for the most part identical with species now living in the lower St. Lawrence and the gulf. These clays are in many cases overlaid by sands, occasionally interstratified with clay, which also contain marine remains. The two are regarded as forming parts of one formation, and as corresponding to the upper and lower divisions of the Champlain clay of the Vermont geologists. Dr. J. W. Dawson, who has carefully studied these deposits in Canada, distinguishes the lower as the Leda clay, from one of its characteristic shells; and the upper, for a similar reason, as the Saxicava sand. He considers the one as having been formed in shallow waters, and the other as a deep-water deposit, and conceives that portions of the

Champlain clay.

Leda clay.

Saxicava sand

two divisions may have been contemporaneous. In some places, as at Beauport, the clay appears to be wanting, and a layer of sand contains the fossils of the lower division, which is, in its turn, covered by the Saxicava sand. In other parts, as in Vermont, considerable portions of brownish clay are interstratified with this upper sand.

Distribution

If a line be drawn from the outlet of Lake Champlain to Ottawa, and from the extremities of this, as a base, two others be carried to Quebec, there will be included a very level triangular area of about 9,000 square miles, for the greater part covered by the Champlain clays and sands. The plains on either side of the St. Lawrence below Quebec are occupied by the same formation, which is found at intervals as far down as Matanne; while on the north side, it covers an extensive area in the valley of the Saguenay, and around lake St. John and its tributaries. The clay itself in many cases forms the surface soil; but in the higher portions of the area it is very often overlaid by sands, which form a complete border around the triangular district just indicated. Clays belonging to the lower division are however found at various levels from the surface of the sea to 600 feet above it, and in some cases they have been observed some feet below the sea-level. The lower clay is ordinarily more or less calcareous, and bluish. Occasionally, however, it is interstratified with beds of grey, brown, and reddish colors, and it generally contains but few pebbles or boulders. The sands of this formation are silicious, and apparently derived from the Laurentian rocks. They frequently contain grains of magnetic iron ore and of garnet.

Lower clays.

Ottawa

Along the south bank of the Ottawa River, from the city of Ottawa to Hawkesbury, and again from Point Fortune to its junction with the St. Lawrence, the lower clay is seen in banks of from twenty to forty feet in height. The river is 118 feet above the sea at Ottawa, and about sixty feet lower in its eastern part; so that the clays, from Point Fortune downward, although precisely similar in character to those farther up the river, are at a lower level. The overlying sand generally approaches to within a short distance of the river, concealing the clay, except along the streams. The greatest breadth of the level clay surface which has been observed here is in the township of L'Orignal, where it extends about fifteen miles back from the river. Small numbers of the shells of *Saxicava rugosa* and *Tellina Grœnlandica* are found wherever these clays have been recognized along the Ottawa. About the mouth of Green's Creek, in Gloucester, a bed in the clay, near high-water mark, abounds in nodular masses, which are strewn along the shore of the Ottawa for two miles to the eastward. These seem to have been formed by a process of concretion around various organic remains, which are found on breaking open the nodules. Among the fossils imbedded in these are fishes, of which the most abundant is the *Mallotus villosus*, or capeling of the lower St. Lawrence. A single speci-

Green's Creek

men each of the *Cyclopterus lumpus*, or lump-sucker, and of a species of Cottus, has been found here. Several specimens of a common star-fish, and numbers of marine shells, including *Tellina Grœnlandica* and *Saxicava rugosa*, are also met with here; besides which are a species of fresh-water shell, and various land-plants. Among the latter, Dr. Dawson has recognized the following species: *Drosera rotundifolia*, *Trifolium repens*, *Potentilla Norvegica*, *P. tridentata*, *P. Canadensis*, *Arctostaphylos uva-ursi*, *Populus balsamifera*, *Potamogeton perfoliata*, and *P. natans*; besides grasses, carices, mosses, and algæ. The height of this deposit is 118 feet above the sea. The capeling is also found in nodules in clay on the Chaudière Lake, at 183 feet; on the Madawaska, at 206 feet; and at Fort Coulonge Lake, at 365 feet above the sea. **Fossil fishes.** **Land plants.**

The clays of this series are well seen along the tributaries of the Ottawa, in the seigniories of Vaudreuil, Soulange, and Rigaud, and also on the South Petite Nation River. On the Rivière à la Graisse, in Rigaud, the inferior parts of the section exhibit an exceedingly fine bluish or greyish calcareous clay, free from pebbles, overlaid by a similar clay, brownish in color, in which is interstratified a band of reddish clay from one to two feet in thickness. Analyses of these clays will be found on page 641. Very similar sections occur on the same river, in Hawkesbury and Lochiel, and also on the Rivières de l'Ile and Baudette. Clays of this series are observed on the St. Lawrence as far up as Dickinson's Landing, where a fine brownish calcareous variety is overlaid by a coarser clay holding pebbles and boulders derived from the Calciferous formation, with others of Laurentian origin. These clays occupy the banks of the river, for the most part, down to the Cascades. **Rigaud.**

On the north side of the Ottawa, from Hull to Isle Jesus, the clay often covers a considerable breadth between the river and the Laurentian hills, and extends among these for several miles up the larger tributaries. The river Rouge enters the Ottawa between hills of bare rock; but on its western side, in the fourth range of Grenville, a bank of clay 125 feet in thickness occurs, the summit of which is 405 feet above the sea. Again, not far east of this river, in the rear of Grenville and in the front of Harrington, is an area of several hundred acres underlaid by stratified blue clay, the surface of which is about 500 feet above the sea. Several similar portions of clay are found in this vicinity. These higher clays have as yet yielded no fossils; but *Tellina Grœnlandica*, *Saxicava rugosa*, *Balanus Hameri*, and *B. crenatus* are found in a clay 120 feet above the sea in the bank of the Ottawa, in Grenville. **River Rouge.**

The superficial deposits in the vicinity of Montreal have been more carefully studied than those of any other part of Lower Canada; and Dr. Dawson, who has devoted much time to their examination, has published in *The Canadian Naturalist* a description from which the following details are taken. **Montreal.**

The isolated mass of intrusive rock which rises about 750 feet above the sea, and forms the mountain of Montreal, exhibits upon its sides a series of ancient beaches, serving to mark the stages by which the land rose to its present level, after the tertiary period. The most strongly marked of these ancient sea-margins are at heights of 470, 440, 386, and 220 feet over the sea-level, the St. Lawrence at Montreal being considered as twenty feet above the sea.* The highest of these beaches is on the property of Mr. D. Davidson, above Côte des Neiges. A section of it exhibits, in descending order: I. Eight feet of angular stones and sand. II. Five and a half feet of fine gravel, with inclined layers of shells, chiefly *Saxicava rugosa*. III. Six feet of stratified sand, with a few shells. These beds are of very limited breadth, and rest against the steep side of the mountain, fronting the mouth of the Ottawa. They are evidently the remains of a beach thrown up in a little cove or strait between the two summits of the then partially submerged hill, and are the highest recent fossiliferous deposits known in Canada.

Côte des Neiges.

Sherbrooke Street.

Below the lowest terrace, and about 100 feet above the St. Lawrence, in the plateau along Sherbrooke Street, the stratified deposits consist of fine grained sand, in some places underlaid or replaced by stratified gravel, and holding shells in its lower portion. This sand is underlaid by an unctuous calcareous clay, which is grey, occasionally with brown and reddish colors, and also holds marine shells. This rests upon the clay of the boulder formation, which is filled with rounded and striated fragments of various rocks. The total thickness of these deposits is at least 100 feet, of which the boulder formation forms the greater part. The sand however often attains a thickness of ten feet, and the fine clay occasionally amounts to twenty feet. These stratified deposits also sometimes contain boulders both of Laurentian rocks, and of the dolerite of the mountain. Dr. Bigsby long since observed that the boulders derived from the latter source have been drifted principally to the southwestward; in which direction they are said to have been traced for a distance of 270 miles, to the south shore of Lake Ontario, marking the direction of the ancient currents or glaciers as having been from the northeast. It is to be remarked that the northeast side of the mountain is bare and abrupt, and it is there that the successive terraces may be best observed. On this side as elsewhere, the rocks beneath the boulder formation are polished and grooved. The directions of the striæ are there from 40° to 70° degrees east of north. In many places, the surface of the boulder formation, beneath the stratified clay, has been deeply

Boulder formation.

Mount Royal.

* In the report of the Board of Works for 1845, it is stated by the Hon. H. H. Killaly, then President of the Board, that the summer level of the St. Lawrence in the harbor of Montreal, is $12\frac{6}{12}$ feet over the summer level of Lake St. Peter, and the level of this lake is the datum (see page 109) from which the heights of the great lakes, and of other elevations in the interior of Canada, are usually estimated.

furrowed, as if by currents; and in like manner, the surface of this clay is sometimes cut into trenches, which are filled by the overlying sand. On the other hand, in places more sheltered, the boulder formation passes into the fine clay, or into gravel, and the latter into sand. It is in such localities, where evidences of denudation are absent, that marine fossils most abound.

The city of Montreal is built upon the deposits just described. Near the base of the mountain, at about 100 feet above the river, a fine yellowish sand is seen in many places. Excavations near McGill College showed this sand resting upon a very fine unctuous grey clay, both containing a few boulders, and underlaid by the boulder formation, which comes to the surface toward the foot of the mountain. In some places the surface of the clay is cut into furrows, which are filled with sand; but in others the sand rests upon an unbroken surface, and a layer of greyish sandy clay forms a transition between them. The sand here contains no shells, but the intermediate bed of sandy clay holds ten species, chiefly of common American littoral shells. Among these *Saxicava* and *Tellina* predominate. The clay beneath contains but few shells, and these are of two species, the so-called *Leda Portlandica*, which is now identified with the living arctic species *L. truncata*, and *Astarte Laurentiana*. Of the species observed in these deposits, the latter is the only one which has not yet been found living in the present seas. Both of these shells occur chiefly in the upper layers of the clay, and they have their valves attached. In a continuation of these beds, an excavation below Sherbrooke Street discloses twelve feet of the Leda clay, in layers of from half an inch to three inches, separated by very thin partings of sandy clay containing small shells and fragments. Near the bottom is a thicker sandy layer holding numerous shells of mollusca, together with foraminifera.

McGill College.

At the Mile-end quarries, upon a slight ridge, are found stratified sand and gravel, holding boulders and shells in the lower part. The deposit sometimes rests directly upon the limestone rock, which is at other times covered with a thin layer of the boulder formation. The lower clay is here wanting, having perhaps been removed by denudation. A thick deposit of this clay is however seen at the brick-yard of Messrs. Peel & Comte near by, where it is overlaid by the Saxicava sand, and has furnished one of the pelvic bones of a seal, and several of the caudal vertebræ of a cetacean, *Beluga Vermontana;* besides fragments of the white cedar, *Thuja occidentalis*.

Mile-end.

Bones of the whale.

Between the little ridge at the quarries and another caused by a trap dyke near the house of Mr. James Logan, is a slight depression holding an accumulation of beds rich in fossils, which present the following section. Beneath about two feet of soil and sand, underlaid by a very thin stratum of clay, are found eight inches of grey sand, holding in small numbers,

Logan's farm.

Saxicava, *Mytilus*, *Tellina*, and *Mya;* the valves generally united. Then, after about a foot of tough reddish clay, containing a few specimens of *Astarte* and *Leda*, succeeds another layer of grey sand, of the same thickness as the former, and holding the same fossils, besides *Balanus* and *Trichotropis;* the shells being in three thin layers. Below this are fifteen inches of sand or clay holding *Saxicava*, and resting upon a layer of three inches of sandy clay, which is rich in deep-sea shells, foraminifera, and sponges. The white silicious spiculæ of the latter (*Tethea Logani* of Dawson) resemble tufts of asbestus. Two feet of sand and clay, with a few fossils, including foraminifera and algæ, with *Lepralia* attached, conclude this section of about eight feet; which rests upon a stony clay belonging to the boulder formation. In a thick deposit of clay about three quarters of a mile to the east of this, and about forty feet lower, in Messrs. Peel & Comte's clay-pit in St. Mary's suburbs, there have been obtained, in addition to several species of marine shells and the spiculæ of sponges, the skeleton of a seal, *Phoca Grœnlandica*. At Messrs. Bulmer & Shepherd's brick-yard, close by, several of the bones of a young seal were met with, and a few of those of other animals, including one or two which appear to be the bones of a bird. The brick-yard at the Tanneries exhibits many of the above enumerated marine shells at the summit of the lower clay, and in the overlying sands.

Bones of seals and birds.

Besides the localities already mentioned, the boulder formation is seen in excavations in Dorchester and Lagauchetière Streets, and in the gravel pits on the Lachine railway. The steep descent at Beaver Hall, and farther on, along the Lachine road, marks the limit of the cutting formerly made by the St. Lawrence in these superficial deposits. In the ancient river-bed in Craig Street, and near the Tanneries, the river gravel is met with, occasionally with fresh-water shells. In some parts the action of the river has laid bare the grooved surfaces of rocks beneath. Far out in the river, in sinking for some of the piers of the Victoria Bridge, a great thickness of the boulder formation was met with; and in dredging in the current immediately below the city, the material brought up was apparently the ancient marine clay, and it contained the shells of *Tellina*. Similar clays are found by dredging in Lake St. Peter.

Lachine road.

Victoria Bridge.

Clays which belong to the lower division, and are employed for the manufacture of bricks and coarse pottery, are found in very many localities along the valleys of the Richelieu, and on both sides of the St. Lawrence as far as Quebec. In many places bands of a brownish-red color are interstratified with the bluish or ash-grey clay, and exhibit a jointed structure, which causes them to split into thin vertical plates and prisms. A good example of this interstratification is seen in a cliff of clay eighty-five feet in height, in the Little Rivière du Chêne, in the seigniory of Deschaillons. Near this is Cap à la Roche, which rises 155 feet above the St.

Lawrence; being the highest land in that vicinity. It presents the following section in ascending order. After five feet concealed at the water's edge, are twenty feet of yellowish-grey sand, with layers of black magnetic iron sand; the deposit being coarser and less yellow toward the base. To this succeed ninety feet of bluish impalpable clay, with grey and brown bands; above which is a narrow terrace, strewn with gneiss boulders, where the strata are concealed. Then follow five feet of ochreous sand, forming a broader terrace; beyond which is the third and highest step of thirty feet, which is supposed to be partly of yellow and partly of grey sand, and is strewn both at the base and summit with gneiss boulders. This overlying sand is wanting a little farther down the river; where the high banks in Lotbinière appear to be in many parts composed of clay to the summit, although in other parts capped by sand. At St. Jean-Deschaillons red bricks are extensively manufactured from the clay; which is said to be upward of 100 feet in thickness, and to repose upon a bed of twelve feet of sand. These sections are interesting as showing stratified sands beneath a great thickness of the lower clay. At St. Nicholas numerous fossil shells have been found in a sandy clay, 180 feet above the sea, and at the head of a rocky ravine about 400 yards south of the St. Lawrence. On the north shore, about twelve miles up the Jacques Cartier River, the lower clay is again met with, holding shells of *Tellina* and *Astarte*, and overlaid by twelve feet of sand.

Deschaillons.

St. Nicholas.

Below Quebec, the lower clay extends in a nearly continuous belt from Point Lévis to Matanne. Marine shells are found in clay at the sea-level on the east side of the bay at the mouth of Rivière du Loup, but from this locality to Cacouna, the surface of the clay slopes up to a height of more than a hundred feet. At Rivière du Loup, the shells of *Mya* and *Tellina* are found imbedded in the sand and disintegrated shale of an ancient beach, only a few feet above the present sea level. Similar beaches, which seldom attain more than fifteen feet above high-water mark, are met with in many localities along this southern shore, from Rivière du Loup to the Magdalen River. A low terrace, about five feet above the highest tides, and averaging about 100 yards in breadth, extends, with a few interruptions, from Rimouski to Whale Cape, a distance of seventy-five miles. It is composed of sand, gravel, and broken shells, and makes a good roadway, as well as a productive soil. The shells in this terrace are of the same species as now inhabit the adjacent waters. Besides these, bones of the whale and the morse have been found partially imbedded in this deposit, in several places between Bic and Matanne. At Ste. Anne des Monts, five or six terraces rise one above another to a height of about twenty-five feet above the sea. All of them abound in fragments of shells, belonging to the common littoral species. Shells of *Natica*, *Saxicava*, and *Balanus* are found in sand upon the Metis River, 245 feet above the sea. Near the mouth

Rivière du Loup.

Bones of the whale and the morse.

Metis.

of this river is a terrace fifty feet in height; and in a similar terrace, at the mouth of the Matanne River, a layer of shells is found at forty-four feet, resting on blue clay, and overlaid by six feet of sand. Portions of clay are also met with in some of the bays on the north coast of Gaspé. One of these, holding marine shells, forms a plateau of ninety feet in height on the west side of the Magdalen River, stretching for two or three miles along the coast, with a breadth of about a mile on the Magdalen. In the interior, stratified clays occur at the head of Lake Matapedia, at a height of 480 feet, and near the outlet of the same lake, at 530 feet above the sea; but in neither locality have they been observed to contain fossils. No stratified clay has yet been observed on or near the eastern coast of the peninsula of Gaspé; but a considerable area of it occurs on the south side, at the mouth of the Great Cascapedia River. It extends along the coast for three and a half miles to the east, and eleven miles to the west of the mouth of the river, and to a variable distance back. In this clay, *Mya* and *Saxicava* are found in a great number of successive beds to a height of seventeen feet over high-water mark, in the position which the shells occupied when in life. Each bed is separated from the one below it by a thin layer of sand, which also fills the cylindrical openings through which the inhabitants of the shells once communicated with the surface.

