ACADIAN GEOLOGY:

AN ACCOUNT OF THE

GEOLOGICAL STRUCTURE AND MINERAL RESOURCES

OF

NOVA SCOTIA,

AND PORTIONS OF THE NEIGHBOURING PROVINCES
OF BRITISH AMERICA.

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TO SIR CHARLES LYELL, F.R.S., F.G.S., &c.

MY DEAR SIR,

To a young naturalist labouring in a comparatively remote and isolated position, no aid can be more valuable than the encouragement and co-operation of those who, from the vantage-ground of a high scientific reputation, and in the great literary centre of the Anglo-Saxon world, are prosecuting similar pursuits. For such benefits, most freely and generously bestowed, I am indebted to you; and I gladly avail myself of the opportunity afforded by the publication of this volume, to express, in dedicating it to you, my grateful sense of your kindness in guiding my humble efforts as a geological observer.

I am,

With sincere gratitude and respect,

Yours faithfully,

J. W. DAWSON.

PREFACE.

THIS work is intended to place within the reach of the people of the districts to which it relates, a popular account of the more recent discoveries in the geology and mineral resources of their country, and at the same time to give to geologists in Britain and America, a connected view of the structure of a very interesting portion of the American continent. The author has therefore endeavoured to be sufficiently elementary and practical for his readers in the colonies, and at the same time sufficiently accurate and original to do some service to general geology. In extenuation of his short-comings in the attainment of either or both of these ends, he must plead the difficulty of securing this double utility, and the disadvantages incident to the preparation of the work at a distance from large public collections and libraries of reference.

The geological map, though much more perfect than any previously published, must be viewed as merely a rough approximation to the truth. For aid in completing the map of Cape Breton, the author is indebted to Richard Brown, Esq. of Sydney; and for the boundaries of formations in New Brunswick, to the map prepared by Professor Robb of Fredericton for Johnston's Agricultural Report on that province. For the limits of formations in Nova Scotia Proper, he has trusted entirely to his own notes.

Several of the illustrations have been reprinted, by permission of the Council of the Geological Society of London, from the author's papers in their journal, and are credited accordingly in the list of illustrations.

PICTOU, March 1855.

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CHAPTER I.

INTRODUCTION—GEOLOGICAL BIBLIOGRAPHY OF NOVA SCOTIA, &c.

The aboriginal Micmacs of Nova Scotia, being of a practical turn of mind, were in the habit of bestowing on places the names of the useful articles which could be found in them, affixing to such terms the word *Acadie*, denoting the local abundance of the particular objects to which the names referred. The early French settlers appear to have supposed this common termination to be the proper name of the country, and applied it as the general designation of the region now constituting the provinces of Nova Scotia, New Brunswick, and Prince Edward Island; which still retain Acadia as their poetical appellation, and as a convenient general term for the Lower Provinces of British America as distinguished from Canada. Hence the title Acadian Geology is appropriate to this work, not only because that name was first bestowed on Nova Scotia, but because the structure of this province, as exposed in its excellent coast sections, furnishes a key to that of the neighbouring regions, which I have endeavoured to apply to such portions of them as I have explored. This title is farther justified by the circumstance that the Acadian provinces form a well-marked geological district, distinguished from all the neighbouring parts of America by the enormous and remarkable development within it of rocks of the Carboniferous and New Red Sandstone systems.

Nova Scotia, unlike the greater number of the states and provinces of North America, has not enjoyed the benefit of a public geological survey. Yet, though destitute of this great aid to progress, and regarded as one of the more obscure and insignificant dependencies of the British crown, its mineral resources have been very extensively developed by mining enterprise, its structure has been somewhat minutely examined, and it has afforded some very important contributions to our knowledge of the earth's geological history. Circumstances of a political character, rather than any want of liberality or scientific zeal on the part of the people, have prevented a systematic exploration of the country at the public expense, while the possession of useful minerals deficient in all the neighbouring regions, has made it of necessity one of the most important mining districts in North America. Unfortunately, in one sense, for the colony, its abundant mineral wealth attracted attention at a period when the government of the mother country was not actuated by the liberal spirit that now characterizes its dealings with its dependencies, and when the rights of the colonists were not so jealously or ably guarded as at present. The valuable minerals were reserved by the crown, and were leased to an association of British capitalists, who have opened the principal deposits of coal, and largely exported their produce, and some of whose agents have zealously and successfully aided in exploring the geology of the country. The provincial legislature, however, has evinced a very natural disinclination to expend the public money in the examination of deposits in which its constituents have no direct interest, and which continue to be a fertile subject of controversy with the mining company and the imperial government.

It is to be hoped that these impediments to public action on the subject of geological exploration will soon pass away. Arrangements have been entered into between the province and the mother country, in virtue of which the control of the mines will revert to the former on the expiry of the lease, thirty-two years hence. A recent act of the legislature has empowered the provincial government to grant leases of unopened mines to private speculators. Extensive railway enterprises have been undertaken, which will open up the inland mineral districts. Valuable metallic minerals have been discovered in localities which have escaped the reservation; and negotiations have been commenced with the mining company for the purchase of the unopened coal mines. In all these facts there is promise that the provincial government will soon find itself in a position to institute a scientific investigation of the structure and productions of the country, and it is to be hoped that this will be done by competent persons and on a liberal scale; and not, as has been the case in some neighbouring colonies, in a manner too imperfect to afford trustworthy results. The excellent survey of Canada now in progress under Mr Logan, should be a model to the other provinces in this respect.

In the mean time Nova Scotia may congratulate herself, that the noble monuments of the earth's geological history exposed in her coast cliffs have induced eminent geologists from abroad to occupy themselves with the more interesting parts of the structure of the province, and have cherished a strong taste for geological inquiry among her own sons; and that much has thus been effected as a labour of love, which in other countries would have cost a large expenditure of the public wealth. Much, no doubt, still remains to be done, especially in those districts less fertile in facts interesting to the naturalist; but a glance at the list of publications in the following pages, is sufficient to show how much labour has been voluntarily and gratuitously expended, as well as the importance and interest of the discoveries that have been made.

Though, however, a large amount of valuable information has been accumulated, it is scattered through the numbers of scientific journals and other publications, inaccessible to the general reader, and not easily referred to by the geological student; and it is in its nature fragmentary, and incapable of affording a complete view of the structure of the country. These considerations, and the possession of a mass of unpublished notes which have been accumulating for the last fourteen years, have induced the author to undertake the present work; and he trusts that in doing so he will render an acceptable service not only to his own countrymen and to the inhabitants of the other Acadian provinces, but to those geologists in Britain and America who may be acquainted with his published papers, and may desire a more complete acquaintance with Acadian geology.