Matanne. Cascapedia.

In the Gaspé peninsula thick beds of gravel and sand are spread over the boulder formation in the valleys of the rivers and brooks, particularly in their lower portions. On the Magdalen River, these have been observed up to a height of about 1600 feet above the sea. Near the coast also, deposits of gravel and sand are found around many of the bays and coves, and like those on the rivers they are often worn into terraces. On the south side of the Northwest Arm of Gaspé Bay, an ancient beach, 154 feet above the sea, is marked by a sudden step along a hill-side, and traces of other beaches are found at lower levels in the neighborhood. A terrace varying from thirty-five to forty-three feet in height, begins on the north side of the York River, six miles from its source, and continues regularly for about three miles, cutting off the bends of the stream. Two miles and a half west of the long sand beach in Mal-bay, well marked terraces occur not far from the Malbay River, at the estimated elevations of eight, fifteen, and fifty feet above the sea. *Mya arenaria*, *M. truncata*, *Cardium Grœnlandicum*, and *Tellina proxima* are found at about fifteen feet above high-water mark, in a deposit of sand, covering several hundred acres, at Anse aux Gascons in Port Daniel Bay.

Gaspé. York River. Malbay River.

On the northern side of the St. Lawrence, stratified clays occur in the valleys of Murray Bay and Bay St. Paul. At Murray Bay the lower clay, containing fossils, is seen exposed along the shore at low tide. Farther up is a flat of sand and gravel, about thirty feet over the sea, con-

Murray Bay.

taining shells of *Tellina*. Above this is a well marked terrace 100 feet high, which presents a steep bank of clay, and is surmounted by another less distinct, at 182 feet. Beyond this the ground rises in a steep slope, on which the highest observed shore-mark is a narrow beach of rounded pebbles at 326 feet: this becomes a wide terrace farther to the north, and on the opposite side of the bay. Clays are not however confined to the lower levels, but occur regularly stratified throughout the terraces, and in some places present sections of sixty and eighty feet in height. At Bay St. Paul similar terraces were observed; the heights of the two best marked of these were found to be approximately 130 and 360 feet above high-water mark. Marine fossils occur throughout the strata in which these terraces are worn, and still higher, at 390 feet above the sea-level. The numerous land-slips, which are so common here, and elsewhere throughout these clay deposits, seem to be due to the presence of arenaceous beds near the base, which permit the percolation of water; while the unsupported nearly vertical cliffs allow movements to occur, causing fissures, down which surface-waters flow, until, reaching the sandy layer, they undermine the mass. The weight of this then causes the base to slide outward, until at last a vertical section of the cliff lies nearly horizontally in the valley below. In this, among other ways, the successive terraces have doubtless been formed in the clays which once filled these valleys. The lower levels, both at Bay St. Paul and Murray Bay, are in many places strewn with masses of clay, detached by land-slips from the heights around. These have been rounded, either by the subsequent action of the receding waters, or by the weather, and now present hillocks and conical mounds, often of singular regularity.

Bay St Paul.

Land-slips

In the valley of the Saguenay, marine clays, generally overlaid by sand and gravel, are found almost everywhere between Ha-ha Bay and the west side of Lake St. John; as well as between that bay and Chicoutimi, and on both sides of the Saguenay River above and below the latter place. Between Chicoutimi and Ha-ha Bay, the clay is sometimes 600 feet in thickness, and is subject to immense land-slips, by which areas of many acres are sometimes removed from their original place. Between Lake Kenogami and Belle Rivière, the clay has a thickness of 100 feet; and about half a mile below the falls of the latter river, at a height of about 400 feet above the sea, it contains the shells of *Saxicava*. The same species was found on the Alphonse River, at a height of about 150 feet; and it was also found associated with several other marine species at a much lower level, in a bed of sand near Chicoutimi church.

Saguenay

On the island of Anticosti bluish-grey clays occur on the Becscie and Otter Rivers; and clay cliffs from sixty to seventy feet high extend for about five miles along the coast near the St. Mary's River. These clays are frequently calcareous, and contain numerous pebbles of limestone.

Anticosti

Labrador. On the coast of Labrador clays occur containing many species of marine fossils, which have been collected by Captain Orlebar, R.N., and Mr. J. S. Packard of Brunswick, Maine. They are found in Tertiary Bay, and some other localities, in deposits but little above high-water mark.

Mingan Islands. On Large Island, one of the Mingans, there occurs a succession of ancient beaches, which are composed of small limestone pebbles. Except where covered by moss, but little difference is perceptible between these and the beach at present washed by the sea. They form successive terraces rising one above another from five to thirty feet, the highest attaining about 100 feet above high-water mark. Another feature strongly marking the change in the relative levels of sea and land is the presence on this island of what from their shape have been termed flower-pot rocks. They are composed of horizontal layers of limestone piled on one another, and are the remains of stratified masses that were once united, but have been gradually worn away by the destructive action of the sea. Many of these standing out of the water at various heights, according to the state of the tide, show the waves still at work on them, while some are seen high up on the island, demonstrating a similar action when the land was from fifty to sixty feet below its present level.

Flower-pot rocks.

Upper sands. The sand which has been noticed as overlying the clays in most of their localities, is in some parts of the country developed to such an extent as to require a more special mention. This is particularly the case on the north side of the St. Lawrence, where it forms a belt at the base of the Laurentide hills, from the Ottawa to Cape Tourmente. This belt expands to a breadth of thirty miles on the St. Maurice River, where it reaches to the St. Lawrence, and stretches several miles along the shore. To the westward it covers much of the surface in the triangular area between the St. Lawrence and the Ottawa, east of the meridian of Kingston. The whole of the higher lands in the townships of Edwardsburgh, Augusta, and the south part of Oxford, are covered by a fine yellow sand, which is frequently blown up into dunes. The same appears to be the case with the sand between Ottawa and Prescott. These sands cover the valleys of the South Petite Nation River, and are largely developed in West Hawkesbury, Lochiel, Kenyon, Nepean, Fitzroy, and Pakenham. Fossil shells, chiefly *Saxicava rugosa* and *Tellina Grœnlandica*, are found in many places in the sands of this district. The highest observed locality of these shells is in Nepean, at 410 feet above the sea. They are also found in Kenyon, at 335 feet; in Fitzroy, at 330 feet; and in Winchester at 300 feet. A mixture of marine and fresh-water shells occurs in a sandy clay near Pakenham mills, at a height of 266 feet. The bed, which is four and a half feet thick, is overlaid by ten feet of clay, surmounted by ten feet of sand and surface soil.

St. Maurice.

Ottawa.

Pakenham mills.

These sands are also met with in that part of the province south of the

St. Lawrence, along the boundary of New York. From the east side of Missisquoi Bay another belt of sand extends between the clay plains of the south shore of the St. Lawrence, which it partially overlies, and the more elevated region to the southeast, as far as Metis. A considerable development of the sand is also seen on the west side of the Richelieu at Sorel, and thence stretching southward. Near Clarenceville, shells of *Tellina* are found associated with *Limnea*, and three species of *Unio*, in a sandy clay ninety-eight feet above the level of the sea, and about ten feet above the level of Lake Champlain, in what may have been the site of an ancient estuary. At the Wallbridge mills, in Stanbridge, *Saxicava* and other marine shells occur in sand at a height of about 160 feet. Near the Upton station on the Grand Trunk railway, the shells of *Saxicava*, *Tellina*, and *Mya* are found with comminuted fragments of *Mytilus*, occupying a cleft in the limestone at a height of 300 feet above the sea-level; the presence of these littoral shells marking a former sea-beach. Sorel Clarenceville. Upton

A remarkable locality of fossil shells occurs near Beauport, about two and a half miles northeast of Quebec, and a quarter of a mile from the St. Lawrence. The deposit is exposed on the side of a ravine 110 feet deep, and the bank, whose summit is about 150 feet above the sea, consists of stratified sand and gravel, resting upon the unstratified boulder formation, which, as usual, is without fossils. About twenty feet from the top is a bed twelve feet in thickness, composed almost wholly of the shells of *Saxicava*, *Tellina*, etc. Between this deposit of littoral shells and the boulder clay, Dr. Dawson has observed a sandy layer of about three inches, filled with deep-water shells, such as *Fusus*, *Pecten*, and *Rhynchonella*. In this layer, as well as beneath it, resting upon, or partially imbedded in the boulder clay, and adhering to stones, which are often smoothed or striated, as if by glacial action, are found numerous species of *Balanus*, of *Spirorbis*, and of several genera of bryozoa. This lower stratum of sand represents the Leda clay of Montreal, and is rich in the fossils which are usually found at the surface of that deposit. It will be observed however that the *Leda*, which characterizes it in so many other localities, and which inhabited only a clayey bottom, is here wanting. Foraminifera, which abound in the clays of Montreal, are also comparatively rare in the lower sand of Beauport. Shells of *Saxicava* and *Tellina* occur in horizontal beds of sand and clay, about a quarter of a mile from the locality just described, and at a height of 200 feet. They also occur in a bed of sand near the bridge above the Falls of Montmorenci. Similar deposits, but without shells, have been observed farther inland, several miles to the northwest, and at heights between 300 and 400 feet above the sea. In this connection may be mentioned an interesting deposit of very fine silicious sand, which occurs at Laval, on the right bank of the Bras, just at its junction with the Montmorenci River. Here, in a cliff which is about 150 feet in height Beauport.

Laval. above the river, beneath about fifty feet of yellowish sand mixed with boulders of gneiss, is exposed a thickness of fifteen feet of the silicious earth. It is of two colors, yellow and grey, which are somewhat irregularly interstratified. The materials of the lower part of the escarpment are concealed. This earth, from its fineness, has been used at Quebec as a plate powder, and was supposed to be of infusorial origin. A microscopic examination, however, shows it to be nothing more than a fine quartz sand. The fossiliferous sands occurring at the lower levels along the borders of the lower St. Lawrence, contain an assemblage of fossils somewhat different from those of the higher levels, approaching more nearly to the present fauna of the Gulf. These sands are no doubt more recent than those of the higher levels.

The following is a list of the invertebrate animals which have been found in a fossil state in the post-tertiary deposits of Eastern Canada; without however including the numerous species of foraminifera, many of them new, which have been described by Dr. Dawson (*Canadian Naturalist*, vol. iv, page 26). In the left-hand column the number prefixed to certain species denotes the page of this volume on which they will be found figured; and in the right-hand columns, stars indicate eight of the more important localities in which the fossils have been observed. Of these numbered columns 1 is for Pakenham mills, and the next four are in the vicinity of Montreal; 2 being Logan's farm, 3 Coteau Baron, 4 the Mile-end quarries, and 5 the grounds of McGill College. 6 is St. Nicholas, 7 Beauport, and 8 Tertiary Bay, Labrador.

LIST OF INVERTEBRATE FOSSIL ANIMALS IN THE POST-TERTIARY DEPOSITS.

Page	RADIATA.	1	2	3	4	5	6	7	8
	PROTOZOA.								
	Tethea Logani, Dawson. (nov. sp.)		*						
	ECHINODERMATA.								
	Ophiocoma —— ?							*	
	Echinus granularis, Lamarck						*	*	*
	Psolus phantapus, Linnæus		*						
	MOLLUSCA.								
	BRYOZOA.								
	Hippothoa catenularia, Jameson							*	*
	" expansa, Dawson. (nov. sp.)							*	
	Tubulipora flabellaris, Fabricius							*	
	Lepralia hyalina, Johnston							*	
	" pertusa, Thompson							*	*
	" quadricornuta, Dawson. (nov. sp.)		*						

POST-TERTIARY FOSSILS.—*Continued.*

Page		1	2	3	4	5	6	7	8
	BRACHIOPODA.								
963	Rhynchonella (Hypothyris) psittacea, Gmelin	..	..	..	..	..	*	*	*
	LAMELLIBRANCHIATA.								
963	Pecten Islandicus, Chemnitz	..	..	..	..	..	..	*	
963	Leda truncata, Wood. (L. Portlandica.)	..	*	..	..	*			
	" pygmæa, Münster.[1]								
	" caudata, Donovan. (L. minuta, Fabricius.)	..	*						
	Crenella glandula, Totten. (C. decussata, Montague.)	..	*						
	" nigra, Gray	..	*	..	..	..	..	*	
963	Mytilus edulis, Linnæus	..	*	*	*	*	*	*	
	Unio cardium, Rafinesque.[2] (U. ventricosus, Barnes.)								
	" rectus, Lamarck.								
	Sphærium (Cyclas) ——?	*	*						
	Cardium Islandicum, Linnæus	..	..	..	..	..	..	*	
	" (Serripes) Grœnlandicum, Chemnitz	..	..	..	..	..	..	*	
963	Astarte Laurentiana, Lyell	..	*	*	*	*	*	*	
	" elliptica, Brown	..	..	..	..	..	..	..	*
	Mesodesma deaurata, Hanley.[3] (M. Jauresii, De Joannis.)								
964	Tellina Grœnlandica, Beck	*	*	*	*	*	*	*	
964	" proxima, Brown	..	*	..	*	*	*	*	*
	Macoma inflata	..	*						
963	Mya truncata, Linnæus	..	*	*	*	..	*	*	
963	" arenaria, Linnæus	..	*	*	*	*	..	*	
964	Saxicava rugosa, Linnæus	..	*	*	..	*	*	*	
	" arctica, Linn. (var. of S. rugosa)	..	*	..	..	..	..	..	*
	" distorta, Say. (var. of S. rugosa)	..	*						
	GASTEROPODA.								
	Opisthobranchiata.								
	Cylichna oryza, Totten. (C. cylindracea?)	..	*	..	*	*			
	Bulla (Diaphana) debilis, Gould	..	*						
	Prosobranchiata.								
	Amicula vestita, Gray	..	*						
964	Acmæa (Lepeta) cœca, Müller	..	*						
	Puncturella (Cemoria) Noachina, Linnæus	..	..	..	..	..	..	*	*
	Margarita helicina, Fabricius	..	*						
	Lacuna neritoidea, Gould	..	*						
	Littorina palliata, Say	..	..	..	..	..	..	*	
	Rissoa obsoleta? Searles Wood	..	*						
	Paludina decisa, Say	*							
	Valvata tricarinata, Say	*							
	Amnicola porata, Say	*							
964	Scalaria Grœnlandica, Perry	..	..	..	..	..	..	*	
	Turritella erosa, Couthouy	..	..	..	..	..	..	*	*
	" costulata, Mighels	..	..	..	..	..	..	..	*
	Aporrhais occidentalis, Beck	..	..	..	..	..	..	..	*
	Aclis (Alvania) ascaris, Searles Wood	..	*						
	Menestho albula, Müller	..	..	..	..	..	..	*	

POST-TERTIARY FOSSILS.—*Concluded.*

Page	*Prosobranchiata.*—Continued.	1	2	3	4	5	6	7	8
	Velutina zonata, Gould	..	*	..	..	..		*	
964	Natica clausa, Sowerby	..	*	..	*	..	*	*	*
	" (Lunatia) heros, Say	..	..	..	..	..	..	*	
964	" " Grœnlandica, Müller. (N. pusilla, Say.)	..	..	..	..		..	*	
964	" (Amauropsis) helicoides, Johnston	..	*						
	Mangelia (Bela) turricula, Montague	..	*	..	..	..	..	..	*
	" " harpularia, Couthouy	..	..	..	.	.	..	..	*
	" " rufa, Gould	..	..	..	.	..	..	..	*
964	Buccinum undatum, Linnæus	..	*	*	..	..	*	*	*
	" ciliatum, Fabricius	..	*	..	..	..	..	*	
	Admete viridula, Stimpson,	..	*						
964	Fusus tornatus, Gould	..	*	*	.	*	*	*	*
964	Trophon scalariforme, Gould	..	*						
964	Trichotropis borealis, Broderip and Sowerby	..	*	*	*	*	*	*	*
	" arctica, Middendorff	..	*						
	Pulmonata.								
	Helix striatella, Anthony	*							
	Limnœa umbrosa, Say	..	*	*					
	" caperata, Say	..	..	*					
	" elodes, Say	*							
	Planorbis bicarinatus, Say	*							
	" trivolvis, Say	*							
	" parvus, Say	*							
	ARTICULATA.								
	ANNULATA.								
	Cytheridea Mulleri, Munster	..	*						
	Spirorbis vitrea, Fabricius	..	*	.	*		.	*	*
	" spirillum, Linnæus	..	..	..	..	..	..	*	
	" carinata, Montague	..	..	..		..	..	*	*
	" sinistrorsa, Montague	..	..	..	..	..	..	*	
	Serpula vermicularis, Linnæus	..	*						
	CIRRIPEDA.								
964	Balanus Hameri, Ascanius	..	..	..		..	*	*	
	" crenatus, Bruguière	.	*	*	*	..	*	*	
	" porcatus, Da Costa	.	..	..		..	..	*	*

[1] *Leda pygmæa* has only been observed at Green's Creek in Gloucester, where it is found adhering to a sea-weed, and associated with *Tellina Grœnlandica*, *Saxicava rugosa*, and the fossil fishes already mentioned on page 916.

[2] *Unio cardium* and *U. rectus* have been observed only in one locality, near Clarenceville, where they are associated with a *Limnæa*, and with *Tellina Groenlandica* and *Mya arenaria*, in a bed of sandy clay about ten feet above the level of Lake Champlain.

[3] *Mesodesma deaurata* has been found at the mouth of the Matanne River, where it is associated with *Mytilus edulis*, *Tellina Grœnlandica*, *Mya arenaria*, *Saxicava rugosa*, *Natica clausa*, *Balanus Hameri*, and *B. crenatus*; and in the lower terraces along the coast.

Gold-bearing drift.

The superficial deposits of the higher portions of south-eastern Canada, embracing the Notre Dame Mountains, and the country to the southeast of them, have been but partially examined. The unmodified drift, which contains the gold of that region, is derived from the disintegration of the rocks of the region, but contains a few boulders derived from the Laurentide hills. It has however been in great part re-arranged by the action of water; and stratified deposits of clay sand and gravel are found at various heights throughout the region, but they have hitherto been very little studied. At the southern extremity of Lake Memphramagog, which, according to the Vermont surveyors, is only 685 feet above the sea, a terrace of clay is met with at an elevation of ninety-three feet above the lake, or 778 feet above the sea-level. This is the highest deposit of clay which has been observed in Vermont; but stratified sand and gravel are found above it, arranged in successive terraces, to a height of 579 feet over the lake, or 1264 feet above the sea; and similar stratified deposits form a regular terrace-like beach in Ripton on the Green Mountains at a height of 2196 feet (Geology of Vermont, 1862). Ancient beaches are described by Dr. Hitchcock as existing in the White Mountains, at elevations of 2449 feet and 2665 feet above the sea. If, as is probable, the superficial materials of this portion of the continent were re-arranged and stratified during the slow elevation of the submerged land, it would follow that the higher stratified deposits are of a greater antiquity than the clays and sand of the St. Lawrence and Champlain valleys. In the Gaspé peninsula no foreign boulders have as yet been observed in the boulder formation; which there appears to be altogether composed of the debris of the rocks of the country. It is exposed in the valleys of rivers and brooks, sometimes to a depth of a hundred feet. As in other regions of the province, the boulders and pebbles are frequently grooved and striated, and are thrown together in great confusion in a tough mixture of sand and clay.

Lake Memphramagog.

Ancient beaches

Boulder formation.

Age of the drift.

The boulder formation, or glacial drift, both in the British Islands and North America, is by Lyell referred to the age of the newer pliocene, or most recent division of the tertiary series, of which it marks the close; while the stratified deposits which overlie it, and consist in part of the materials of the boulder formation re-arranged by the agency of water, are by the same authority classed among post-tertiary strata. Although no tertiary deposits older than the boulder formation have yet been recognized in Canada, they are met with in various parts of the United States.

At the western base of the Green Mountains, at Brandon in Vermont, there is found beneath the unstratified boulder formation, and reposing upon the older rocks, a deposit of tertiary strata, which are of great scientific as well as economic interest. This locality is about 520 feet above the sea, and presents beds of gravel and sand, with kaolin or porcelain

Miocene of Vermont. clay, yellow ochre, limonite or brown hematite, oxyd of manganese, and lignite or fossil wood. The latter is obtained in sufficient quantities to be employed as fuel, and contains many fossil fruits, from the examination of which Mr. Lesquereux is led to refer this deposit to the age of the miocene, or the middle division of the tertiary period. The ores of iron and manganese of this deposit, as well as the ochres and kaolin, are advantageously wrought; and are to be distinguished from the deposits of ores and ochres which have been described as occurring in Canada, and which belong to a more recent period. The oxyd of manganese, which belongs to the species psilomelane and pyrolusite, is pure, and often crystalline; and the limonite is much less impure than that of the St. Lawrence valley. Deposits of this ore, often with manganese, and with kaolin, are found in many localities along the west side of the Green Mountains, and at various levels up to more than 1000 feet. On the east side of these mountains, similar deposits also occur in several places, as at Plymouth, where iron and manganese ores, with clays, are met with upon a terrace 1168 feet above the sea. These deposits, although regarded as similar to that of Brandon, are probably of a different age. None of them have yet been found along the extension of the Green Mountains into Canada; but the possibility of their occurrence in the Eastern Townships should be kept in mind, inasmuch as both the ores and clays are of considerable economic importance.

Recent deposits. The deposits of bog manganese and of bog iron ores and ochres which are found in various parts of Canada, overlying the stratified clays and sands, have already been described with considerable detail under their respective heads in the twenty-first chapter. They are all of recent origin, and, like the peat and fresh-water shell marl with which they are associated, are still in many cases in the process of formation. The history of the peat bogs and marl beds has also been given in the same chapter. Deposits of silicious infusorial earth, which are frequent in Nova Scotia and in Vermont, appear to be comparatively rare in Canada. The only locality of this kind as yet known is in the valley of the Petewahweh River, about thirty-five miles from its mouth; where a fine white infusorial silica, which is made up of the shields of the most common species of protophytes, is said to occur in considerable quantities.

APPENDIX:

CONTAINING,

I.

A TABULAR VIEW OF THE ROCKS OF GREAT BRITAIN AND NORTH AMERICA; WITH NOTES;

II.

A CATALOGUE OF THE LOWER SILURIAN FOSSILS OF CANADA;

III.

ADDITIONAL FIGURES OF PALÆOZOIC FOSSILS, AND FIGURES OF SOME FROM THE RECENT DEPOSITS.

TABLE OF THE PROBABLE EQUIVALENTS AMONG THE PALÆOZOIC ROCKS OF GREAT BRITAIN AND NORTH AMERICA.

	I. Great Britain.	II. Western Canada.	III. Eastern Canada.	IV. New York.	V. Pennsylvania.	VI. Tennessee.
Carboniferous.	Carboniferous series.	....	.... Bonaventure formation.	....	XIII. XII. Seral. XI. Umbral. X. Vespertine.	X. Coal measures. IX. Mountain limestone. VIII. Silicious group.
Devonian.	Upper Devonian. Middle Devonian. Lower Devonian.	.... Chemung and Portage group. Hamilton formation. Corniferous formation. Oriskany formation.	Gaspé sandstones, and Famine River limestones.	Catskill group. Chemung group. Portage group. Genessee slates. Hamilton group. Upper Helderberg gr.: Onondaga and Corniferous limestones. Schoharie grit. Canda-galli grit. Oriskany sandstone.	Ponent. IX. Vergent. Cadent. VIII. Post-meridional. VII. Meridional.	VII. Black shales. VI. Dyestone and grey limestone group.
Upper Silurian.	Ludlow group.	.... Water limestone. Onondaga formation.	Limestones of Gaspé and the Bay of Chaleurs.	Lower Helderberg gr.: Upper Pentamerus, Encrinal, Delthyris, Pentamerus, and Tentaculite limestones. Water-lime group. Onondaga salt group.	VI. Pre-meridional. Scalent.	
Middle Silurian.	Wenlock limestones. Upper Llandovery rocks. Lower Llandovery rocks.	Guelph formation. Anticosti group: Niagara formation. Clinton formation. Medina formation.	Limestones of the Chatte River.	.... Niagara limestone. Clinton group. Medina sandstone. Oneida conglomerate.	Surgent. V. IV. Levant.	
Lower Silurian.	Caradoc or Bala group. Upper Llandeilo rocks. Lower Llandeilo rocks. Lingula flags.	Hudson River gr.: Hudson River formation, and Utica formation. Trenton group: Trenton formation. Black River and Birdseye formation. Chazy formation. Calciferous formation. Potsdam sandstone.	.... Hudson River and Trenton groups probably wanting. .... Quebec group. Potsdam group.	Hudson River gr.: Hudson Riv'r shales, or Loraine shales. Utica slate. Trenton, Black River, and Birdseye limestones. Chazy limestone. Calciferous sandstone. Potsdam sandstone.	III. Matinal. II. Auroral. I. Primal.	V. Central limestones and shales; including the Stones River and Nashville sub-groups. .... IV. Magnesian limestones III. Chilhowee sandstones
						II. Ococe conglomerates I. Mica slate group.

NOTES TO THE PRECEDING TABLE.

In this table are shown in parallel columns the various sub-divisions of the palæozoic formations which have been recognized in different parts of North America, with their probable equivalents in Great Britain. It will be seen that in Canada a portion of the Upper Silurian series has been made a separate division, under the name of Middle Silurian. The Oriskany formation is assumed to be the base of the Devonian system, in accordance with the synchronism of De Verneuil; but the fauna of the Gaspé limestones, at present under examination, seems to indicate that it would be more proper to place that limit farther down in the series. At Cape Gaspé, the upper eight hundred feet of these limestones (p. 393) hold an intimate association of Lower Helderberg and Devonian species, and the *Psilophyton princeps* of the sandstones (page 397) has been found in the upper part of the limestones. There is no palæontological break between these limestones, and the Oriskany sandstone which overlies them, of sufficient importance to constitute a dividing line between two great systems. At this locality the difference between the upper limestones and the Oriskany formation is not greater, so far as regards the fossils by which they are characterized, than that between the Trenton formation and the Hudson River group. But if, guided by these considerations, we should place the upper limestones of Cape Gaspé in the Devonian, then the whole of the Lower Helderberg, down to the Water limestone, would follow; and the Upper Silurian would be represented, in Eastern Canada, only by the series of fossiliferous rocks on the Bay of Chaleurs, of which a descriptive section is given at page 443. These rocks contain a fauna, which is, upon the whole, distinct from that of the Niagara and Guelph formations on the one hand, and from that of the Lower Helderberg on the other; while at the same time it is more closely allied to the fauna of the Ludlow group of England than any other yet discovered in the Silurian rocks of America. It seems to occupy a position between the Niagara and the Lower Helderberg, but to be more intimately connected with the former than with the latter. The Middle Silurian of Canada, as limited in the above table, appears to represent very nearly the Wenlock limestone, and the Llandovery rocks of England. In both countries this part of the series is strongly characterized by immense numbers of large *Pentameri*, with numerous corals and crinoids.

Devonian.

Upper Silurian.

The Lower Silurian rocks may be separated, on palæontological grounds, into two divisions, an upper and a lower. The former includes all the formations from the base of the Birdseye and Black River to the top of the Hudson River group. The fossils of this division constitute a single large but compact fauna, having its greatest development in the Birdseye and Black River, and Trenton formations, and declining upwards to the top of the Hudson River formation. At certain horizons we find peculiar groups of species which have a wide geographical distribution, but, so far as is at present known, only a limited vertical range. Among these may be mentioned the peculiar corals and cephalopods of the Black River, the several species of the genus *Triarthrus* in the Utica formation, and the large orthides of the Hudson River. The most abundant and characteristic species, however, range through the whole division. A very large proportion of the Trenton species (excepting the crinoids and cystideans,) appeared suddenly in the seas, in the region of western Canada, just at the commencement of the period of the deposition of the lower strata of the Birdseye and Black River formation.

Lower Silurian.

Upper division.

The lower division, consisting of the Chazy, Calciferous, and Potsdam formations, including the Quebec group, holds a large fauna, which is, upon the whole, specifically distinct from that of the upper division. This fauna flourished most vigorously during the period of the deposition of the Quebec group, and the upper part of the Calciferous formation. About twenty of the Chazy species pass upward into the Black River and Trenton formations, while the Chazy is connected with the Calciferous by the Quebec group. Owing to the difficulty in collecting the fossils, our knowledge of this lower fauna is evidently far from being complete. But we at least know this much, that it

Lower division.

consists of a large number of peculiar genera and species, and that, viewed in a general way, it is different from the great fauna of the upper division of the Lower Silurian rocks. The upper fauna is considered to be the palæontological equivalent of that of the Bala or Caradoc formation of Britain, while the lower represents that of the Llandeilo.

British equivalents.

Nearly all of the species which are common to the Lower Silurian of England and Canada occur only in the Bala in the former country, and only in the rocks lying above the base of the Chazy in Canada. The great zones of cystideæ are also found in the same horizon in both countries. On the other hand the peculiar aspect of the trilobites, and the great number of graptolites in the lower fauna of Canada, indicate a parallelism with the Llandeilo. It is impossible to show the exact horizon of the line between the Bala and Llandeilo, in Canada, but for the present it is assumed to be in the break between the Chazy and Black River formations. On account of the abundance of cystideæ in the Chazy, it may however be hereafter found advisable to add this formation to the Bala rocks, as suggested in CANADIAN ORGANIC REMAINS, Decade iii, page 12.

The succession of the North American rocks given in the columns of the table will now be noticed.

Western Canada.

II. WESTERN CANADA.—This district includes all that portion of the province north and west of the great dislocation, including the north side of the St. Lawrence to the Gulf, and the Island of Anticosti. The succession and the nomenclature of its formations as already given on page 20, differ but little from that of the New York rocks. The Oneida or Shawangunk conglomerate, the Schoharie and Cauda-galli grits, and the Genessee slates of New York, are however local formations, not yet recognized in Western Canada. If, with Mr. Hall, the magnesian beds of the Water-lime, containing *Eurypterus*, be regarded as subordinate to the Onondaga salt group, the Lower Helderberg group will have no representative in the western division of Canada, if we except the masses of fossiliferous limestone in the conglomerates of St. Helen's Island, (page 356). This group is also absent from western New York. The highest palæozoic strata of southwestern Canada, which are the black shales of Bosanquet, include only the base of the Portage group. The Guelph formation of western Canada is not known in the state of New York.

Eastern Canada.

III. EASTERN CANADA.—By this designation is meant that portion of the province lying to the south and east of the great break, whose course has been described in this volume on pages 233 and 709. This region includes the greater part of Lower Canada south of the St. Lawrence; and the rocks of the strait of Belle Isle and of the adjacent parts of Newfoundland belong to the same area. In this region, the Potsdam group, as already shown (pages 283, 288 and 879), appears as a great accumulation of limestones, sandstones, and shales, several thousand feet in thickness. The Quebec group, consisting of the Phillipsburgh, Lévis, and Sillery divisions, is another similar series of strata, not less in amount. The Calciferous and Chazy formations are shown by their organic remains to be representatives of portions of this great group; and the Potsdam formation in like manner represents a part of the Potsdam group.

Taconic system.

The Taconic system of Emmons, which he supposed to be a distinct series of rocks more ancient than the Potsdam, appears to consist, for the greater part at least, of the strata of the Potsdam and Quebec groups. The Upper Copper-bearing rocks of Lake Superior are regarded as occupying the position of the Quebec group, to which they bear some resemblance in lithological and mineralogical characters. They may perhaps include the Potsdam group. The higher members of the Silurian and the Devonian rocks, so far as yet recognized in this region, have been noticed on the preceding page, and are described in this volume under the title of the Gaspé series.

New York.

IV. NEW YORK.—The divisions of the rocks adopted by the geologists of this state, and since recognized by Mr. Hall in his Palæontology, are too well known to require further notice. They have been made the basis of the nomenclature adopted for the corresponding rocks of Canada.

V. PENNSYLVANIA.—The Roman numerals given under this head correspond to the thirteen divisions adopted by Rogers in 1836, in his first Report on the geology of the state. In the names in the adjoining column, which were subsequently given by him, the palæozoic period is supposed to represent a day, the divisions of which are named from the sun's apparent course in the heavens. (Report on the Geology of Pennsylvania, 1857, vol. I, p. 105). The base of the Primal series of Pennsylvania, according to Rogers, consists of a conglomerate, more largely developed in Virginia and Tennessee, and having in the first-mentioned state a thickness of 150 feet. This is followed by 1200 feet of brownish and greenish-grey shales, overlaid by 300 feet of sandstone with *Scolithus*, and succeeded by 700 feet of shales, often talcose, which form the summit of the Primal division. The Auroral division in Pennsylvania is said to consist chiefly of magnesian limestones, which vary from 2500 feet to more than 5000 feet in thickness, and are by Rogers supposed to correspond to the Calciferous, Chazy, and Black River formations. These two divisions of Rogers may probably represent the Potsdam and Quebec groups of Eastern Canada. Pennsylvania

VI. TENNESSEE.—The succession here given is taken from Safford's Report, published in 1856. The lower members of the series appear in the eastern part of the state, where the group III consists of several thousand feet of sandstones and shales, including near the top a white sandstone with *Scolithus*. The group IV in like manner consists of several thousand feet of sandstones and shales, with limestones, often magnesian. These two groups, which are regarded by Safford as equivalent to the Potsdam and Calciferous formations, resemble the Potsdam and Quebec groups of Eastern Canada, and the Primal and Auroral divisions of Pennsylvania. The groups I and II appear to be like the altered strata of the Quebec group in eastern Canada, and are perhaps repetitions of III and IV, in a disturbed and metamorphosed condition. The group V in Eastern Tennessee includes in its upper part a large mass of sandy shales, and has a total thickness of about 2000 feet, but thins out to the westward. The great accumulation of sandstones, shales, and limestones, which make up the Potsdam and Quebec groups of Eastern Canada, Pennsylvania, and Tennessee, is represented in the Mississippi valley by a few hundred feet of sandstones and limestones. These constitute what has been called the Magnesian Limestone series of Missouri, which is divided into four parts by three intervening sandstones. It has a total thickness of about 1300 feet, and is followed by the Trenton and Hudson River groups, and by the Upper Silurian and Devonian series, the whole represented by a few hundred feet of strata, chiefly calcareous. The Lower Magnesian limestone, and the St. Peter's sandstone of Owen, which in Iowa underlie the Trenton group, have a thickness of about 800 feet. Above the latter group is the Galena or lead-bearing limestone of Iowa and Illinois. This constitutes the Upper Magnesian limestone of Owen, formerly known as the Cliff limestone of the west, which however included the strata up to the base of the Devonian. The great mass of Upper Devonian and Carboniferous sandstones and shales of Eastern Canada, New York, and Pennsylvania, is represented in the Mississippi valley by a few hundred feet of strata, chiefly calcareous. The whole Devonian series in Iowa and Illinois is only about 200 feet in thickness, and is directly succeeded by the Carboniferous limestones, which are in their turn overlaid by the Coal measures. These limestones are by Hall divided into the Burlington, Keokuk, and Warsaw limestones, the latter two being the Archimedes limestone of Owen. To this succeed the St. Louis limestones, which in Iowa support the Coal measures; while in Missouri about 200 feet of sandstone intervene, followed in some parts by an overlying member, called the Kaskaskia or Upper Archimedes limestone. The total thickness of this Carboniferous limestone group in Iowa is less than 400 feet, but it increases to more than 1200 feet in Missouri and Tennessee.