The earliest account of the geology of Nova Scotia with which I am acquainted, is contained in an elaborate paper in Silliman's Journal for 1828, by C. T. Jackson and F. Alger, Esqs., gentlemen who have since established for themselves a distinguished reputation. Messrs Jackson and Alger directed their attention principally to the trap and red sandstone formations of the western districts, and the interesting crystallized minerals contained in the former; but they also gave a tolerably correct view of the distribution of the principal rock formations throughout the province, and made the earliest attempt to represent them on a geological map. Their determinations of the minerals of the trap district are accurate, and their catalogue of these minerals still admits of scarcely any extension. This paper was published in a separate form in 1832.

An important addition was made to the geology of the province in 1829, in a chapter contributed to Haliburton's History of Nova Scotia, by Messrs Brown and Smith, then exploring the province on behalf of the General Mining Association; and the former of whom has subsequently been one of the most successful investigators of the geology of the coal formation. The article in Haliburton relates principally to the eastern districts; and is chiefly remarkable as containing the most accurate views of the development of the carboniferous system in Nova Scotia, promulgated previously to the visit of Sir Charles Lyell in 1842.

In 1836, a volume, entitled "Remarks on the Geology and Mineralogy of Nova Scotia, by A. Gesner, Esq.," was published and extensively circulated in the province, and it is still from this work that a great portion of the local public derive their ideas of the geological structure of the country. This work was in great part a popular *resumé* of the previously published discoveries of Jackson and Alger, with many additional facts collected by its author in the course of careful examinations of the coasts of the Bay of Fundy, and more hurried journeys in other parts of the province. Though disfigured by some inaccuracies in nomenclature, and very deficient in information as to the arrangement and superposition of rocks, Dr Gesner's work was of great service in directing popular attention within the province to the subject of geology, and it is still an excellent guide to the localities of interesting mineral specimens.

In 1841, W. E. Logan, Esq., now provincial geologist in Canada, made a short tour in Nova Scotia, and contributed a paper on the subject to the Geological Society of London. In 1843, Mr Logan, in passing through Nova Scotia on his way to Canada, visited the South Joggins, and executed the remarkable section which he published in 1845 in his first Report on the Geology of Canada. This section, which includes detailed descriptions and measurements of more than fourteen thousand feet of beds, and occupies sixty-five octavo pages, is a remarkable monument of his industry and powers of observation, and gives a detailed view of nearly the whole thickness of the coal formation of Nova Scotia.

The year 1842 forms an epoch in the history of geology in Nova Scotia. In that year Sir Charles Lyell visited the province, and carefully examined some of the more difficult features of its geological structure, which had baffled or misled previous inquirers. Sir Charles also performed the valuable service of placing in communication with each other, and with the geologists of Great Britain, the inquirers already at work on the geology of the province, and of stimulating their activity, and directing it into the most profitable channels. The writer of the present work gratefully acknowledges his obligations in these respects. The results obtained by Sir Charles, which much modified and enlarged the views previously entertained of the structure of Nova Scotia, were communicated to the Geological Society, and a popular account of them was given in his "Travels in North America."

Since 1842, a great number of papers on the geology of Nova Scotia have been published in the scientific journals. The following list includes most of these, arranged according to their dates, and the periodicals in which they have appeared.

Papers on the Geology of Nova Scotia and New Brunswick, published in the Proceedings and Journal of the Geological Society of London.

1842–43.

1. On the upright Fossil Trees found at different levels in the Coal-strata of Nova Scotia. Lyell, Geol. Proc. iv. p. 176–178.
2. On the Coal-formation of Nova Scotia, and on the Age of the Gypsum. Lyell, *ibid.* p. 184–186.
3. A Geological Map of Nova Scotia. By A. Gesner, *ibid.* p. 186–190. 4to map.

1843–44.

4. On the Geology of Cape Breton. R. Brown, *ibid.* p. 269–272. 4 woodcuts.
5. On the Lower Carboniferous or Gypsiferous formation of Nova Scotia. J. W. Dawson, *ibid.* p. 272–281. 6 woodcuts.
6. On the Geology of Cape Breton. R. Brown, *ibid.* p. 424–430. 3 woodcuts.

7. On the Newer Coal-formation of the East part of Nova Scotia. Dawson, *ibid.* p. 504–512. 4to map, 4 woodcuts.

1846.

8. Notice of some Fossils found in the Coal-formation of Nova Scotia. Dawson, Geol. Journ. ii. p. 132–136. 1 woodcut.
9. Notes on the Fossils communicated by Mr Dawson. Bunbury, *ibid.* p. 136–139. 1 8vo plate.
10. On a group of erect Fossil Trees in the Sydney Coal-formation, Cape Breton. R. Brown, *ibid.* p. 393–396. 3 woodcuts.

1847.

11. On the Gypsiferous Strata of Cape Dauphin, Cape Breton. R. Brown, Geol. Journ. iii. p. 257–260. 2 woodcuts.
12. Description of an upright Lepidodendron, with Stigmaria-roots, Sydney, Cape Breton. R. Brown, Geol. Journ. iv. p. 46–50. 7 woodcuts.
13. On the New Red Sandstone of Nova Scotia. Dawson, *ibid.* p. 50–59. 4to map and section.

1848.

14. On the Colouring Matter of Red Sandstones, and the White Beds associated with them. Dawson, Geol. Journ. v. p. 25–30.
15. On the Gypsum of Nova Scotia. Gesner, *ibid.* pp. 129, 130. 1 woodcut.
16. Notice of the Gypsum of Plaster Cove. Dawson, *ibid.* p. 335–339. 3 woodcuts.
17. Description of erect Sigillariæ, Sydney, Cape Breton. R. Brown, *ibid.* p. 354–360. 9 woodcuts.

1849.

18. On the Lower Coal-measures of the Sydney Coal-field, Cape Breton. R. Brown, Geol. Journ. vi. p. 115–133. 9 woodcuts.
19. On the Metamorphic and Metalliferous Rocks of the East of Nova Scotia. Dawson, *ibid.* p. 347–364. 4 woodcuts.
20. Notice of the occurrence of upright Calamites, near Pictou, Nova Scotia. Dawson, Geol. Journ. vii. p. 194–196. 3 woodcuts.
21. On a Fossil Fern from Cape Breton. Bunbury, Geol. Journ. viii. p. 31–35. 1 plate.

1852.

22. Notes on the Red Sandstone of Nova Scotia. Dawson, *ibid.* p. 398–400. 2 woodcuts.
23. On the Remains of a Reptile and a Land-shell in an erect Fossil Tree in the Coal-measures of Nova Scotia. Lyell, Dawson, Wyman, and Owen, Geol. Journ. ix. p. 58–67. 3 plates, 1 woodcut.
24. On the Albert Mine, New Brunswick. Dawson, *ibid.* p. 107–115. 7 woodcuts.

1853.

25. On the Coal-measures of the South Joggins. Dawson, *ibid.* x. p. 1–42. 25 woodcuts.
26. On the Structure of the Albion Coal-measures. Dawson; with Journals of Exploratory Works, by H. Poole. *Ibid.* x. p. 42–47.
27. On a Fossil embedded in a mass of Pictou Coal. Professor Owen, *ibid.* x. pp. 207, 208. Lithographic plate.

In the Proceedings of the Royal Society of Edinburgh.

1. On the Boulder-formation and Superficial Drift of Nova Scotia. Dawson, Abstract. 1847.
2. On the Mode of Occurrence of Gypsum in Nova Scotia. Dawson, Abstract. 1847.

In the Journals of the Legislature of Nova Scotia.

1. Reports of the Committee on Mines.
2. Report on the Coal-fields of Caribou Cove and River Inhabitants. Dawson, 1846.

Notices of the Geology of Nova Scotia have also appeared in Gesner's Industrial Resources of Nova Scotia, Taylor's Statistics of Coal, Marcou's Geological Map of the United States and British Provinces, and Dawson's Handbook of the Geography and Natural History of Nova Scotia.

As portions of New Brunswick and Prince Edward Island are described in this work, I may mention the principal publications on the Geology of those Provinces.

Gesner's Geological Survey of New Brunswick. 1839–1843.

Dr Robb's Notices of the Geology of New Brunswick in Johnston's Report. 1849.

Jackson's Report on the Albert Coal Mine (New Brunswick). 1851.

Deposition of R. C. Taylor, &c., on the Albert Mine. 1851.

Perley's Handbook for Emigrants. 1854.

Geological Excursion in Prince Edward Island. Dawson, Haszard's Gazette. 1842.

Gesner's Report on the Geology of Prince Edward Island. 1846.

Leidy on *Bathygnathus Borealis*, an extinct Saurian of the New Red Sandstone of Prince Edward Island. 1854.

Several other papers, on the geology of Nova Scotia and the neighbouring provinces, of minor importance, or to which I have not now the means of reference, have been published, especially in the American journals.

It will be seen that large materials exist for a mere compilation on the subject of this work. I shall, however, endeavour to confine myself as far as possible to original facts, of course giving due credit to my fellow-labourers, where it may be necessary to refer to their publications, for materials to supplement my own notes. I may also state here, that, in addition to unpublished materials, this work is intended to give in a popular form the substance of my printed papers; but the matter of these has not been transferred to the following pages, except in a few cases where lists of beds and descriptions of sections admitted of no variation in terms. The reader desirous of farther information may therefore consult with profit all the papers in the above list, for the more full and technical discussion of the points to which they relate, as well as for detailed descriptions and figures of many fossils merely noticed in this work.

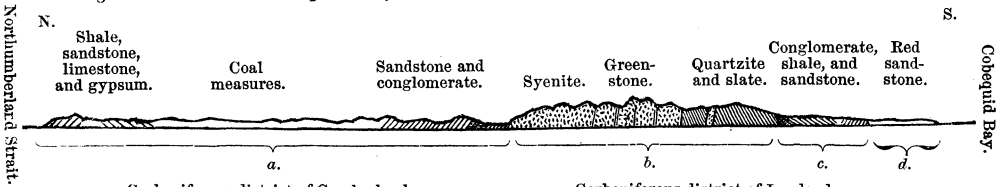
CHAPTER II.

GENERAL DESCRIPTION OF NOVA SCOTIA—TABULAR ARRANGEMENT OF FORMATIONS.

Let the reader glance at the map, and he will readily perceive some of the principal physical features of the region we have to describe. It consists of a peninsula and island, situated between north latitude 43° 25′ and 47°, and between west longitude 59° 40′ and 66° 25′; and bounded on the south-eastern side by the Atlantic, and on the western and northern sides by the Bay of Fundy, New Brunswick, and the Gulf of St Lawrence. The peninsular part, Nova Scotia Proper, is 250 miles in length, and about 100 in its extreme breadth, and is attached to the mainland of North America by a low isthmus sixteen miles in width. Its form is nearly triangular, and its surface is occupied by several rock formations, arranged for the most part in lines corresponding with its longest or Atlantic coast line. The insular part, Cape Breton, barely separated from the mainland by the narrow strait of Canseau, is 100 miles in extreme length and eighty in breadth; and its rock

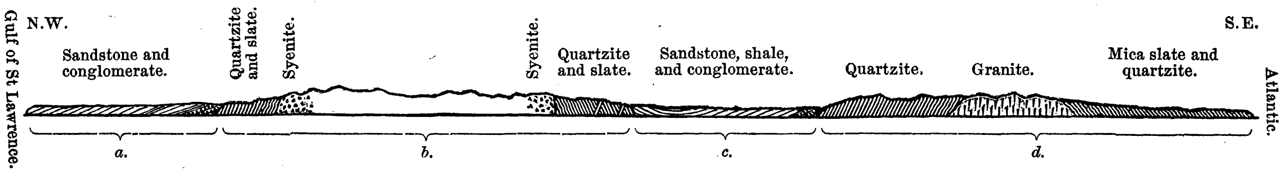
GENERAL SECTIONS ILLUSTRATIVE OF THE ARRANGEMENT OF ROCK FORMATIONS IN NOVA SCOTIA.

Fig. 1.—*Section across the Cobequid Hills from the Mouth of Great Village River to Pugwash.—Distance* 20 *miles.*



a. Carboniferous district of Cumberland.
b. Metamorphic band of the Cobequid Hills.
c. Carboniferous district of Londonderry.
d. New red sandstone of Londonderry.

Fig. 2.—*Section from the Mouth of St Mary's River to the Mouth of Barney's River.—Distance* 50 *miles.*



a. Lower carboniferous beds of the eastern extremity of the Pictou carboniferous district.
b. Syenitic-metamorphic district of Merigomish Hills and East Branch of St Mary's River.
c. Carboniferous valley, extending along West Branch of St Mary's River.
d. Granitic-metamorphic band of Atlantic coast.

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formations are similar to those of Nova Scotia Proper, though more irregularly distributed.

The three sides of the triangle formed by Nova Scotia Proper, are, as seen on the map, distinguished by marked differences of outline. That fronting the north-west is deeply indented by large arms of the sea, separated by precipitous promontories. The longest side, that facing the Atlantic, is dotted with innumerable islands, and penetrated everywhere by small inlets and indentations. The northern shore, fronting the Gulf of St Lawrence, is comparatively smooth and uniform in its coast-lines. This is also the character of the eastern coast of Cape Breton; while its remaining sides are very irregular, and its interior is occupied by a lake-like arm of the sea, which, but for the isthmus of St Peter's less than a mile in width, would cut it into two parts.