Tennessee

Missouri

Iowa

CATALOGUE OF LOWER SILURIAN FOSSILS.

The following catalogue contains a list of all the hitherto described species of Lower Silurian fossils from Canadian localities, with the exception of the fossils from the Quebec group. There are a few other species, mostly orthoceratites, yet to be determined. The study of the Middle Silurian, Upper Silurian, and Devonian fossils of Canada, is not yet sufficiently advanced to render practicable the preparation of a catalogue of them approaching to completeness; and the same may be said of those of the Quebec group. The described fossils from this group, however, are figured in the eleventh chapter, and a list of these found at Point Lévis is given on page 862, with the exception of the graptolitidæ, of which a complete list is placed at the end of this catalogue.

In the succeeding pages, the columns to the right hand side, indicate by asterisks the vertical range of the species through the divisions of the Lower Silurian series; and in the last column will be seen what species pass upwards into the Middle Silurian rocks. The abbreviations at the head of these columns have the following significations: P. G., Potsdam group; Cal., Calciferous formation; Ch., Chazy; B. B., Birdseye and Black River; Tr., Trenton; Ut., Utica; H. R., Hudson River formation; and M. S., Middle Silurian series. The abbreviations used in the list of authorities and references, are as follows with their explanations:

Am. Jour. Sci.	American Journal of Science and Arts (Silliman's Journal); New Haven, Conn.
Ann. Nat. Hist.	Annals and Magazine of Natural History; London.
Ann. Rep. N. Y.	Annual Reports of the Geological Survey of New York.
Br. Pal. Foss.	British Palæozoic Fossils, by Sedgwick and McCoy.
Can. Jour.	Canadian Journal of Industry, Science, and Art; Toronto.
Can. Nat. Geol.	Canadian Naturalist and Geologist; Montreal.
Dec.	Decades of the Geological Survey of Canada.
Geol. Rep. N. Y.	Final Reports of the Geological Survey of New York.
Geol. Trans.	Transactions of the Geological Society of London.
Jour. A. N. S.	Journal of the Academy of Nat. Sciences of Philadelphia.
Jour. Geol. Soc.	Journal of the Geological Society of London.
Mem. Geol. Sur.	Memoirs of the Geological Survey of Great Britain.
Pal. Foss.	Palæozoic Fossils of Canada; published by the Geological Survey as "New Species of Lower Silurian Fossils."
Pal. N. Y.	Palæontology of New York. James Hall.
Polyp. Foss.	Polypiers Fossiles. Edwards and Haime; Paris.
Proc. A. N. S.	Proc. of the Academy of Nat. Sciences of Philadelphia.
Proc. Am. Assoc.	Proceedings of the American Association for the Advancement of Science.
Reg. Rep.	Annual Reports, Regents of the University of New York.
Rep.	Reports of the Geological Survey of Canada.
Rep. Brit. Assoc.	Reports, British Association for the Advancement of Science.
Rep. Geol. Wis.	Report on the Geology of Wisconsin. D. D. Owen.
Sil. Faun. W. Tenn.	Die Silurische Fauna des West. Tennessee. Dr. Ferd. Roemer.
Sup. Mon. Lim.	Supplement to Nó. 1 of a Monograph of the Limniades, etc., Haldeman, 1840.
Urwelt.	Urwelt Russlands. Eichwald.
Zool. Jour.	Journal of the Zoological Society of London.

CATALOGUE OF THE LOWER SILURIAN FOSSILS OF CANADA, NOT INCLUDING THOSE OF THE QUEBEC GROUP.

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. B.	Tr.	Ut.	H. R.	M. S.
	PLANTÆ.									
	PALÆOPHYCUS.	Hall, Pal. N. Y., i, 7, 1847.								
	P. irregularis.	" " " pl. 2, fig. 3.	..	*						
	— tubularis.	" " " figs. 1, 2, 4, 5.	..	*						
	— Beauharnoisensis.	Billings, Pal. Foss., 98.	..	*						
	— Beverleyensis.	" " 97.	*	*						
	— congregatus.	" " 3.	*							
	— funiculus.	" " 98.	..	*						
	— incipiens.	" " 2.	*							
	— obscurus.	" " 98.	..	..	..	..	*			
	BUTHOTREPHIS.	Hall, Pal. N. Y., i, 8, 1847.								
	B. gracilis.	" " " pl. 21, fig. 1.	..	..	..	..	*			
	LICROPHYCUS.	Billings, Pal. Foss., 99, June, 1862.								
	L. Hiltonensis.	" " 101.	..	..	..	*	*			
	— Hudsonicus.	" " "	..	..	..	..	..	..	*	
	— minor.	" " 100, fig. 88.	..	..	..	..	*			
	— Ottawaensis.	" " 99, " 87.	..	..	..	..	*			
	— succulens.	*Buthotrephis succulens*, Hall, Pal. N.Y., i, pl. 22, fig. 2.	..	..	..	..	*			
	RUSOPHYCUS.	Hall, Pal. N. Y., ii, 83, 1853.								
	R. Grenvillensis.	Billings, Pal. Foss., 101.	..	..	*					
	BEATRICEA.	Billings, Rep. 1857, 343.								
	B. nodulosa.	" " " 344.	..	..	..	..	..	..	*	*
	— undulata.	" " " "	..	..	..	..	..	..	*	
	PROTOZOA.									
	RECEPTACULITES.	Defrance, 1827.								
	R. occidentalis.	Salter, Dec. i, 45, = *R. Neptuni*, Hall, Pal. N. Y., i, 68, pl. 24, fig. 3.	..	..	..	*	*			
	— Iowensis.	Owen, Rep. Geol. Wis., pl. 2, fig. 13.	..	..	..	..	*			
	— calciferus.	Billings, Pal. Foss.		*						
	AMORPHOZOA.									
	EOSPONGIA.	Billings, Pal. Foss., 18, Nov. 1861.								
	E. Roemeri.	" " 19, " "	..	..	*					
	— varians.	" " " " "	..	..	*					
	ASTYLOSPONGIA.	Roemer, Sil. Faun. W. Tenn., 1860.								
	A. parvula.	Billings, Pal. Foss., 20. [1847.	..	..	..	..	*			
	STROMATOPORA.	Goldfuss, 1830. *Stromatocerium*, Hall,								
140	S. rugosa.	*Stromatocerium rugosum*, Hall, Pal. N. Y., i, pl. 12.	..	*	*	*				
	— compacta.	Billings, Pal. Foss., 55.	..	..	*	*				
	— Canadensis.	" "	..	..	..	..	..	..	*	

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Continued.*

Page.	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. B.	Tr.	Ut.	H. R.	M. S.
	ARCHEOCYATHUS.[1]	Billings, Pal. Foss., 3, Nov. 1861.								
283	A. Atlanticus.	" " 4.	*							
	— Minganensis.	*Petraia Minganensis*, Billings, Can. Nat. Geol., iv, 346.	*	*						
	ZOOPHYTA.									
	PROTARÆA.	Edwards & Haime, Polyp. Foss., 208.								
	P. vetusta.	*Porites vetusta*, Hall, Pal. N. Y., i, pl. 25, fig. 5.	..	..	..	..	*			
	HELIOLITES.	Dana. Zooph., 541, 1846.								
	H. megastoma.	McCoy, Br. Pal. Foss., pl. 1 C. fig. 4.	..	..	..	..	..	..	*	*
	FAVOSITES.	Goldfuss.								
	F. Gothlandica.	"	..	..	..	..	..	..	*	*
	STENOPORA.	Goldfuss.								
156	S. fibrosa.	"	..	..	*	*	*	*	*	*
156	— petropolitana.	Pander.	..	..	*	*	*	*	*	
	— patula.	Billings, Can. Nat. Geol., iv, 427.	..	..	*					
	— adhærens.	" " " "	..	..	*					
	BOLBOPORITES.	Pander.								
	B. Americanus.	Billings, Can. Nat. Geol., iv, 429.	..	..	*					
	HALYSITES.	Fischer,								
	H. catenulatus.	Linnæus.	..	..	..	*	*		*	*
	TETRADIUM.	Dana.								
139	T. fibratum.	Safford, Am. Jour. Sci. [2], xxii, 237.	..	..	..	*	..	..	*	
	COLUMNARIA.	Goldfuss.								
139	C. alveolata.	"	..	..	..	*				
	— parva.	Billings, Can. Nat. Geol., iv, 428.	..	..	*					
124	— incerta.	" " " "	..	..	*					
	— Goldfussi.	" Rep. 1858, 166.	..	..	..	..	..	..	*	
	— Blainvilli.	" " " "	..	..	..	..	..	..	*	
	— rigida.	" " " 167.	..	..	..	..	..	..	*	
	— erratica.	" " " "	..	..	..	..	*			
	PALÆOPHYLLUM.	Billings, 1858.								
	P. rugosum.	" Rep. 1858, 168.	..	..	..	..	*			
	FAVISTELLA.[2]	Dana, Zooph., 538, 1846.								
206	F. stellata.	Hall, Pal. N. Y., i, pl. 75, fig. 1.	..	..	..	..	..	..	*	
	PETRAIA.	Lonsdale. *Streptelasma* or *Streptoplasma*. Hall.								
	P. profunda.	Hall. *Streptoplasma profunda*. Pal. N. Y., i, pl. 12, fig. 4.	..	..	..	*				
156	— corniculum.	Hall. *Streptelasma corniculum* + *crassa* + *multilamellosa* + *parva*. Pal. N.Y., i, pl. 25, fig. 1–4.	..	..	..	*	*			
	— aperta.	Billings, Pal. Foss., 102.	..	..	..	*				
	— rustica.	" Rep. 1858, 168.	..	..	..	..	..	..	*	
	ZAPHRENTIS.	Rafinesque, 1820.								
208	Z. Canadensis.	Billings, Pal. Foss., 105.	..	..	..	..	..	..	*	

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Continued.*

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. B.	Tr.	Ut.	H. R.	M. S.
	CRINOIDEÆ.									
	BLASTOIDOCRINUS.	Billings, 1859.								
	B. carchariædens.	" Dec. iv, 18.	..	..	*					
	CARABOCRINUS.	Billings, 1857.								
	C. radiatus.	" Rep. 1857, 276. Dec. iv, 31.	..	..	..	..	*			
	— tuberculatus.	" Dec. iv, 33.	..	..	..	..	..	..	*	
	— Vancortlandtii.	" " " 32.	..	..	..	..	*			
	CLEIOCRINUS.	Billings, 1857.								
	C. regius.	" Rep. 1857, 277. Dec. iv, 53.	..	..	..	..	*			
	— grandis.	" Dec. iv, 54.	..	..	..	..	*			
	— magnificus.	" " " "	..	..	..	..	*			
	DENDROCRINUS.	Hall, 1852.								
	D. acutidactylus.	Billings, Rep. 1857, 266. Dec. iv, 37.	..	..	..	..	*			
	— conjugans.	" " " 268. " " 41.	..	..	..	..	*			
	— cylindricus.	" " " " " " 44.	..	..	..	..	*			
	— gregarius.	" " " 265. " " 36.	..	..	..	..	*			
	— humilis.	" " " 270. " " 39.	..	..	..	..	*			
	— Jewettii.	" " " " " " 43.	..	..	..	..	*			
	— latibrachiatus.	" " " " " " 39.	..	..	..	..	*			
	— proboscidiatus.	" " " 267. " " 38.	..	..	..	..	*			
	— rusticus.	" " " 270. " " 41.	..	..	..	..	*			
	— similis.	" " " 267. " " 40.	..	..	..	..	*			
	GLYPTOCRINUS.	Hall, 1847.								
	G. lacunosus.	Billings, Rep. 1857, 261. Dec. iv, 61.	..	..	..	..	*			
	— marginatus.	" " " 260. " " 59.	..	..	..	..	*			
	— ornatus.	" " " " " " 60.	..	..	..	..	*			
	— priscus.	" " " 257. " " 56.	..	..	..	*				
	— quinquepartitus.	" Dec. pl. 8, fig. 4.	..	..	..	..	*			
	— ramulosus.	" Can. Nat. Geol., i, 54. Rep. 1857, 258. Dec. iv, 57.	..	..	..	*	*			
	HETEROCRINUS.	Hall, 1847.								
	H. articulosus.	Billings, Dec. iv, 51.	..	..	..	..	*			
	— Canadensis.	" " " 48.	..	..	..	..	*			
	— inæqualis.	" " " 51.	..	..	..	..	*			
	— tenuis.	" " " 50. Rep. 1857, 273.	..	..	..	..	*			
	HYBOCRINUS.	Billings, 1857.								
	H. conicus.	" Rep. 1857, 274. Dec. iv, 29.	..	..	..	..	*			
	— tumidus.	" " " 275. " " 28.	..	..	..	..	*			
	— pristinus.	" Dec. iv, 23.	..	..	*					
	LECANOCRINUS.	Hall, 1856.								
	L. elegans.	Billings, Rep. 1857, 278. Dec. iv, 47.	..	..	..	..	*			
	— lævis.	" " " " " " "	..	..	..	..	*			
	PACHYOCRINUS.	Billings, 1859.								
	P. crassibasalis.	" Dec. iv, 22.	..	..	*					
	PALÆOCRINUS.	Billings, 1859.								
	P. angulatus.	" *Dendrocrinus angulotus.* Rep. 1857, 269. Dec. iv, 45.	..	..	..	..	*			

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Continued.*

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. R	Tr.	Ut.	H. R.	M. S.
	Palæocrinus.—*Con.*									
	P. pulchellus.	Billings, Rep. 1857, 269. Dec. iv, 46.	..	..	..	..	*			
	— rhombiferus.	" " " " " " 45.	..	..	..	..	*			
	— striatus.	" " " " " " 25.	..	..	*					
	Porocrinus.	Billings, 1857.								
	P. conicus.	" Rep. 1857, 279. Dec. iv, 34.	..	..	..	..	*			
	Reteocrinus.	Billings, 1859.								
	R. fimbriatus.	" Dec. iv, 65.	..	..	..	..	..	..	*	
	— stellaris.	" " " 64.	..	..	..	..	*			
	Rhodocrinus.	Miller, 1821, = *Thysanocrinus*, Hall.								
	R. asperatus.	Billings, Dec. iv, 27.	..	..	*					
	— pyriformis.	" " " 61.	..	..	..	..	*			
	— microbasalis.	*Thysanocrinus*, (*Rhodocrinus*) *microbasalis*. Billings, Rep. 1857, 264. Dec. iv, 63.	..	..	..	..	*			
	Syringocrinus.	Billings, 1859.								
	S. paradoxicus.	" Dec. iv, 65.	..	..	..	..	*			
	CYSTIDEÆ.									
	Amygdalocystites.	Billings, 1854.								
	A. florealis.	" Can. Jour. [1], ii, 270. Rep. 1857, 289. Dec. iii, 63.	..	..	..	..	*			
	— radiatus.	Billings, 1854. Can. Jour. [1], ii, 271. Rep. 1857, 289. Dec. iii, 65.	..	..	..	..	*			
	— tenuistriatus.	Billings, 1854. Can. Jour. [1], ii, 271. Rep. 1857, 289. Dec. iv, 64.	..	..	..	..	*			
	Ateleocystites.	Billings, 1858.								
	A. Huxleyi.	" Dec. iii, 72.	..	..	..	..	*			
	Comarocystites.	Billings, 1854.								
	C. punctatus.	" Dec. iii. 61.	..	..	..	..	*			
	Glyptocystites.	Billings, 1854.								
	G. Forbesi.	" Rep. 1857, 283. Dec. iii, 59.	..	..	*					
	— gracilis.	" " " 283. " " 59.	..	..	..	..	*			
	— Logani.	" " " 282. " " 57.	..	..	..	..	*			
	— multiporus.	" Can. Jour. [1], ii, 215. Rep. 1857, 281. Dec. iii, 54.	..	..	..	..	*			
	Malocystites.	Billings, 1858.								
	M. Barrandei.	" Dec. iv, 67.	..	..	*					
	— Murchisoni.	" " " 66.	..	..	*					
	Palæocystites.	Billings, 1858.								
	P. Chapmani.	" Dec. iii, 71.	..	..	*					
	— Dawsoni.	" " " 70.	..	..	*					
	— pulcher.	" Can. Nat. Geol., iv, 430.	..	..	*					
	— tenuiradiatus.	*Actinocrinus tenuiradiatus*, Hall. Pal. N. Y., i, 18, pl. 4, figs. 8, 9. Billings, Dec. iii, 69.	*							

CATALOGUE OF LOWER SILURIAN FOSSILS—*continued.*

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. R.	Tr.	U.	H. R.	M. S.
	Pleurocystites.	Billings, 1854.								
	P. Anticostiensis.	" Rep. 1857, 288. Dec. iii, 52.	..	..	..	..	.	..	*	
	— elegans.	" " " 287. " " 51.	..	..	..		*			
	— filitextus.	" Can. Jour. [1], ii, 252, Rep. 1857, 286. Dec. iii, 50.	..	..	..	..	*			
	— exornatus.	Billings, Dec. iii, 52.	..	..	..	..	*			
	— robustus.	" " " 49.	..	..	..	..	*			
	— squamosus.	" " " "	..	..	..	..	*			
	Cyclocystoides.	Billings and Salter, 1858.								
	C. Halli.	" " Dec. iii, 86.	..	..	..	..	*			
	ASTERIADÆ.									
	Palasterina.	McCoy, 1851.								
	P. rugosa.	Billings, Rep. 1857, 291. Dec. iii, 77.	..	..	..	..	..	..	*	
	— stellata.	" " " 290. " " 76.	..	..	..	..	*			
	Petraster.	Billings, 1858.								
	P. rigidus.	*Palasterina rigidus*, Billings, Rep. 1857, 291. Dec. iii, 80.	..	..	..	..	*			
	Stenaster.	Billings, 1858.								
	S. Salteri.	" Dec. iii, 78.	..	..	..	..	*			
	— pulchellus.	*Palæaster pulchella*, Billings, Rep. 1857, 292. Dec. iii. 79.	..	..	..	..	*			
	Tæniaster.	Billings, 1858.								
	T. cylindricus.	*Palæocoma cylindrica*, Billings. Rep. 1857, 292. Dec. iii, 81.	..	..	..	..	*			
	— spinosus.	Billings, Dec. iii, 81.	..	..	..	..	*			
	EDRIOASTERIDÆ.									
	Agelacrinites.	Vanuxem.								
	A. Billingsii.	Chapman, Can. Jour. [2], v, 358.	..	..	..	..	*			
	— Dicksoni.	Billings, Dec. iii, 84.	..	..	..	..	*			
	Edrioaster.	Billings, 1858. *Cyclaster*, Billings, 1857, not *Cyclaster* of Leymerie and Cotteau.								
	E. Bigsbyi.	*Cyclaster Bigsbyi*, Billings, Rep. 1857, 293. Dec. iii, 82.	..	..	..	..	*			
	BRYOZOA.									
	Ptilodictya.	Lonsdale, 1839, = *Stictopora*, Hall.								
158	P. acuta.	Hall, Pal. N. Y., i. pl. 26, fig. 3.	..	..	..	*	*	*	*	*
	— fenestrata.	" " " " 4, " 4.	..	..	*					
	— labyrinthica.	" " " " 12, " 8.	..	..	..	*				
158	— recta.	*Escharopora recta*, Hall, pl. 26, fig. 1,	..	..	..	*	*			
	Coscinium.	Keyserling, 1846, = *Clathropora*, Hall, 1852.								
158	C. proavium.	Eichwald, Urwelt., ii, pl. 1, fig. 5.	..	..	*	*	*			
	Intricaria.	Defrance, 1826.								
	I. ? reticulata.	Hall, Pal. N. Y., pl. 26, fig. 8.	..	..	..	..	*			

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Continued.*

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. B.	Tr.	Ut.	H. R.	M. S.
	POLYPORA.	McCoy, 1844.								
	P. gracilis?	*Retepora incepta*, and *R. gracilis*, Hall, Pal. N. Y., i, pl. 4, fig. 1, 2.	..	..	*					
	ARTHROCLEMA.	Billings, 1862.								
157	A. pulchella.	" Pal. Foss., 54.	..	..	..	..	*			
	GRAPTOLITHUS.	Linnæus.								
	G. amplexicaule.	Hall, Pal. N. Y., i, pl. 26, fig. 11.	..	..	..	..	*			
200	— bicornis.	" " " " 73, " 2.	..	..	..	..	..	*	*	
	— mucronatus.	" " " " 73, " 1.	..	..	..	..	..	*		
200	— ramosus.	" " " " " " 3.	..	..	..	..	..	*	*	
200	— pristis.	Hisinger.	..	..	..	..	..	*		
	BRACHIOPODA.									
	LINGULA.	Bruguière, 1789.								
102	L. acuminata.	Conrad, Ann. Rep. N. Y., 1839, 64, = *L. antiqua*, Hall, pars.	*	*						
	— crassa.	Hall, Pal. N. Y., i, pl. 30, fig. 8.	..	..	..	..	*			
161	— curta.	" " " " " " 6.	..	..	..	..	*			
161	— elongata.	" " " " " " 5.	..	..	..	..	*			
	— equalis.	" " " " " " 3.	..	..	..	..	*			
161	— obtusa.	" " " " " " 7.	..	..	..	..	*			
	— riciniformis.	" " " " " " 2.	..	..	..	..	*			
161	— quadrata.	Eichwald.	..	..	..	..	*	..	*	
124	— Belli.	Billings, Can. Nat. Geol., iv, 431.	..	..	*					
141	— Eva.	" " vi, 150.	..	..	..	*				
124	— Huronensis.	" " iv, 433.	..	..	*	*				
124	— Lyelli.	" " " 348.	..	..	*					
113	— Mantelli.	" " " 349.	..	*						
161	— Briseis.	" Pal. Foss., 48.	..	..	..	..	*			
210	— Canadensis.	" " 114.	..	..	..	..	..	..	*	
161	— Coboutgensis.	" " 48.	..	..	..	..	*			
	— Daphne.	*Lingula attenuata*, Hall, not Sowerby.	..	..	..	..	*			
	— Forbesi.	Billings, Pal. Foss., 115.	..	..	..	..	.	..	*	
141	— Kingstonensis.	" " 48.	..	..	..	*				
	— Parryi.	" " 20.	..	..	..	..	*			
	— Philomela.	" " 49.	..	..	..	..	*			
161	— Progne.	" " 47.	..	..	..	..	*			
	OBOLUS.	Eichwald, 1829.								
142	O. Canadensis.	Billings, Rep. 1858, 189.	..	..	..	*				
284	— Labradoricus.	" Pal. Foss., 5.	*							
	OBOLELLA.	Billings, 1861.								
284	O. chromatica.	" Pal. Foss., 7.	*							
	— cingulata.	" " " 8.	*							
	EICHWALDIA.	Billings, 1858.								
142	E. subtrigonalis.	" Rep. 1858, 192.	..	..	..	*				
	— Anticostiensis.	Pal. Foss.	..	..	..	..	..	..	*	
	DISCINA.	Lamarck, 1817.								
159	D. Circe.	Billings, Pal. Foss., 51.	..	..	..	..	*			
159	— Pelopea.	" " 52.	..	..	..	..	*			

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	TREMATIS.	Sharpe.								
159	T. Huronensis.	Billings, Pal. Foss., 53.	..	..	..	*	*			
159	— Montrealensis.	" " 52.	..	..	..	..	*			
159	— Ottawaensis.	" " 53.	..	..	..	..	*			
	— cancellata.	G. B. Sowerby, Zool. Jour., ii, pl. 11, fig. 6.	..	..	..	..	*			
159	— terminalis.	Emmons, Geol. Rep. N.Y., 395, fig. 4.	..	..	..	..	*			
159	— filosa.	*Orbicula filosa*, Hall, Pal. N. Y., i, pl. 30, fig. 9.	..	..	..	..	*			
	LEPTÆNA.	Dalman, 1827.								
163	L. Sericea.	Sowerby.	..	..	..	..	*	*	*	*
	STROPHOMENA.	Rafinesque.								
163	S. alternata.	Conrad, Ann. Rep. N. Y., 1838, 115.	..	..	*	*	*	*	*	*
	— Camerata.	" Jour. A. N. S., viii, 5, pl. 14.	..	..	..	..	*			
	— Ceres.	Billings, Can. Nat. Geol., v, 54.	..	..	..	..	..	..	*	*
163	— deltoidea.	Conrad, Ann. Rep. N. Y., 1838, 115.	.	..	..	..	*			
	— recta.[3]	" Proc. A. N. S., i, 332.	..	..	..	*	*			
	— subtenta.	"	..	..	..	..	..	..	*	
	— incrassata.	Hall, Pal. N. Y., i, pl. 4, 1.	..	..	*	*	*	..	*	
164	— filitexta.	" " " " 31, fig. 3.	..	..	..	*	*	..	*	
	— planumbona.	" " " " " " 4.	..	..	..	..	*	..	*	
209	— Hecuba.	Billings, Can. Nat. Geol., v. 60.	..	..	..	..	..	..	*	
209	— fluctuosa.	" " " 58.	..	..	..	..	..	..	*	
209	— nitens.	" " " 53.	..	..	..	..	..	..	*	
164	— Thalia.	" " " 59.	..	..	..	..	*			
	— Arethusa.	" Pal. Foss., 132. [fig. 4.	..	..	..	..	..	..	*	
	— tenuistriata.	Sowerby, Hall, Pal. N. Y., i, pl. 31 A,	..	..	..	..	*			
	— imbrex ?	Pander.	..	..	..	..	..	..	*	
311	— pecten.[3]	Linnæus.	..	..	..	..	..	..	*	*
	ORTHIS.	Dalman, 1827.								
	O. deflecta.	*Strophomena deflecta*, Conrad. Proc. A. N. S., i, 332. *Leptæna deflecta*, Hall, Pal. N. Y., i, 113. pl. 31, B. fig. 5, *O. deflecta*, Safford. Am. Jour. Sci. [2], xii, 355.	..	..	..	*	*			
130	— disparalis.	Conrad, Proc. A. N. S., i, 333.	..	..	*	*				
130	— perveta.	" " " "	..	..	*	*				
	— subæquata.	" " " "	..	..	*	*	*			
167	— tricenaria.	" " " "	..	..	*	*	*	*	*	
165	— pectinella.	" Ann. Rep N. Y. 1840, 201.	..	..	..	*	*			
167	— lynx.	Eichwald.	..	..	..	..	*	*	*	*
165	— testudinaria.	Dalman.	..	..	..	*	*	*	*	*
167	— insculpta.	Hall, Pal. N. Y., i, pl. 32, fig. 12.	..	..	..	*	*	*		
210	— occidentalis.	" " " " 32 A, fig. 2.	..	..	..	.	..	*		
165	— plicatella.	" " " " 32, fig. 9.	..	..	..	*	*	*		
165	— subquadrata.	" " " " 32 A, fig. 1.	..	..	..	..	*	*	*	
312	— porcata.	McCoy, Br. Pal.Foss., pl.1 H, fig.41,42.	..	..	..	..	*	..	*	*
	— retrosa.	Salter, Mem. Geol. Sur., ii, pl. 27, figs. 3, 4.	..	..	..	..	*	*		

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	Orthis.—*Con.*									
130	O. acuminata.	Billings, Can. Nat. Geol., iv, 440.			*					
129	— borealis.	" " " 436.			*		*			
129	— imperator.	" " " 435.			*					
	— piger.	" " " 442.			*					
129	— platys.	" " " 438.			*					
	— Porcia.	" " " 439.			*					
	Orthisina.	D'Orbigny, 1849.				*	*		*	*
	O. Verneuili.	Eichwald.								
113	— grandæva.	Billings, Can. Nat. Geol., iv, 349.		*						
284	— festinata.	" Pal. Foss., 9.	*							
	Porambonites.	Pander, 1830.								
	P. Ottawaensis.	Billings, Pal. Foss., 140.				*				
	Rhynchonella.	Fischer, 1809. *Atrypa*, pars, Pal. N. Y.								
211	R. capax.	*Atrypa capax*, Conrad, Jour. A.N.S., viii, 264., pl. 14, fig. 21. *Atrypa increbescens*, pars.							*	
211	— modesta.	Say, *Atrypa modesta*, Hall, Pal. N. Y., i, pl. 33, fig. 15.							*	
168	— increbescens.	Hall, pars. Pal. N. Y., pl. 33.				*	*			
168	— recurvirostra.	" " " " fig. 5.				*	*	*	*	
126	— plena.	" " " 4, " 7.			*					
211	— Anticostiensis.	Billings, Pal. Foss., 142.							*	
126	— orientalis.	" Can. Nat. Geol., iv, 443.			*					
	Camerella.	Billings, August, 1859. *Triplesia*, Hall, October, 1859.								
231	C. calcifera.	Billings, Can. Nat. Geol., vi, 318.		*						
127	— longirostra.	" " iv, 302.			*					
143	— Panderi.	" " " "				*				
127	— varians.	" " " 445.			*					
143	— Volborthi.	" " " 301. [Hall.				*				
	— extans.	*Atrpya extans*, Conrad. *Triplesia extans*,					*			
	— nucleus.	*Atrypa nucleus*, Hall, Pal. N. Y., i, pl. 33, fig. 2. [i. pl. 33, fig. 10.					*			
168	— hemiplicata.	*Atrypa hemiplicata*, Hall, Pal. N. Y.,					*			
	— antiquata.	Billings, Pal. Foss., 10.	*							
	Athyris.	McCoy, 1844.								
212	A. Headi.	Billings, Pal. Foss., 147.							*	
212	— borealis.	Variety from Lake St. John.							*	
212	— Anticostiensis.	" from Anticosti.							*	
	LAMELLIBRANCHIATA.									
	Avicula.	Klein, 1753.								
215	A. demissa.	Conrad, Jour. A.N.S., viii, pl. 13, fig. 3.							*	
170	— elliptica.	Hall, Pal. N. Y., i, pl. 36, fig. 3.					*			
170	— Hermione.	Billings, Pal. Foss., 40.					*			
	— Trentonensis.	Conrad, Jour. A.N.S., viii, pl. 12, fig. 10.					*			

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	AMBONYCHIA.	Hall, 1847.								
	A. amygdalina.	Hall, Pal. N. Y., i, pl. 36, fig. 6.	..	..	..	*	*			
	— orbicularis.	" " " " " " 5.	..	..	..	..	*			
215	— radiata.	" " " " 80, " 4.	..	..	..	..	*	..	*	*
	— undata.	" " " " 36, " 7.	..	..	..	*	*			
	VANUXEMIA.	Billings, 1858.								
	V. inconstans.	" Can. Geol. Nat., iii, 438.	..	..	*	..				
	— Bayfieldii.	" " " 439.	..	..	..	..	..	..	*	
131	— Montrealensis.	" " iv, 444.	..	..	*					
	CYRTODONTA.	Billings, 1858.								
147	C. obtusa.	*Ambonychia obtusa*, Hall, Pal. N.Y., i, pl. 36, fig. 8.	..	..	..	*	*			
	— subangulata.	*Edmondia subangulata*, Hall, Pal. N.Y., i, pl. 35, fig. 2.	..	..	..	*	*			
	— subtruncata.	*E. subtruncata*, Hall, pl. 35, fig. 3.	..	..	..	*	*			
148	— Canadensis.	Billings, Can. Nat. Geol., iii, 434.	..	..	..	*	*			
147	— cordiformis.	" " " 437.	..	..	..	*	*			
147	— Huronensis.	" " " 432.	..	..	..	*	*			
148	— rugosa.	" " " 432.	..	..	..	*				
	— spinifera.	" " " 435.	..	..	..	*				
148	— subcarinata.	" " " 433.	..	..	..	*				
	— sigmoidea.	" " " 438.	..	..	..	*				
	— breviuscula.	" " iv, 446.	..	..	*					
	— Emma.	" Pal. Foss., 150.	..	..	..	..	..	..	*	
	— Harrietta.	" " 149.	..	..	..	..	..	..	*	
151	— Hindi.	" " 151.	..	..	..	..	..	..	*	
	— Leucothea.	" " 46.	..	..	..	*				
	— ponderosa.	" " 150.	..	..	..	..	..	..	*	
	CTENODONTA.	Salter, 1851. *Tellinomya*, Hall.								
175	C. dubia.	Hall, Pal. N. Y., i, pl. 34, fig. 6.	..	..	..	*	*		*	
176	— gibbosa.	" " " " " " 5.	..	..	..	*	*			
175	— levata.	" " " " " " 1.	..	..	..	*	*			
176	— nasuta.	" " " " " " 3.	..	..	..	*	*			
175	— astartæformis.	Salter, Dec., i, pl. 8, fig. 7.	..	..	..	*				
175	— contracta.	" " " " " " 4, 5.	..	..	..	*	*			
	— gibberula.	" " " " " " 6.	..	..	..					
	— Logani.	" " " " " " 3.	..	..	..		*			
143	— abrupta.	Billings, Pal. Foss., 46.	..	..	..	*				
216	— Iphigenia.	" " 152.	..	..	..	..	..	..	*	
	MODIOLOPSIS.	Hall, 1847.								
175	M. carinata.	" Pal. N. Y., i, pl. 35, fig. 11.	..	..	..	..	*			
	— faba.	Conrad, " " " " 6.	..	..	..	*	*			
213	— modiolaris.	" " " " 81, 82.	..	..	..	..	..	..	*	
	— mytiloides.	Hall, " " " 35, fig. 4.	..	..	..	*	*			
	— subspatulata.	" " " " " " 9.	..	..	..	*	*			
172	— Gesneri.	Billings, Pal. Foss., 35, 43.	..	..	..	*	*			
143	— Maia.	" " 44.	..	..	..	*				