It will be observed that the characters of these several coast-lines, as well as the different physical districts of the province, are well marked by the arrangement of the tints which distinguish the different geological formations. The boundaries of these often coincide with those of ranges of hills, and the general direction both of the hills and lines of rock-formation is N. E. and S. W., which is the prevailing direction of the structure of the whole eastern part of North America. The whole contour of the country indeed, as well as the directions of its coasts, rivers, and hills, depends on the nature and arrangement of its rocks, and on the elevatory movements to which they have been subjected. The former determine the minor details of the surface and the coast lines: the latter, the elevation and distribution of the rocky masses on the great scale. For illustrations of this, I may refer the reader to the two general sections prefixed to this chapter, in connexion with the following explanation of the colours on the map.

The carmine and purple portions of the map, representing the oldest rocks in the province—rocks partly ejected in a molten state from the interior of the earth, and partly metamorphosed or altered by heat, extend in an unbroken band along the whole Atlantic coast; wide at its western end, and tapering to a point in the eastern. This belt of country is in some parts low, rugged, and broken, and in others boldly undulating. It is traversed by many rocky ridges, and abounds in lakes, bogs, and streams. Its soils are often sterile and stony, though it has also large tracts of fertile soil, supporting noble forests, and fine agricultural settlements. Its maritime situation and numerous harbours, have made it the abode of a large fishing and trading population; and these advantages have also given to it the capital of the province, and several of the most prosperous towns and villages. This district is low at the Atlantic coast, and gradually rises to the height of a few hundreds of feet at its northern limit, where it descends somewhat suddenly to the level of the inland valleys, which in the greater part of its length separate it from the district next to be mentioned.

The very irregular bands and patches, coloured blue, with deep carmine lines and spots, also consist of altered rocks, with others of igneous origin, poured through them from beneath; but the whole of somewhat later age than the rocks of the Atlantic coast. This district consists in great part of elevated ridges. It includes the highest and most continuous hills in the province, none of which, however, exceed 1200 feet in height, and the sources of all the principal rivers. Its hills are covered with fertile soil, and in their natural state support some of the finest forests in the country; and it includes valuable deposits of metallic minerals. Its deep ravines, cascades, and fine wood-clothed precipices, afford the nearest approach to picturesque mountain scenery that a country so little elevated as Nova Scotia can boast.

The portions coloured yellow and red represent low and undulating districts, stretching in plains or narrow valleys between and into the higher lands already described. The larger of these, that coloured yellow, is the great carboniferous district, including all the valuable deposits of coal, freestone, grindstone, gypsum, and limestone, and having fertile soils over the greater part of its surface. It is, therefore, the principal abode of the mining, quarrying, and agricultural population. The red district, which is of comparatively small dimensions, represents the New Red Sandstone, a later formation covered by light and productive soil, and containing some of the oldest and finest agricultural settlements.

The long green band, extending along the hilly district on the south coast of the Bay of Fundy, and the isolated patches of the same colour on the opposite side of Minas Channel and Basin, are the most recent rocks in Nova Scotia, being masses of volcanic origin which have been poured through the New Red Sandstone formation. They constitute marked and picturesque features in the scenery of the western counties, and along their flanks and on their summits afford fertile soils and support valuable forests.

Lastly, the recent alluvium produced by the tides of the Bay of Fundy, and forming marsh soils of almost inexhaustible fertility, is represented by certain limited stripes and patches of a brown colour.

While, however, each of the geological formations which appear on the map, has its special influence on the contour, coast-outlines, scenery, and industrial resources of the country, there is a great variety of minor differences within each; for a geological formation, though it often includes a group of rocks characterized merely as rocks by many features in common, is distinguished from others, not so much on this ground, as by the period when it was formed, and the fossils characteristic of that period which it contains; consequently we shall often find very dissimilar conditions and mineral productions in neighbouring parts of the same geological district.

Such being the general physical features of Nova Scotia, it belongs to us, as geologists, to inquire into the structure of its different rock-formations, the various materials of which they are composed, the manner in which they were formed, the periods of the earth's history in which they were produced, and the evidences they afford of the condition of the earth in those periods, the fossils which are embedded in them, and the useful minerals which they contain. No farther introduction will be required to enable the non-geological reader to understand the conclusions arrived at on these subjects, as well as in some degree the manner in which geologists reach these conclusions. Nature, when carefully examined and minutely described, is her own best interpreter; and I have endeavoured so to arrange the subjects treated of, as to lead gradually from those modern causes and changes with which nearly all are familiar, to the more ancient natural processes and events, which can be understood only by calling the modern conditions of the earth's surface as witnesses to prove the nature and origin of their predecessors. Fortunately Nova Scotia affords in its modern deposits many remarkable parallels to the conditions evidenced by its rock-formations; and when we fail to discover such analogies within the province, they can generally be obtained by a reference to other countries with which the greater number of intelligent persons are familiar. Should any farther aid be required, it may be obtained by a reference to any of those elementary geological works which are now so numerous and accessible. For these reasons, I shall not detain the reader with any geological information of a general character, other than that contained in the following table, which shows the formations already noticed in connexion with the map and sections, in their relation to the complete geological series, as represented in the rocks of Britain and those of the great mainland of North America.

Tabular View of Rock Formations in Nova Scotia, compared with those of England, the United States, and Canada.

Systems or Groups of Formations.	Names and Localities in England, United States, and Canada.	Names and Localities in Nova Scotia, &c.
I. MODERN AND POST TERTIARY.		
Modern.	Peat Mosses, Shell Marls, Estuary Deposits and Deltas, River Alluvia.	Peat Bogs and Savannahs, River Intervales, Marshes.

Post-Pliocene.	Superficial gravels and Raised Beaches.	Gravel ridges and mounds.

II. TERTIARY.

Newer Pliocene.	Boulder-formation, Cavern deposits, Upper Crag, England. Boulder-formation, United States.	Boulder-formation or drift.
Older Pliocene.	Lower Crag, England. Tertiary Clay and Sand of North Carolina, Maryland, &c.	Not found in Nova Scotia.
Miocene.	Tertiary Clays and Sands of North Carolina, Maryland, New York, Massachusetts, &c.	Not found in Nova Scotia.
Eocene.	Bagshot beds, London Clay, &c. Green Sands and Marls of Maryland and Virginia. Limestones & Clays of Carolinas, Georgia, &c.	Not found in Nova Scotia.

III. SECONDARY OR MESOZOIC.

Cretaceous.	Chalk, Greensand, Kentish Rag, &c., England. Yellow Limestone and Greensand of New Jersey, &c.	Not found in Nova Scotia.
Wealden.	Weald Clays and Limestone, Hastings Sand, Purbeck beds, England.	Not found in Nova Scotia.
Oolite.	Portland beds, Kimmeridge Clay, Coral rag, Oxford Clay, Cornbrash, Great Oolite and Stonesfield Slate, Fuller's Earth, Inferior Oolite, England.	Not found in Nova Scotia.
Lias.	Argillaceous Limestone, Marl and Clay of Lyme Regis, &c., England. Sandstone, Shale & Coal of Richmond, Virginia.	Not found in Nova Scotia.
Trias.	Upper New Red Sandstone, England. New Red Sandstone of Connecticut, &c.?	New Red Sandstone of Nova Scotia and Prince Edward Island?