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	Modiolopsis.—*Con.*									
173	M. Meyeri.	Billings, Pal. Foss., 42.	..	..	..	*	*			
143	— Nais.	" " 45.	..	..	..	*				
	— Adrastia.	" " 45.	..	..	..	*	*			
	— parviuscula.	" Can. Nat. Geol., iv, 446.	..	..	*					
	Matheria.	Billings, 1858.								
147	M. tener.	" Can. Nat. Geol., iii, 440.	..	..	..	..	*			
	Orthonota.	Conrad, 1841.								
	O. pholadis.	" Ann. Rep. N. Y. 1838, 118.	..	..	..	..	..	..	*	
	— contracta.	Hall, Pal. N. Y., i, pl. 82, fig. 8.	..	..	..	..	..	..	*	
216	— parallela.	" " " " " " 7.	..	..	..	..	..	..	*	
	Lyrodesma.	Conrad, 1841.								
176	L. postriata.	Emmons, Geol. Rep. N. Y., 399.	..	..	..	*	*	*	*	
	Cleidophorus.	Hall, 1847.								
	Several small species.		..	..	..	..	..	..	*	
	Conocardium.	Bronn, 1835.								
113	C. Blumenbachium.	Billings, Can. Nat. Geol., iv, 350.	..	*						
143	— immaturum.	" Pal. Foss., 41.	..	..	..	*				
	GASTEROPODA.									
	Holopea.	Hall, 1847.								
	H. dilucula.	" Pal. N. Y., i, pl. 3, fig. 7.	..	*						
	— obliqua.	" " " " 37, fig. 2.	..	..	..	..	*			
	— paludiniformis.	" " " " " " 3.	..	..	..	..	*			
	— symmetrica.	" " " " " " 1.	..	..	..	*				
	— turgida.	" " " " 3, " 9, 10.	..	*						
	— Lavinia.	Billings, Pal. Foss., 28.	..	..	..	..	*			
	— Nereis.	" " 27.	..	..	..	*	*			
	— Proserpina.	" " 28.	..	..	*					
145	— Pyrene.	" " . 27.	..	..	..	*				
	— ovalis.	" Can. Nat. Geol., iv, 351.		*						
	Cyclonema.[3]	Hall, 1852.								
217	C. bilix.	*Pleurotomaria bilix*, Conrad. Jour.	..	..	..	..	*	..	*	
		A. N. S., viii, pl. 16, fig. 10.	..	..	..	..	*			
178	— Hageri.	Billings, Pal. Foss., 29.	..	..	..	..	*			
178	— Montrealensis.	" " 30.	..	..	..	*	*			
178	— Halliana.	Salter, Dec., i, pl. 6, fig. 1.	..	..	..	*				
	— semicarinata.	" " " " " " 2.								
	Subulites.	Conrad. (Hall, 1847.)								
120	S. calcifera.	Billings, Can. Nat. Geol., iv, 360.	..	*						
183	— elongatus.	Conrad, M. S., Emmons. Geol. Rep. N. Y. 392, fig. 3. Hall, Pal. N. Y., i, pl. 39, fig. 5.	..	..	..	*	*			
	— parvulus.	Billings, Pal. Foss., 36.	..	..	..	..	*			
	— Richardsoni.	" Rep. 1857, 306.	..	..	..	..	..	..	*	
	— subfusiformis.	*Murchisonia subfusiformis*, Hall, Pal. N. Y., i, pl. 39, fig. 2.	..	..	..	*	*			

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	Eunema.	Salter, 1859.								
	E. cerithioides.	" Dec. i, 30. Billings, Pal. Foss., 35.	..	..	..	*				
180	— Erigone.	Billings, Pal. Foss., 35.	..	..	..	*				
	— pagoda.	Salter, Dec. i, pl. 6, fig. 5.	..	..	..	*				
145	— strigillata.	" " " " 6, " 4.	..	..	..	*				
	— prisca.	Billings, Can. Nat. Geol., iv, 360.	..	*						
	Loxonema.	Phillips, 1841.								
	L. Murrayana.	Salter, Dec. i, pl. 6, fig. 6.	..	..	..	*				
	Helicotoma.	Salter, 1856.								
	H. perstriata.	Billings, Can. Nat. Geol., iv, 356.	..	*						
	— planulata.	Salter, Dec., i, pl. 2, figs. 5-7.	..	..	..	*	*			
	— larvata.	" " " " " " 11-14.	..	..	..	*	*			
	— spinosa.	" " " " " " 9-10.	..	..	..	*				
	Maclurea.	Lesueur, 1818.								
	M. Atlantica.	Billings, Can. Nat. Geol., iv, 459.	..	..	*					
	— magna.	Lesueur, Jour. A. N. S., i, pl. 13, figs. 1, 2, 3.	..	..	*					
	— matutina.	Hall, Pal. N. Y., i, pl. 3, fig. 3.	..	*						
	— Logani.	Salter, Rep. Brit. Assoc. 1851. Trans. Sec. 63. Dec. i, pl. 1.	..	..	..	*				
	Ophileta.	Vanuxem, 1842.								
115	O. compacta.	Salter, Dec. i, pl. 3.	..	*						
180	— Ottawaensis.	Billings, Can. Nat. Geol., v, 167.	..	..	..	..	*			
	Straparollus.	Montfort, 1810.								
144	S. asperostriatus.	Billings, Can. Nat. Geol., v, 162.	..	..	..	*				
144	— Circe.	" " " 161.	..	..	..	*				
144	— Eurydice.	" " " 162.	..	..	..	*				
	Ecculiomphalus.	Portlock, 1843.								
	E. Trentonensis.	Conrad, Jour. A.N.S., viii, pl. 17, fig. 4.	..	..	..	..	*			
	Trochonema.	Salter, 1859.								
	T. tricarinata.	Billings, Can. Nat. Geol., iv, 356.	..	*						
145	— umbilicata.	*Pleurotomaria umbilicata*, Hall.	..	..	*	*	*	*	*	
	Pleurotomaria.	Defrance, 1825.								
	P. abrupta.	Billings, Can. Nat. Geol., iv, 354.		*						
	— Americana.	" " v, 164.								
		P. lenticularis, Hall, not Sowerby.	..	..	..	*	*			
	— Amphitrite.	Billings, Pal. Foss., 32.	..	..	*					
	— aperta.	Salter, Dec. i, pl. 2, fig. 4.	..	..	..	*	*			
145	— Arachne.	Billings, Pal. Foss., 31.	..	..	..	*	*			
117	— calcifera.	" Can. Nat. Geol., iv, 352.	..	*						
132	— calyx.	" " " 454.	..	..	*					
	— Crevieri.	" " " 456.	..	..	*					
132	— docens.	" " " 452.	..	..	*					
144	— Eugenia.	" Pal. Foss., 30.	..	..	..	*				
119	— gregaria.	" Can. Nat. Geol., iv, 355.	..	*						
	— Helena.	" " v, 165.	..	..	..	..	..	..	*	
	— immatura.	" " iv, 454.	..	..	*					

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	PLEUROTOMARIA.—*Con.*									
117	P. Laurentina.	Billings, Can. Nat. Geol., iv, 354.		*						
	— lapicida.	Salter, Dec. i, pl. 2, figs. 1-3.				*	*			
	— miser.	Billings, Can. Nat. Geol., iv, 354.		*						
	— nodulosa.	Hall, Pal. N. Y., i, pl. 10, fig. 10.				*	*			
	— pauper.	Billings, Can. Nat. Geol., iv, 457.			*					
	— Progne.	" " v, 163.				*	*			
117	— Ramsayi.	" " iv, 351.		*						
	— rotuloides.	Hall, Pal. N. Y., i, pl, 37, fig. 7.				*	*			
180	— subconica.	" " " " " " 8.				*	*		*	
	— Circe.	Billings, Rep. 1857, 303.							*	
181	— supracingulata.	" " " 302.					*			
	MURCHISONIA.	D'Archiac and De Verneuil, 1841.								
119	M. Anna.	Billings, Can. Nat. Geol., iv, 358.		*						
120	— arenaria.	" " " 359.		*						
	— aspera.	" " " 458.			*					
183	— bellicinta.	Hall, Pal. N. Y., i, pl. 39, fig. 1.				*	*			
	— bicincta.	" " " " 38, " 5.				*	*			
183	— gracilis.	" " " " 39, " 4.				*	*		*	
	— helicteres.	Salter, Dec. i., pl. 4, fig. 4.				*	*			
	— Hermione.	Billings, Pal. Foss., 33.				*				
	— infrequens.	" Can. Nat. Geol., iv, 457.			*					
119	— linearis.	" " " 359.		*						
	— modesta.	" Rep. 1857, 299.							*	
	— multivolvis.	" " " 244.							*	
	— perangulata.	Hall, Pal. N. Y., i, pl. 10, fig. 4.				*	*			
	— Procris.	Billings, Pal. Foss., 35.				*				
	— rugosa.	" Rep. 1857, 299.							*	
145	— serrulata.	Salter, Dec. i, pl. 4, fig. 1.				*	*			
	— teretiformis.	Billings, Rep. 1857, 298.							*	
	— varians.	" " " 300.							*	
	— ventricosa.	Hall, Pal. N. Y., i, pl. 10, fig. 3.				*	*			
	METOPTOMA.	Phillips, 1836.								
	M. dubia.	Hall, Pal. N. Y., i, pl. 4, fig. 11.			*					
	— deformis.	" " " " " " 10.			*					
	— patelliformis.	" " " "40, " 2.					*			
	— Alceste.	Billings, Pal. Foss., 153.							*	
145	— Erato.	" " 39.				*				
	— Estella.	" " 153.							*	
	— Nycteis.	" " 38.		*						
	— Trentonensis.	" " 40.					*			
	HETEROPODA.									
	CYRTOLITES.	Conrad, 1838.								
	C. compressus.	*Phragmolites compressus*, Conrad, Ann. Rep. N. Y. 1838, 119. *C. compressus*, Hall, Pal. N. Y., i, pl. 40 A, fig. 2.				*	*			
217	— ornatus.	Conrad, Ann. Rep. N. Y. 1838, 118. Hall, Pal. N. Y., pl. 84., fig. 1.							*	

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Continued.*

Page	Genera and Species.	Authors and References.	P. C.	Cal.	Ch.	B. R.	Tr.	Ut.	H. R.	M. S.
	Bellerophon.	Montfort, 1810. *Bucania*, Hall, pars.								
146	B. Argo.	Billings, Can. Nat. Geol., v, 167.	..	..	..	*	*			
	— bidorsatus.	Hall, Pal. N. Y., i, pl. 40, fig. 8.	..	..	..	*	*			
184	— bilobatus.	Sowerby.	..	..	..	*	*	*	*	*
146	— Charon.	Billings, Can. Nat. Geol., v, 169.	..	..	..	*	*			
146	— disculus.	" " " 168.	..	..	..	*	*			
	— expansus.	Hall, Pal. N. Y., i, pl. 40, fig. 7.	..	..	..	*	*			
	— punctifrons.	Conrad, Emmons, Hall, Pal. N. Y., i, pl. 40, fig. 1.	..	..	..	*	*			
146	— sulcatinus.	Emmons, Geol. Rep. N. Y., 312.	..	..	..	*	*			
	PTEROPODA.									
	Pterotheca.	Salter, 1852, = *Clioderma*, Hall, 14th Reg. Rep., 98.								
	P. expansa.	*Delthyris expansus*, Emmons, Geol. Rep. N. Y., 397. *Clioderma expansa*, Hall, 14th Reg. Rep., 98.	..	..	..	*	*			
	Theca.	Sowerby; Morris, 1844.								
	T. (sps. undescr.)		..	..	..	..	*			
	Salterella.	Billings, 1861.								
	S. obtusa.	" Pal. Foss., 18.	*							
	— pulchella.	" " "	*							
285	— rugosa.	" " 17.	*							
	CEPHALOPODA.									
	Orthoceras.	Breyn, 1732.								
	(1)—*Species figured in Pal. N. Y., vol. i.*									
	O. amplicameratum.	Hall, Pal. N. Y., i, pl. 51, fig. 1.	..	..	..	*	*			
150	— anceps.	*Gonioceras anceps*, Hall, Pal. N. Y., i, pl. 14.	..	..	..	*				
	— anellum.	Conrad, Proc. A. N. S., i, 334. Hall, Pal. N. Y., i, pl. 43, fig. 6.	..	..	..	*	*			
	— annulatum.	Hall, Pal. N. Y., i, pl. 44.	..	..	..	*	*			
	— arcuoliratum.	" " " " 42, fig. 7.	..	..	..	*	*			
149	— Bigsbyi.	Stokes, Geol. Trans. [2], i, 195, pl. 25, figs. 1-3, 1824. *Ormoceras tenuifilum*, Hall, Pal. N.Y., i, pl. 15, 16,17.	..	..	..	*				
	— bilineatum.	Hall, Pal. N. Y., i, pl. 43, figs. 2-3.	..	..	*	*	*	..	*	
218	— crebriseptum.	" " " " 86, fig. 2.	..	..	..	..	..	..	*	
	— fusiforme.	" " " " 20.	..	..	..	*	*			
	— junceum.	" " " " 47, fig. 3.	..	..	..	..	*			
	— laqueatum.	" " " " 3, " 12.	..	..	..	*				
	— longissimum.	*Endoceras longissimum*, and *E. multitubulatum*, Hall, Pal.N.Y., i, pl.18.	..	..	..	*	*			
	— multicameratum.	Emmons, Geo. Rep. N. Y., 382. Hall, Pal. N. Y., i, pl. 11, fig. 1.	..	..	*	*	*			

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Continued.*

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. B.	Tr.	Ut.	H. R.	M. S.
	Orthoceras.—*Con.*									
	O. primigenium.	Vanuxem, Geol. Rep. N. Y., 36, fig. 4, Hall, Pal. N. Y., i, pl. 3, fig. 11.	..	*						
	— proteiforme.	*Endoceras proteiforme*, Hall, Pal. N.Y., i, pl. 46.	..	..	..	*	*			
	— recticameratum.	Hall, Pal. N.Y., i, pl. 11, fig. 1 d.	..	..	..	*				
	— strangulatum.	" " " " 46, " 4.	..	..	..	..	*			
	— strigatum.	" " " " 56, " 1.	..	..	..	*	*			
	— subarcuatum.	" " " " 7, " 3.	..	..	*					
	(2) — *Species described by E. B. in Canadian publications.*									
	O. Anticostiense.	Billings, Rep. 1857, 316.	..	..	..	..	..	..	*	
	— Allumettense.	" " " 331.	..	..	*	*				
	— balteatum.	" " " 318.	..	..	..	..	..	..	*	
	— cornuum.	" " " 329.	..	..	*					
	— decrescens.	" " " 337.	..	..	..	*	*			
	— formosum.	" " " 317.	..	..	..	..	*	..	*	
	— hastatum.	" " " 333.	..	..	..	*	*			
	— Huronense.	" " " 337.	..	..	..	..	*			
	— Lyelli.	" " " 320.	..	..	..	..	..	..	*	
	— magnisulcatum.	" " " 330.	..	..	..	..	..	..	*	
	— Minganense.	" " " 319.	..	..	*	*				
	— Murrayi.	" " " 332.	..	..	..	*	*			
	— Ottawaense.	" " " 331.	..	..	..	*	*			
	— perannulatum.	" " " 320.	..	..	..	..	..	..	*	
	— propinquum.	" " " 320.	..	..	..	..	..	..	*	
	— Python.	" " " 335.	..	..	..	..	*			
	— Sedgwicki.	" " " 320.	..	..	..	..	..	..	*	
	— vulgatum.	" " " 337.	..	..	..	..	*			
	— xiphias.	" " " 318.	..	..	..	..	*			
	— Antenor.	" Can. Nat. Geol., iv, 463.	..	..	*					
121	— Becki.	" " " 362.	..	*						
121	— deparcum.	" " " 363.	..	*						
121	— Lamarcki.	" " " 362.	..	*						
	— Maro.	" " " 461.	..	..	*					
121	— Montrealensis.	" " " 363.	..	*						
	— Shumardi.	" " " 460.	..	..	*					
121	— sordidum.	" " " 363.	..	*						
	— pertinax.	" " v. 175.	..	..	..	*				
	— rapax.	" " " 176.	..	..	..	*				
	— tener.	" " " 174.	..	..	.	*				
	— Menelaus.	" Pal. Foss., 26.	..	..	..	*				
	— perparvum.	" " 27.	..	..	..	*				
	Cyrtoceras.	Goldfuss, 1833.								
	C. annulatum.	Hall, Pal. N. Y., i, pl. 41, fig. 4.	..	..	..	*	*			
	— Billingsii.	Salter, Dec. i, pl. 7, figs. 5, 6.	..	..	..	*				

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Continued.*

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. R.	Tr.	Ut.	H. R.	M. S.
	CYRTOCERAS.—*Con.*									
	C. constrictum.	*Oncoceras constrictum*, Hall, Pal. N.Y., i, pl. 41, fig. 6.				*	*			
	— exiguum.	Billings, Can. Nat. Geol., v, 172.					*			
	— falx.	" Rep. 1857, 314.				*	*			
	— Lysander.	" Pal. Foss., 161.							*	
	— macrostomum.	Hall, Pal. N. Y., i, pl. 42, fig. 1.				*				
	— multicameratum.	" " " " " " 4.				*				
	— McCoyi.	Billings, Can. Nat. Geol., iv, 467.			*					
	— regulare.	" Rep. 1857, 314.				*	*			
	— simplex.	" " " 313.				*	*			
	— sinuatum.	" " " 315.				*				
	— subturbinatum.	" " " 312.			*	*				
	GOMPHOCERAS.	Sowerby.								
	G. obesum.	Billings, Rep. 1857, 311.							*	
	PHRAGMOCERAS.	Broderip, 1839.								
	P. præmaturum.	Billings, Can. Nat. Geol., v, 173.				*	*			
	LITUITES.	Breyn, 1732.								
	L. magnificum.	*Gyroceras magnificum*, Billings, Rep. 1857, 307.							*	
	— undatum.	Hall, Pal. N. Y., i, pl. 13.				*				
	— vagrans.	*Gyroceras vagrans*, Billings, Rep. 1857, 308.				*				
	NAUTILUS.	Breyn, 1732.								
	N. Hercules.	Billings, Rep. 1857, 306.							*	
	— Jason.	" Can. Nat. Geol., iv, 464.			*					
	— natator.	" " " 466.			*					
	— tyrans.	" " " 465.			*					
	ASCOCERAS.	Barrande.								
218	A. Canadense.	Billings, Rep. 1857, 310.							*	
	— Newberryi.	" Pal. Foss., 163.							*	
	PILOCERAS.	Salter.								
	P. Canadense.	Billings, Can. Nat. Geol., v. 171.		*						
	CRUSTACEA.									
	ASAPHUS.	Brongniart, 1822; includes *Isotelus* of DeKay.								
204	A. Canadensis.	Chapman, Can. Jour. [2], i, 482; ii, 47; iii, 230. Ann. Nat. Hist. [3], ii, 9, fig. 1.						*		
	— Halli.	Chapman, Can. Jour. [2], ii, 235. " Ann. Nat. Hist. [3], ii, 14, fig. 2.						*		
	— Hincksii.	" " iv, 2.						*		
184	— megistos.	Locke, Proc. Am. Assoc. 1841, 221.				*	*		*	*
184	— platycephalus.	Stokes, 1822. *Isotelus gigas*, De Kay, 1824.			*	*	*	*	*	