IV. PRIMARY OR PALAEOZOIC.

Permian.	Magnesian Limestone and Lower New Red Sandstone, England. New Red Sandstone of Connecticut, &c.?	New Red Sandstone of Nova Scotia and Prince Edward Island, if not belonging to group above.
Carboniferous.	Coal Measures, Millstone Grit and Carboniferous or Mountain Limestone, England. Coal Measures and Lower Carboniferous Limestone, Sandstone & Conglomerate of Pennsylvania, Virginia, Ohio, Illinois, &c.	Upper & Middle Coal-formation, & Lower Carboniferous Limestone, Gypsum, Marl, Sandstone, & Conglomerate of Nova Scotia & Cape Breton
Devonian.	Old Red Sandstone, and Slaty and Calciferous rocks of South Devon, England. Old Red Sandstone, Chemung group, Portage group, Genesee Slate, Tully Limestone, Hamilton group, Marcellus Slate, Corniferous Limestone, Onondaga Limestone, Schoharie	Fossiliferous Slates of Bear River, Nictau, New Canaan, Pictou, Arisaig, &c. Per-

	Grit, Cauda-galli Grit, Oriskany Sandstone of New York. Upper Calcareous Schist and Sandstone of Gaspé, Lower Canada; Upper Limestone, Upper Canada.	haps also parts of the metamorphic rocks of the Cobequid and Pictou hills, &c.
Upper Silurian.	Brecon Limestone, Ludlow Limestone and Shale, Wenlock or Dudley Limestone, England. Silurian rocks of New York, &c. from the Upper Pentamerus Limestone to the Gray Sandstone, inclusive. Limestone and Schist of Gaspé (chiefly), Lower Canada.	Possibly some of the Metamorphic, non-fossiliferous rocks of Nova Scotia and Cape Breton, and perhaps some of the fossiliferous slates, the fossils of which have not yet been determined and compared.
Lower Silurian.	Caradoc Sandstones, Llandeilo Flags & Schists, England. Silurian rocks of New York from the Hudson River group to the Potsdam Sandstone, inclusive. Conglomerate Limestone, Tourette's Sandstone, Graptolite Schist, of Lower Canada.	Possibly some of the Metamorphic, non-fossiliferous rocks of Atlantic coast of Nova Scotia.

V. AZOIC.

Azoic.	Oldest Metamorphic rocks of Canada.	Possibly some of the Metamorphic, non-fossiliferous rocks of Nova Scotia and Cape Breton.

The English formations in the above Table have been taken from Lyell's Elements. Those of the United States from Marcou's Geological Map.

CHAPTER III.

MODERN ALLUVIAL DEPOSITS.

MARSHES—SUBMARINE FORESTS—INTERVALES—LAKE DEPOSITS—INFUSORIAL EARTH—LAKE MARGINS—PEAT BOGS.

THE western part of Nova Scotia presents some fine examples of *marine alluvial soils*. The tide-wave that sweeps to the north-east, along the Atlantic coast of the United States, entering the funnel-like mouth of the Bay of Fundy, becomes compressed and elevated, as the sides of the bay gradually approach each other, until in the narrower parts the water runs at the rate of six or seven miles per hour, and the vertical rise of the tide amounts to sixty feet or more. In Cobequid and Chiegnecto Bays, these tides, to an unaccustomed spectator, have rather the aspect of some rare convulsion of nature than of an ordinary daily phenomenon. At low tide, wide flats of brown mud are seen to extend for miles, as if the sea had altogether retired from its bed; and the distant channel appears as a mere stripe of muddy water. At the commencement of flood, a slight ripple is seen to break over the edge of the flats. It rushes swiftly forward, and, covering the lower flats almost instantaneously, gains rapidly on the higher swells of mud, which appear as if they were being dissolved in the turbid waters. At the same time the torrent of red water enters all the channels, creeks, and estuaries; surging, whirling, and foaming, and often having in its front a white, breaking wave, or " bore," which runs steadily forward, meeting and swallowing up the remains of the ebb still trickling down the channels. The mud flats are soon covered, and then, as the stranger sees the water gaining with noiseless and steady rapidity on the steep sides of banks and cliffs, a sense of insecurity creeps over him, as if no limit could be set to the advancing deluge. In a little time, however, he sees that the fiat, " hitherto shalt thou come and no farther," has been issued to the great bay tide: its retreat commences, and the waters rush back as rapidly as they entered.

The rising tide sweeps away the fine material from every exposed bank and cliff, and becomes loaded with mud and extremely fine sand, which, as it stagnates at high water, it deposits in a thin layer on the surface of the flats. This layer, which may vary in thickness from a quarter of an inch to a quarter of a line, is coarser and thicker at the outer edge of the flats than nearer the shore; and hence these flats, as well as the marshes, are usually higher near the channels than at their inner edge. From the same cause, the more rapid deposition of the coarser sediment, the lower side of the layer is arenaceous, and sometimes dotted over with films of mica, while the upper side is fine and slimy, and when dry has a shining and polished surface. The falling tide has little effect on these deposits, and hence the gradual growth of the flats, until they reach such a height that they can be overflowed only by the high spring tides. They then become natural or salt marsh, covered with the coarse grasses and *carices* which grow in such places. So far the process is carried on by the hand of nature; and before the colonization of Nova Scotia, there were large tracts of this grassy alluvium to excite the wonder and delight of the first settlers on the shores of the Bay of Fundy. Man, however, carries the land-making process farther; and by diking and draining, excludes the sea water, and produces a soil capable of yielding for an indefinite period, without manure, the most valuable cultivated grains and grasses. Already there are in Nova Scotia more than forty thousand acres of diked marsh or "dike," as it is more shortly called, the average value of which cannot be estimated at less than twenty pounds currency per acre. The undiked flats, bare at low tide, are of immensely greater extent.

The differences in the nature of the deposit in different parts of the flats, already noticed, produce an important difference in the character of the marsh soils. In the higher parts of the marshes, near the channels, the soil is red and comparatively friable. In the lower parts, and especially near the edge of the upland, it passes into a gray or bluish clay called "blue dike," or, from the circumstance of its containing many vegetable fragments and fibres, "corky dike." These two varieties of marsh differ very materially in their agricultural value. It often happens, however, that in the growth of the deposit, portions of blue marsh become buried under red deposits, so that on digging, two layers or strata are found markedly different from each other in colour and other properties; and this change may be artificially produced by digging channels to admit the turbid red waters to overflow the low blue marsh.

The red marsh, though varying somewhat in quality, is the best soil in the province, and much of it compares favourably with the most celebrated alluvial soils of the old and new worlds. The following analysis of recently deposited marsh mud from Truro, will serve to show the composition of this kind of soil.

	Moisture,	·5
	Organic matter,	1·5
Soluble in Water.	Chlorine, } as common salt,	·095
	Soda, } as common salt,	·115
	Potash,	·013
	Sulphuric Acid, } as gypsum,	·073
	Lime, } as gypsum,	·061
	Alumina,	·005
	Magnesia,	·004
Soluble in Hydrochloric Acid.	Carbonate of Lime,	3·60
	Oxide of Iron,	2·74
	Alumina,	1·20
	Magnesia,	·11
	Soda and Potash,	·8
	Phosphoric Acid,	·09
	Silicious Sand (very fine),	88·00

So valuable is this soil, though nearly destitute of organic matter, that it is found profitable to cart it upon the upland as a manure. Its best varieties have now been cropped without manure for more than two centuries, without becoming unproductive; though there can be no question that under this treatment a gradual diminution of its fertility is perceptible. The weakest point of the marsh land, judging from the above analysis, is its small proportion of phosphates. It is probable, however, that this is in part compensated by the presence of fish bones and other matters of organic origin, which do not appear in an analysis. Yet I have no doubt that the cheapest manure for failing marsh will be found to be bone dust or guano, which, by supplying phosphates, will restore it nearly to its original condition. There seems no reason to suppose that a soil with the fine mixture of mineral ingredients present in the marsh mud, requires any artificial supply of ammoniacal matters. Draining is well known to be essential to the fertility of the marshes, and many valuable tracts of this land are now in an unproductive condition from its neglect. The fertility of failing marsh may also be restored by admitting the sea to cover it with a new deposit. This remedy, however, involves the loss of several crops, as some years are required to remove from the new soil its saline matter. It is, however, observed, that in some situations the newly diked marsh produces spontaneously a crop of couch grass and other upland plants, the seeds of which must have been washed into the sea by streams and deposited with the mud.

The low or inner marsh, which I have previously mentioned, under its other names of blue marsh and corky dike, is much less valuable than the red. It contains, however, much more vegetable matter, and sometimes approaches to the character of a boggy swamp; so that when a quantity of it is taken out and spread over the upland, it forms a useful manure. It emits a fetid smell when recently turned up, and the water oozing from it stains the ground of a rusty colour. It produces in its natural state crops of coarse grass, but when broken up is unproductive, with the sole exception that rank crops of oats can sometimes be obtained from it.

The chemical composition of this singular soil, so unlike the red mud from which it is produced, involves some changes which are of interest both in agriculture and geology. The red marsh derives its colour from the peroxide of iron. In the gray or blue marsh, the iron exists in the state of a sulphuret, as may easily be proved by exposing a piece of it to a red heat, when a strong sulphurous odour is exhaled, and the red colour is restored. The change is produced by the action of the animal and vegetable matters present in the mud. These in their decay have a strong affinity for oxygen, by virtue of which they decompose the sulphuric acid present in sea-water in the forms of sulphate of magnesia and sulphate of lime. The suphur thus liberated enters into combination with hydrogen, obtained from the organic matter or from water, and the product is sulphuretted hydrogen, the gas which gives to the mud its unpleasant smell. This gas, dissolved in the water which permeates the mud, enters into combination with the oxide of iron, producing a sulphuret of iron, which, with the remains of the organic matter, serves to colour the marsh blue or gray. The sulphuret of iron remains unchanged while submerged or water-soaked; but when exposed to the atmosphere, the oxygen of the air acts upon it, and it passes into sulphate of iron or green vitriol,—a substance poisonous to most cultivated crops, and which when dried or exposed to the action of alcaline substances, deposits the hydrated brown oxide of iron. Hence the bad effects of disturbing the blue marsh, and hence also the rusty colour of the water flowing from it. The remedies for this condition of the soil are draining and liming. Draining admits air and removes the saline water. Lime decomposes the sulphate of iron, and produces sulphate of lime and oxide of iron, both of which are useful substances to the farmer.

This singular and complicated series of processes, into all the details of which I have not entered, is of especial interest to the geologist, as it explains the causes which have produced the gray colour and abundance of sulphuret of iron observed in many ancient rocks, which like the blue marsh have been produced from red sediment, changed in colour by the presence of organic matter. It also explains the origin of those singular stains, which, in rocks coloured by iron, so often accompany organic remains, or testify to the former existence of those which have passed away.

Much geological interest attaches to the marine alluvium of the Bay of Fundy, from the great breadth of it laid bare at low tide, and the facilities which it in consequence affords for the study of sun-cracks, impressions of rain-drops, footprints of animals, and other appearances which we find imitated on many ancient rocks. The genuineness of these ancient traces, as well as their mode of preservation, can be illustrated and proved only by the study of modern deposits. I quote a summary of facts of this kind from a paper on rain-prints by Sir Charles Lyell, who was the first to direct attention to these phenomena as exhibited in the Bay of Fundy.*

"The sediment with which the waters are charged is extremely fine, being derived from the destruction of cliffs of red sandstone and shale, belonging chiefly to

* Journal of London Geological Society, vol. vii. p. 239.

the coal-measures. On the borders of even the smallest estuaries communicating with a bay, in which the tides rise sixty feet and upwards, large areas are laid dry for nearly a fortnight between the spring and neap tides, and the mud is then baked in summer by a hot sun, so that it becomes solidified and traversed by cracks caused by shrinkage. Portions of the hardened mud may then be taken up and removed without injury. On examining the edges of each slab, we observe numerous layers, formed by successive tides, usually very thin, sometimes only one-tenth of an inch thick,—of unequal thickness however, because, according to Dr Webster, the night-tides rising a foot higher than the day-tides, throw down more sediment. When a shower of rain falls, the highest portion of the mud-covered flat is usually too hard to receive any impressions; while that recently uncovered by the tide, near the water's edge, is too soft. Between these areas a zone occurs almost as smooth and even as a looking-glass, on which every drop forms a cavity of circular or oval form, and if the shower be transient, these pits retain their shape permanently, being dried by the sun, and being then too firm to be effaced by the action of the succeeding tide, which deposits upon them a new layer of mud. Hence we find on splitting open a slab an inch or more thick, on the upper surface of which the marks of recent rain occur, that an inferior layer, deposited perhaps ten or fourteen tides previously, exhibits on its under surface perfect casts of rain-prints which stand out in relief, the moulds of the same being seen in the layer below."

After mentioning that a continued shower of rain obliterates the more regular impressions, and produces merely a blistered or uneven surface, and describing minutely the characteristics of true rain-marks in their most perfect state, Sir Charles adds :—

"On some of the specimens the winding tubular tracks of worms are seen, which have been bored just beneath the surface. Sometimes the worms have dived beneath the surface, and then reappeared. Occasionally the same mud is traversed by the footprints of birds (*Tringa Minuta*), and of musk rats, minks, dogs, sheep, and cats. The leaves also of the elm, maple, and oak trees have been scattered by the winds over the soft mud, and having been buried under the deposits of succeeding tides, are found on dividing the layers. When the leaves themselves are removed, very faithful impressions, not only of their outline, but of their minutest veins, are left imprinted on the clay."