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Continued.*

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. B.	Tr.	Ut.	H. R.	M. S.
	Acidaspis.	Murchison, 1839.								
190	A. Horani.	Billings, Rep. 1857, 341.	..	..	..	..	*			
	— Trentonensis.	Hall, Pal. N. Y., i, pl. 64, fig. 4.	..	..	..	..	*			
	Amphion.	Pander, 1830.								
133	A. Canadensis.	Billings, Can. Nat. Geol., iv, 381.	..	..	*					
	Ampyx.	Dalman, 1827.								
	A. Halli.	Billings, Pal. Foss., 24.	..	..	*					
	Bathyurus.	Billings, 1859.								
122	B. amplimarginatus.	" Can. Nat. Geol., iv, 365.	..	*						
133	— Angelini.	" " " 468.	..	..	*					
122	— conicus.	" " " 366.	..	*						
	— Cordai.	" " v, 321.	..	*						
122	— Cybele.	" " iv, 366.	..	*						
153	— extans.	*Asaphus? extans*, Hall, Pal. N. Y., i, pl. 60, fig. 2.	..	..	..	*				
	— parvulus.	Billings, Pal. Foss., 16.	*							
	— senectus.	" " 15.	*							
153	— Smithi.	" " 56.	..	..	..	*				
	— spiniger.	*Acidaspis spiniger*, Hall, Pal. N.Y., i, pl. 64, fig. 5.	..	..	..	*	*			
	Bronteus.	Burmeister, 1843.								
188	B. lunatus.	Billings, Rep. 1857, 338.	..	..	..	..	*			
	Calymene.	Brongniart, 1822.								
	C. Blumenbachii.[5]	" Crust. Foss., i, fig 1.	..	..	..	..	*	*	*	
	Cheirurus.	Beyrich, 1815, = *Ceraurus*, Pal. N. Y.								
	C. Icarus.	Billings, Can. Nat. Geol., v, 67.	..	..	..	..	..	..	*	
188	— pleurexanthemus.	*Ceraurus pleurexanthemus*, Green.	..	..	..	*	*	*	*	
	Conocephalites.	Zenker, 1833.								
	C. Adamsi.	Billings, Pal. Foss., 11.	*							
	— arenosus.	" " 15.	*							
	— miser.	" " 11.	*							
	— Teucer.	" " 14.	*							
	— Vulcanus.	" " 13.	*							
	Dalmanites.	Emmerich, 1845.								
187	D. Achates.	Billings, Can. Nat. Geol., v, 63.	..	..	..	..	*			
187	— Bebryx.	" " " 61.	..	..	..	..	*			
	Encrinurus.	Emmrich, 1845.								
	E. vigilans.	*Ceraurus vigilans*, Hall, Pal. N. Y., i, pl. 65, fig. 2.	..	..	..	*	*			
	Harpes.	Goldfuss, 1839.								
133	H. antiquatus.	Billings, Can. Nat. Geol., iv, 468.	..	..	*					
	— Dentoni,	" " viii, 36.	..	..	..	..	*			
	Illænus.	Dalman, 1826.								
	I. Americanus.	Billings, Can. Nat. Geol., iv, 371.	..	..	..	..	*			
151	— angusticollis.	" " " 376.	..	..	..	*				
	— arcturus.	Hall, Pal. N. Y., i, pl. 4, fig. 12.	..	..	*	*				

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Continued.*

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. R.	Tr.	Ut.	H. R.	M. S.
	Illænus.—*Con.*									
133	I. Bayfieldi.	Billings, Can. Nat. Geol., iv, 369.	..	..	*					
	— clavifrons.	" " " 379.	..	..	*	*				
151	— conifrons.	" " " 378.	..	..	..	*				
	— Conradi.	" " " 372.	..	..	*					
133	— globosus.	" " " 367.	..	..	*					
	— grandis.	" " " 380.	..	..	..	..	..	..	*	*
151	— Milleri.	" " " 375.	..	..	..	*	*			
	— orbicaudatus.	" " " 379.	..	..	..	..	..	..	*	*
	— ovatus.	Conrad, Proc. A. N. S., i, 332.	..	..	..	*				
	Lichas.	Dalman, 1826.								
	L. Trentonensis.	*Platynotus Trentonensis*, Conrad, Jour. A. N. S., viii, pl. 16, fig. 16.	..	..	..	*	*			
	Paradoxides.	Brongniart, 1822.								
	P. Thompsoni.	*Olenus Thompsoni*, Hall, 12th Reg. Rep., 59. *Barrandia Thompsoni*, 13th Reg. Rep., 116.	*							
	— Vermontana.	*Olenus Vermontana*, Hall, Loc. cit. These two may probably constitute but one species.	*							
	Phacops.	Emmrich, 1839.								
187	P. callicephalus.	Hall, Pal. N. Y., i, pl. 65, fig. 3. This species is probably a *Dalmanites*.	..	..	..	*	*	..	*	
	Proetus.	Steininger, 1831.								
219	P. Alaricus.	Billings, Can. Nat. Geol., v, 68.	..	..	..	..	..	..	*	
	Triarthrus.	Green.								
202	T. Beckii.	Eaton.	..	..	..	..	..	*		
	— glaber.	Billings, Can. Nat. Geol., iv, 382.	..	..	..	..	..	*		
202	— spinosus.	" Rep. 1857, 340.	..	..	..	..	..	*		
	— Canadensis.	Smith, Can. Jour. [2], vi, 275.	..	..	..	..	..	*		
	Trinucleus.	Lhwyd, 1698.								
190	T. concentricus.	Eaton, 1832.	..	..	..	..	*	*	*	
	Climactichnites.	Logan, Can. Nat. Geol., v, 5, 279.								
	C. Wilsoni.	" " " " fig. 1–5	*							
	Protichnites.	Owen, Jour. Geol. Soc., v, 8, 1852.								
	P. alternans.	" " " pl. 14.	*							
	— latus.	" " " " 11.	*							
	— lineatus.	" " " " 13.	*							
	— multinotatus.	" " " " 12.	*							
	— octonotatus.	" " " " 10.	*							
	— septemnotatus.	" " " " 9.	*							
	ENTOMOSTRACA.									
	Beyrichia.	McCoy, 1850.								

CATALOGUE OF LOWER SILURIAN FOSSILS.—*Concluded.*

Page	Genera and Species.	Authors and References.	P. G.	Cal.	Ch.	B. B.	Tr.	Ut.	H. R.	M. S.
	LEPERDITIA.	Rouault, 1851.								
	L. Canadensis.	Jones, Ann. Nat. Hist. [3], i, 244, pl. 11, figs. 11-15. Dec., iii, pl. 11, figs. 6, 7, 9, 10.	..	..	*	*	*			
	— labrosa.	Jones Dec., iii, pl. 11, fig. 8.	..	..	*					
	— Louckiana.	" " " " " " 11.	..	..	..	*				
	— Paquettiana.	" " " " " " 12.	..	..	..	*				
	— Josephiana.	" " " " " " 16.	..	..	..	*	*			
	— Anticostiana.	" " " " " " 17.	..	..	..	..	..	..	*	*
	— Anna.	" " " " " " 13.	..	*						
	— amygdalina.	" " " " " " 18, 19.	..	..	..	*				
	ISOCHILINA.	Jones, 1858.								
	I. Ottawa.	" Dec. iii, pl. 11, fig. 14.	..	..	..	*				
	— gracilis.	" " " " " " 15.	..	..	..	*				
	CYTHEROPSIS.	McCoy, 1855.								
	C. concinna.	Jones, Ann. Nat. Hist. [3], i, 249, pl. 10, figs. 3, 4.	..	..	..	*				
	— siliqua.	" " " " " " " 6.	..	..	..	*				
	— rugosa.	" " " " " " " 5.	..	..	..	*				
	ANNELIDA?									
	SERPULITES.	McLeay, 1838.								
	S. dissolutus.	Billings, Pal. Foss., 56.	..	..	..	*				
	— splendens.	" Can. Nat. Geol., iv, 470.	..	..	*					
	INCERTÆ SEDIS.									
	SCOLITHUS.	Haldeman, Sup. Mon. Lim. 1840.								
101	S. Canadensis.	Billings, Pal. Foss., 96.	*							
	— linearis.	Hall, Pal. N. Y., i, pl. 1, fig. 1.	*							
	PASCEOLUS.	Billings, Rep. 1857, 342.								
	P. globosus.	" " " 343.	..	..	..	..	*			

[1] It is not certain whether these fossils are sponges or corals.

[2] Edwards and Haime are of opinion that *Favistella* is not generically distinct from *Columnaria*, and that *F. stellata* is specifically identical with *C. alveolata*. Polyp. Foss. 308, 309.

[3] *Strophomena recta* and *S. pecten* appear to belong to the genus *Streptorhynchus*.

[4] The genera *Holopea*, Hall 1847; *Cyclonema*, Hall 1852; *Platyostoma*, Conrad 1839; and *Platyceras*, Conrad 1840, are connected by such numerous transitions that it is scarcely possible to draw lines between them.

[5] *Calymene senaria* of the N. Y. Reports. It may be distinct from the typical form of the species. There are several varieties in the Canadian rocks.

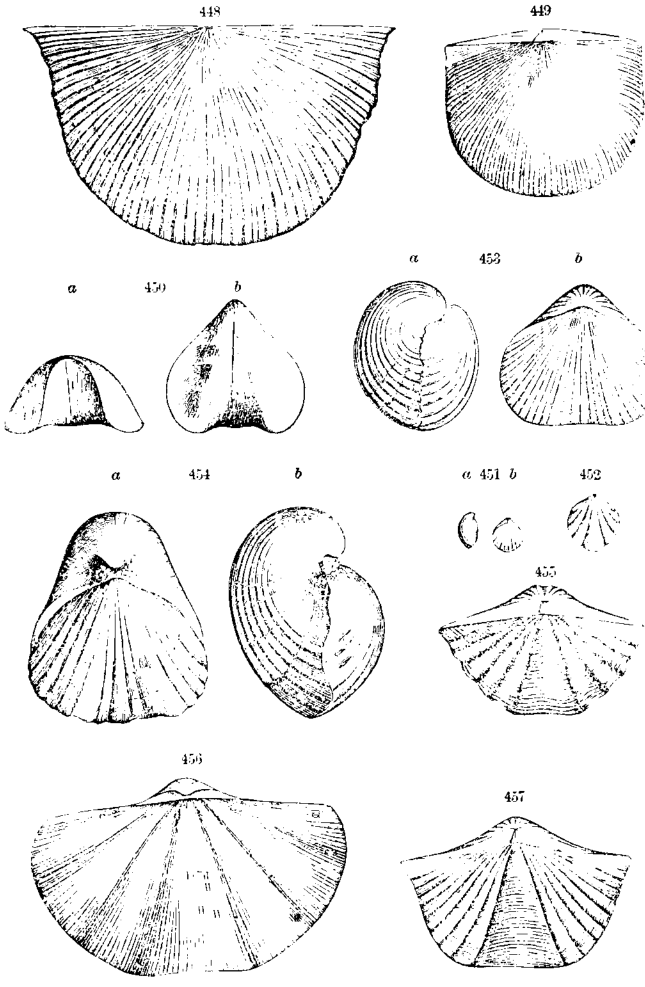
LIST OF THE GRAPTOLITIDÆ OF THE QUEBEC GROUP.

	Decade II.	
Graptolithus.	Plate.	Figure.
G. abnormis,	XI.	6
— alatus,	VI.	9
— antennarius,	XIII.	14–17
— arcuatus,	II.	6–9
— bifidus, (also III, 9, 10)	I.	16–18
— Bigsbyi,	XVI.	22–30
— bryonoides, (also III, 11, 12, and VI, 4?)	IV.	1–10
— constrictus,	I.	23–27
— crucifer,	V.	10
— denticulatus,	IV.	12–16
— extensus,	II.	10–16
— extenuatus,	I.	21, 22
— flexilis,	X.	3–9
— fructicosus, (also VI, 1–3)	V.	6–8
— Headi,	VI.	8
— indentus,	I.	20
— Logani,	IX.	1–9
— Logani var.	XI.	7
— nitidus,	I.	1–9
— octobrachiatus, (also VIII, 1–4)	VII.	1–7
— octonarius,	X.	1–2
— patulus,	I.	10–15
— pennatulus,	III.	1–8
— pristiniformis,	XIII.	11–13
— quadribrachiatus, (also VI, 6, 7)	V.	1–5
— ramulus,	XII.	9, 10
— Richardsoni,	XII.	1–8
— rigidus,	XI.	1–5
— similis,	II.	1–5
Retiolites.		
R. ensiformis,	XIV.	1–5
Retiograptus.		
R. tentaculatus,	XIV.	6–8
Phyllograptus.		
P. angustifolius,	XVI.	17–21
— Anna,	XVI.	11–16
— ilicifolius,	XVI.	1–10
— typus,	XV.	1–12
Dendrograptus.		
D. diffusus,	XVIII.	1–3
— divergens,	XVII.	3–4
— erectus,	XVII.	7

GRAPTOLITIDÆ OF THE QUEBEC GROUP.—*Continued.*

	Decade II.	
Callograptus.	Plate.	Figure.
C. elegans,	XIX.	5–8
— Salteri,	XIX.	1–4
Dictyonema.		
D. irregularis,	XX.	1, 2
— quadrangularis,	XX.	5
— Murrayi,	XX.	6, 7
— robusta,	XX.	3, 4
Ptilograptus.		
P. Geinitzianus,	XXI.	5–8
— plumosus,	XXI.	1–4
Thamnograptus.		
T. Anna,	XXI.	9

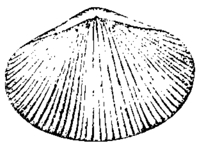
FOSSILS OF THE LOWER HELDERBERG GROUP.



448.—*Strophomena punctulifera* (Conrad); dorsal view.
449.—*Streptorhynchus Woodworthana* (Hall); dorsal view.
450.—*Eatonia peculiaris* (Conrad); *a*, front, and *b*, ventral view.
451.—*Leptocœlia concava* (Hall); *a*, dorsal, and *b*, side view.
452.—*L.* ——— *imbricata* (Hall); dorsal view.
453.—*Pentamerus Verneuilli* (Hall); *a*, dorsal, and *b*, side view.

FOSSILS OF THE LOWER HELDERBERG GROUP.—*Continued.*

458



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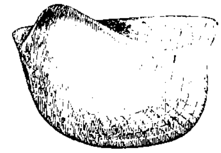

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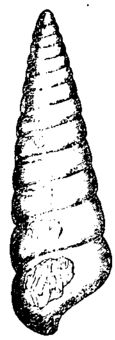

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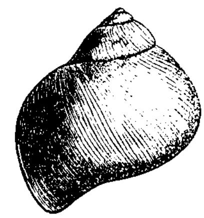
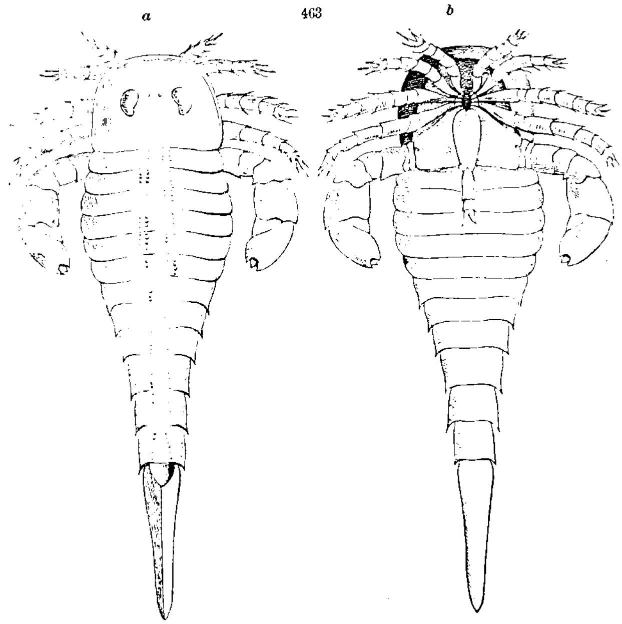
462



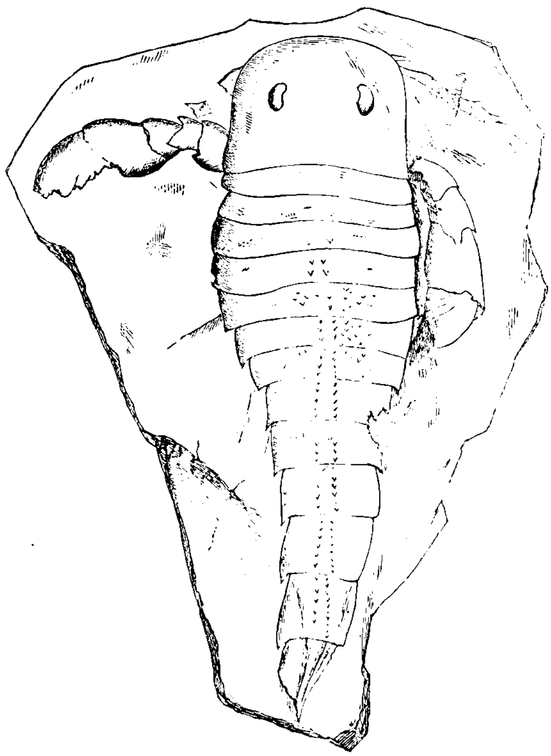
a 463 *b*



458.—*Retzia multistriata* (Hall) ; dorsal view.
459.—*Avicula naviformis* (Conrad) ; left valve.
460.—*Loxonema compacta* (Hall).
461.—*Platyceras ventricosum* (Hall).
462.—*Holopea elegans* (Hall).
463.—*Eurypterus remipes* (Dekay), as restored by Hall ; *a*, upper side, and *b*, under side ; from the water limestone.