We have here a perfect instance in a modern deposit, of phenomena which we shall have to notice in some of the most ancient rocks; and it is only by such minute studies of existing nature, that we can hope to interpret those older appearances.

Submarine Forests.—A still more striking geological fact connected with the marshes, is the presence beneath them of stumps of trees still rooted in the soil, and other indications which prove that much if not the whole of this marine alluvium rests on what once was upland soil supporting forest trees; and that by some change of level, these ancient forests have been submerged and buried under the tidal deposits. To illustrate this, I may describe one of the best instances of these *submarine forests* with which I am acquainted. It occurs on the edge of the marsh, near the mouth of the La Planche river in Cumberland county, at the extremity of Fort

Lawrence ridge which separates the La Planche from the Missaquash; and may be well seen in the neighbourhood of a pier which has recently been erected there.

The upland of Fort Lawrence slopes gently down toward the diked marsh, on crossing which we find outside the dike a narrow space of salt marsh thinly covered with coarse grass and samphire (*Salicornia*), and at the outer edge cut away by the neap tides so as to present a perpendicular step about five feet in height. Below this is seen at low tide a sloping expanse of red mud, in places cut away into furrows by the tides, and in other places covered with patches of soft recently deposited mud. On this slope I saw impressions of rain-drops, sun-cracks, tracks of sandpipers and crows, and abundance of the shells of the little *Sanguinolaria Fusca*, a shell very common in the muddy parts of the Bay of Fundy. There were also a few long straight furrows, still quite distinct in August, but which I was informed had been ploughed by the ice in the past spring. At the distance of 326 paces from the abrupt edge of the marsh, and about 25 feet below the level of the highest tides, which here rise in all about 40 feet, I saw the first of the rooted stumps, which appear in a belt of sand, gravel and stones mixed with mud, which intervenes between the slope of mud already mentioned and the level of low tide. Beyond the stump first seen, and extending to a depth of at least 30 to 35 feet below the level of high tide, other stumps were irregularly scattered as in an open wood. The lowest stump seen was 135 paces beyond the first; and between it and the water level there was a space of 170 paces without stumps, but with scattered fragments of roots and trunks, which may have belonged to rooted trees broken up and swept away by the ice.

On digging under and around some of the stumps, they were found to be rooted in a soil having all the characters of forest soil. In one place it was a reddish sandy loam, like the ordinary upland of Fort Lawrence. In another place it was a black vegetable soil resting on a white sandy subsoil. Immediately over the soil were the remains of a layer of tough bluish clay, with a few vegetable fibres, apparently rootlets of grasses, which seemed to have been the first layer of marsh mud deposited over the upland soil. All the rootlets of the stumps were entire and covered with their bark, and the appearances were perfectly conclusive as to their being in the place of their growth.

Of thirty or forty stumps which I examined, the greater number were pine (*Pinus Strobus*), but a few were beech (*Fagus Ferruginea*); and it is worthy of note that these are trees characteristic rather of dry upland than of low or swampy ground. The pine stumps were quite sound, though somewhat softened and discoloured at the surface. The beech, on the other hand, though retaining much of the appearance of sound wood in the interior, is quite charred at the surface, and is throughout so soft and brittle that large trunks and roots can be cut through with a spade or broken with a slight blow. Owing to their softness the beech stumps are worn down almost to the level of the mud, while some of the pines project more than a foot: even these last are, however, much crushed by the pressure of the ice, which with the tides must eventually remove them. The largest stump observed was a pine two feet six inches in diameter, and showing more than two hundred annual rings of growth. I was informed by respectable and intelligent persons that similar appearances have been observed on the opposite side of the La Planche, and in various other places in Cumberland Basin. It is only, however, in places where the marsh is being cut away by the current that they can be seen, and the stumps when laid bare are soon removed by the ice. Similar beds of stumps and vegetable soil are also occasionally disclosed in digging ditches in the shallower parts of the marshes, and there appears little reason to doubt that the whole of the Cumberland marshes rest on old upland surfaces. A submerged forest is also said to appear at the mouth of the Folly River in Cobequid Bay; and peaty soils and trunks and stumps of trees are of frequent occurrence in digging in the marshes of King's and Annapolis counties. It would seem, therefore, that these appearances are somewhat general throughout the marsh country.

With respect to the age of these submerged stumps, there can be little difference of opinion. They belong to the modern period in geology; and judging from the state of preservation of the wood, after making every allowance for the preservative effect of the salt mud, not to the very oldest part of that period. Yet their antiquity is considerable. The marshes are known to have existed in their present state for two hundred and fifty years; and since these trees grew and were submerged, all the mud of the marshes must have accumulated, at least in its present position. Here then we have a modern phenomenon involving great physical changes in the relations of land and water, and rivalling some of those geological events of which we have evidence in the older rocks.

How did this change of the sea level occur? Only two causes can be assigned. It must have been either the rupture of a barrier previously excluding the sea water, or an actual sinking or subsidence of the whole of the western part of the province. The first of these suppositions is that which most readily recommends itself to the popular mind, and we have at no great distance an instance on a small scale of the effect which might be produced by the rupture of a sea barrier. At the mouth of the St John river, there is a transverse ridge of rock which obstructs the entrance of the tide and the exit of the river water. At low tide the river water falls outward over the ridge. At about half tide the water within and that without are on a level. At high tide there is a strong fall of the tide water inward. Without the barrier the tide rises from twenty to twenty-five feet; within it raises the level of the water only about four feet. Now there can be no question that if this barrier were removed, the tide would daily raise the river to a height which it now attains only in times of flood, while at low tide it would be laid dry to a great depth. If such a change had occurred at some former period, marshes might be found to exist in places which had at one time supported terrestrial plants. Against the application of this explanation, however, to the submarine forests of the Bay of Fundy, we have the great extent of the barrier required, the absence of any existing remains of it, and the great depth below high water at which the remains exist; as it is difficult to suppose that the existence of any barrier, even if it wholly excluded the tide, could produce dry upland at such a level. The effect would rather be the production of a lake, or at the utmost of a morass. For these reasons it can scarcely be supposed that any cause of this kind can apply. It only remains to believe that a subsidence has taken place over a considerable area and to a depth of about forty feet. We have no distinct evidence to show whether this has been sudden or gradual, but analogy would lead us to suppose that it was the latter.