FOSSIL OF THE WATER LIMESTONE.

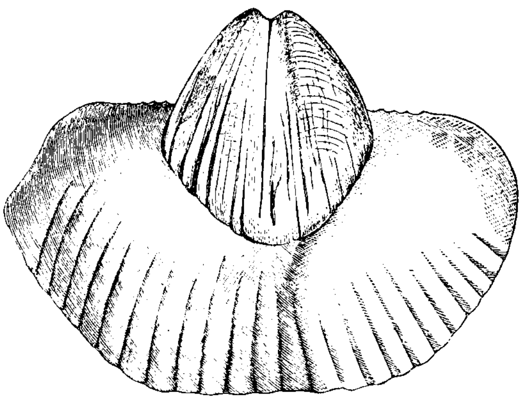
464



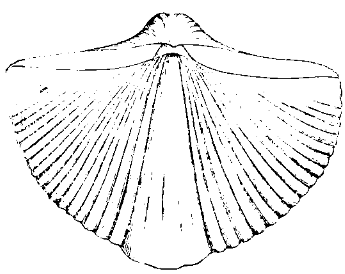
464.—*Eurypterus remipes* (Dekay) ; specimen from Canada West, natural size.

FOSSILS OF THE ORISKANY FORMATION.

465 *b*



465 *a*



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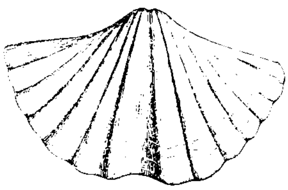

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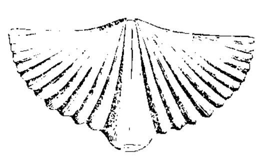


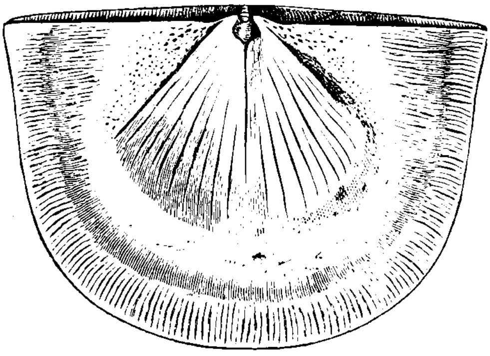
465.—*Spirifera arenosa* (Conrad); *a*, dorsal view; *b*, cast of interior of ventral valve.

466.—*S.* —— *arrecta* (Hall); ventral view.

467.—*S.* —— *varicosa* (Hall); dorsal view.

FOSSILS OF THE ORISKANY FORMATION.—*Continued.*

468



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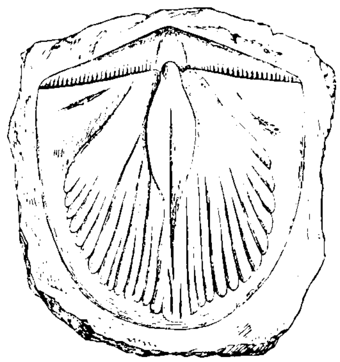

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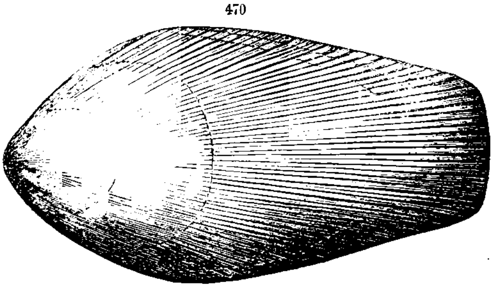
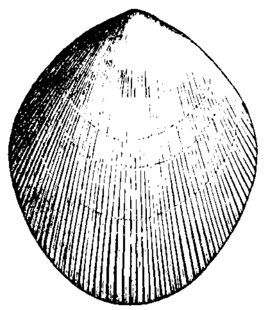


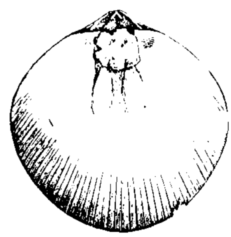
468.—*Strophomena magnifica* (Hall); cast of interior of ventral valve.
469.—*S.* ——— *magniventra* (Hall); cast of interior of ventral valve.
470.—*Rensselæria ovoides* (Eaton); ventral valve.

FOSSILS OF THE ORISKANY FORMATION.—*Continued.*

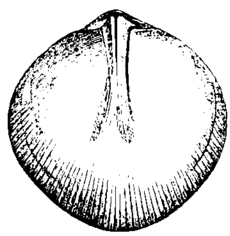
471 *a*



471 *c*



471 *b*



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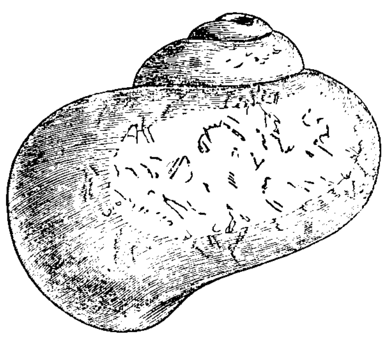
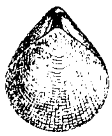


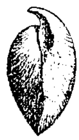
471.—*Rensselæria ovalis* (Hall); *a*, ventral valve; *b*, cast of interior of ventral valve; *c*, cast of interior of dorsal valve.

472.—*Platyostoma ventricosa* (Conrad).

FOSSILS OF THE POST-TERTIARY ; CHAMPLAIN CLAYS.

a 473 b





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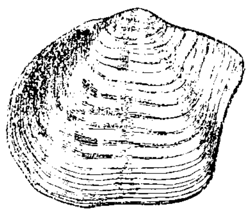
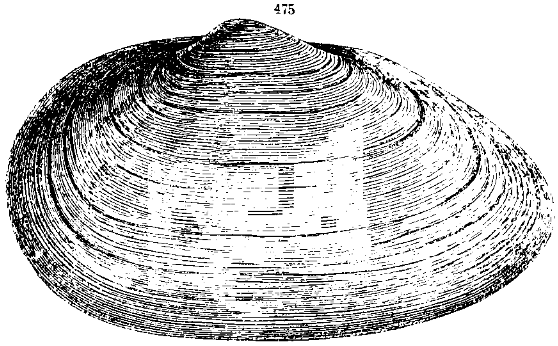


475 a

475



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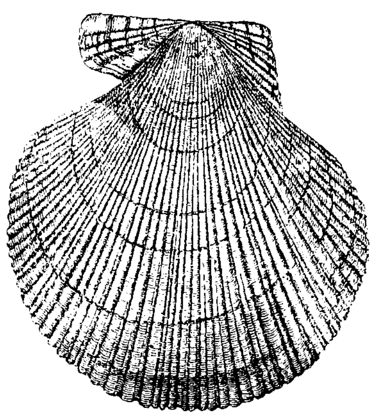

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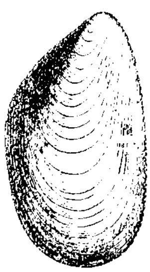

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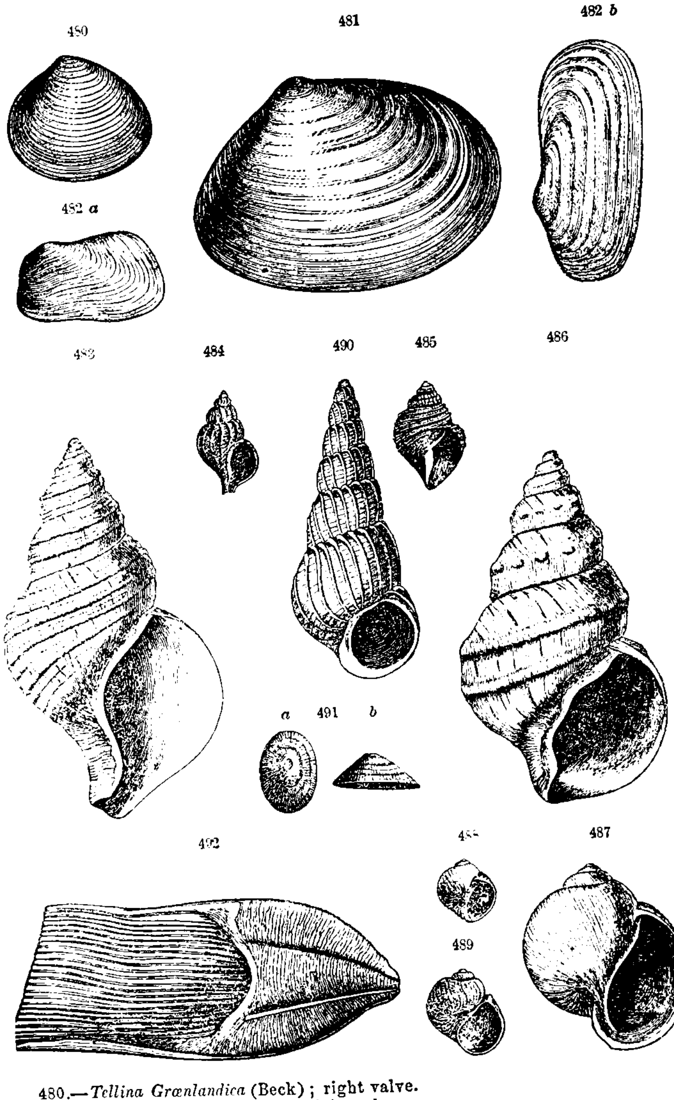
479

473.—*Rhynchonella psittacea* (Linn.) ; *a*, dorsal, and *b*, side view.
474.—*Mya truncata* (Linn.) ; left valve.
475.—*M.— arenaria* (Linn.) ; left valve ; *a*, portion of the hinge.
476.—*Pecten Islandicus* (Muller) ; left valve.
477.—*Mytilus edulis* (Linn) ; right valve.
478.—*Leda truncata* (Gould) ; right valve.
479.—*Astarte Laurentina* (Lyell) ; left valve.

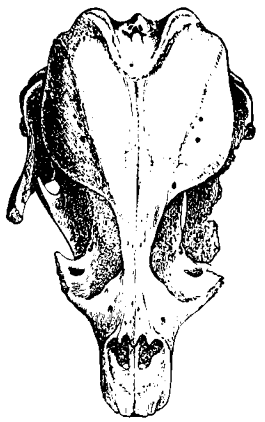
FOSSILS OF THE POST-TERTIARY; CHAMPLAIN CLAYS.—*Continued.*



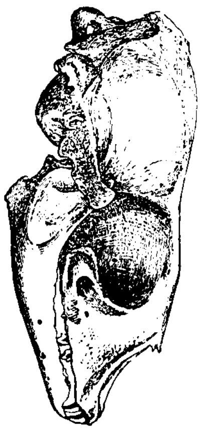
480.—*Tellina Grœnlandica* (Beck); right valve.
481.—*T.* —— *proxima* (Brown); right valve.
482.—*Saxicava rugosa* (Linn.); left valve; *a* and *b*, showing varieties.
483.—*Fusus tornatus* (Gould).
484.—*Trophon scalariforme* (Gould).
485.—*Trichotropis borealis* (Sowerby).
486.—*Buccinum undatum* (Linn.).
487.—*Natica clausa* (Sowerby).
488.—*Natica Grœnlandica* (Müll).
489.—*N.* —— *helicoides* (Johnston).
490.—*Scalaria Grœnlandica* (Perry).
491.—*Acmæa cœca* (Müll.); *a*, *b*, diff. views.
492.—*Balanus Hameri* (Ascanius).

FOSSILS OF THE POST-TERTIARY; CHAMPLAIN CLAYS.—*Continued.*

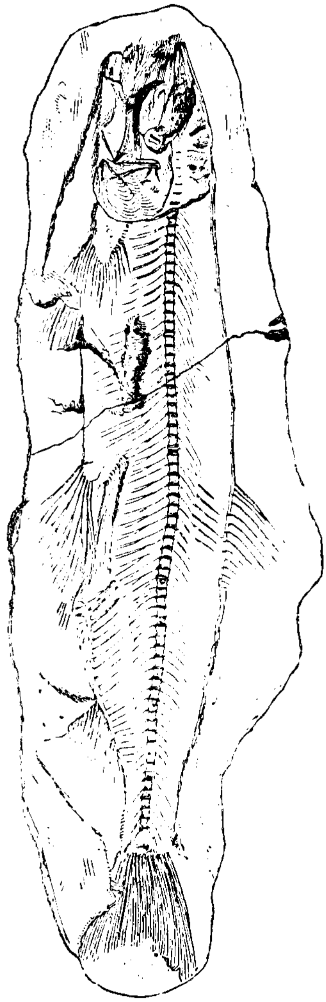
493 *a*



493 *b*



494

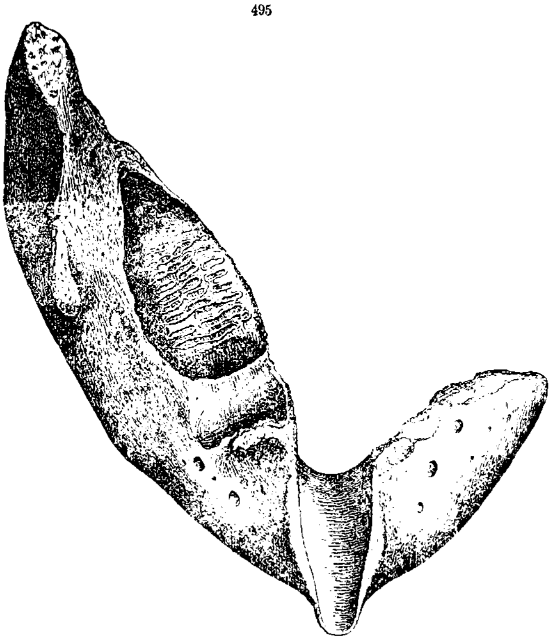


493.—*Phoca Grœnlandica* (Müller); *a* and *b*, two views of the skull, one third of the natural size.

494.—*Mallotus villosus* (Cuvier), natural size.

FOSSILS OF THE POST-TERTIARY DEPOSITS

495



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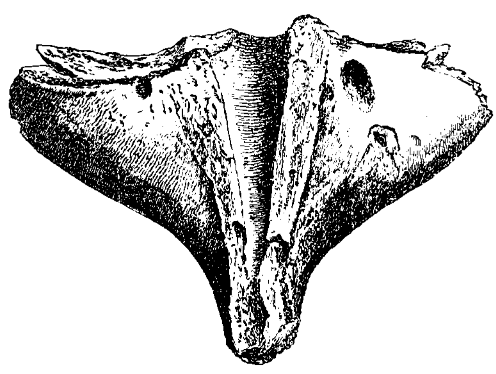
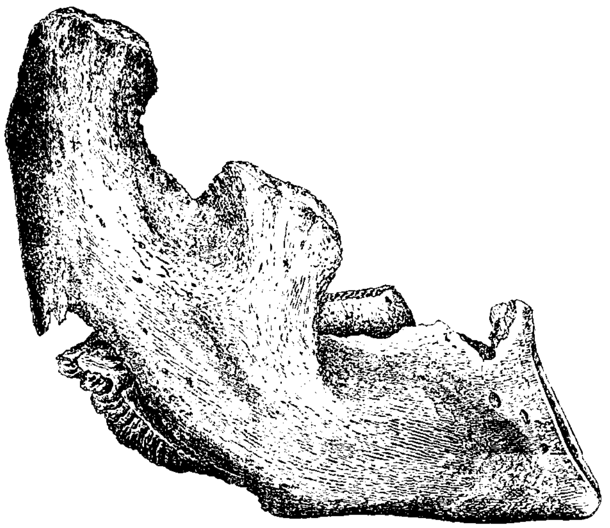


495.—*Euelephas Jacksoni* (Briggs and Foster) ; right ramus and symphysis, with a molar in place; about one sixth of the natural size.

496.—Upper side of symphysis of another individual, with the elevated margins of the gutter broken away; one third of the natural size. Both of these specimens are from Hamilton.

FOSSILS OF THE POST-TERTIARY DEPOSITS.—*Continued.*

497



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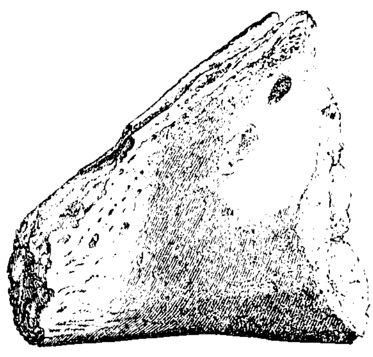

497.—*Euelephas Jacksoni* (Briggs and Foster); side view of the specimen represented in Fig. 495.

498.—Side view of the specimen represented in Fig. 496.

INDEX OF SUBJECTS.*

* Under the head of Mineral Species, pages 973-975, will be found an alphabetical list of the minerals noticed in this volume.

INDEX OF PLACES.