If a gradual subsidence of this kind has occurred in times geologically modern, the question remains, has it ceased, or is the country still subsiding, as Newfoundland and the south of Sweden are supposed to be doing? There are some facts which would seem to indicate that it is. In some localities portions of marsh formerly reclaimed have been abandoned, and it is said that it is now more difficult to maintain the dikes than formerly. We may, however, readily account for all this by supposing that the mud has settled, or that the tides have increased in height or have changed in their direction, in consequence of the contraction of the channels by the diking of new portions of marsh land. We are not therefore under the necessity of arriving at the unpleasant conclusion that our fertile marshes are again settling down beneath the level of the sea, or that the waters of the bay are likely to overflow the upland farms.

I would ask the non-geological reader to pause here, to remark that, in the mud-deposits of the Bay of Fundy, we have an example of a geological formation enclosing remains and traces of several of the animals and plants now inhabiting the province or its shores; and that if in consequence of the colonization of the country, or any physical change, these creatures or any of them were to become extinct, we might find, in digging into the marshes or by examining their borders, traces of the former existence of such extinct animals or plants, just as the remains of the now extinct European beaver and Irish gigantic stag are found in the peat bogs and lake deposits of Great Britain. Farther, we have in the submarine forests the evidence of extensive changes of level; and if we suppose that by such changes occurring in the future, the marshes were to be buried under new deposits until they had been consolidated into rock by pressure, by aqueous infiltration of mineral substances, or by internal heat, and then elevated again to the surface, we should have in their hardened masses a variety of facts which if properly interpreted would throw much light on the present condition of the country. By bearing in mind these obvious conclusions, much time and perplexity may be avoided, when we arrive at the consideration of ancient formations to which changes of these kinds have actually happened.

The principal localities of diked marshes in Nova Scotia are, Chiegnecto Bay and Cumberland Basin, Cobequid Bay, Minas Basin and Annapolis Basin, all of which are parts of the Bay of Fundy. The quantity of marsh in these several places appears from the census of 1851 to be as follows:—

Chiegnecto Bay and Cumberland Basin,	16170	acres
Cobequid Bay, ...	7139	—
Minas Basin, ...	10280	—
Annapolis Basin, ...	2793	—
	36382	—

A considerable breadth of marsh on the New Brunswick side of Chiegnecto Bay, is not included in the above statement.

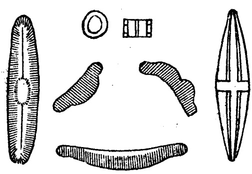
The value of the marshes in an agricultural point of view can hardly be overrated. For the maintenance of cattle and the production of butter and cheese, the marsh counties of Nova Scotia possess facilities unsurpassed and perhaps unequalled by those of any other part of North America.

The principal *Fresh-water Alluvia* are the river intervales, and the deposits forming in the beds of lakes. The intervales occur on the banks of all the streams. They usually consist of fine friable soil resting on hard gravel, and they constitute most productive land for farming purposes, while their fine elms and alder copses form most pleasing features in our river valleys. I am not aware that they present any geological features requiring detailed notice. The lake deposits must be very considerable in amount, as there is an immense number of lakes all receiving sediment from the streams which flow into them. On the most detailed maps of Nova Scotia, about 400 lakes, varying in length from half a mile to fifteen miles, may be counted, and these are but a part, perhaps not much more than half, of the whole number. The mud forming in the bottoms of these lakes must contain large quantities of the remains of fresh water fishes, shell-fish, and other animals, as well as of terrestrial quadrupeds that have been drowned in them or killed on their margins; and should these lakes be artificially drained, such remains may excite much interest. At present, however, I shall refer to only one kind of lake deposit, which is curious as an evidence of the large quantity of matter that may be accumulated by the growth and death of successive generations of creatures too small to be observed individually except by the microscope. This is the substance known to naturalists as *Infusorial earth*, and which has been found to abound not only in the deposits from modern waters, but in some ancient rocks, of which it appears indeed sometimes to form the mass. It is, as found in Nova Scotia, a white and when dry very light friable earth, having a floury texture, and showing when examined in a bright light an infinity of minute shining specks. A little of it diffused in a drop of water, and viewed through a powerful microscope, presents thousands of curiously formed cylindrical, bow-shaped, and rounded transparent bodies, which consist of pure silica or flint, and are the shells which once covered creatures belonging to a tribe of infusoria named *Bacillariæ*, which swarm in stagnant waters, and appear to occupy a place in nature on the confines of the vegetable and animal kingdoms. The shells of these creatures, mixed with a very little earthy sediment, form beds several feet in thickness in some lakes and ponds. The hardness, sharpness, and minute size of these shells render the mass composed of them useful as a polishing material; the best tripoli being in fact an earth of this description. The only specimens of infusorial earth in my possession, and found in Nova Scotia, are from the hills of Earlton and Cornwallis. That from the last named locality is the finer of the two. It was discovered by Dr Webster of Kentville. Professor Bailey of West Point, the well known microscopist, to whom I forwarded specimens from one of the above named localities, states* that the species contained in it are common to Nova Scotia and the northern parts of the United States. He mentions the following as occurring in specimens from Nova Scotia:—*Pinnularia Viridis*, *P. Inæ-*

* Silliman's Journal, vol. xlviii. Most naturalists now refer these organisms to the *Diatomaceæ*, a family of minute aquatic plants.

qualis, *Cocconema Cymbeforme*, *Gallionella Distans*, *Eunotia Monodon*, *&c.*, *Himantidium Arcus*, *Gomphonema Acuminatum*, *Surirella Splendida*, *Stauroneis Bayleii ; Spongiolites*, *&c.* Some of these species are represented in Fig. 3.

Fig. 3.



Coverings of Bacillariæ from recent Fresh-water deposits—Nova Scotia—magnified.

Lake Margins in Nova Scotia are of some geological interest, from the effects of ice-pressure which they exhibit. The expansion of the thick icy sheet which forms on the surface of our lakes in winter, and its drifting to and fro when loosened from the shores by the thaws of spring, heap up very remarkable ridges and embankments of stones, gravel, and earth. In low and muddy shores these actions of the ice, I believe principally the latter, push up long mounds, which look as if an attempt had been made to raise an artificial dike ; and where the shores consist of small stones and gravel, still more regular structures are sometimes produced. Occasionally there are two mounds, one within the other, marking different levels of the water, and I have seen these mounds still remaining, in places where lakes and ponds had been long since filled up and converted into bogs. On rocky shores, large stones are pushed against the bank and packed together until they form huge sloping Cyclopean walls, which testify not only by their mass, but by the manner in which they have been wedged together, to the force that has been applied to them. This last appearance is as well seen in some of the upper lakes of the Shubenacadie as in any others that I have examined. These modern effects of ice-pressure will serve to explain some of the phenomena of the drift or boulder formation, which overspreads the surface of the province.

Bogs and *peaty swamps* form another class of modern deposits which I may notice here. They are very numerous in Nova Scotia, especially in the rocky districts of the Atlantic coast. The largest that I have observed are the Savannahs, near Clyde river in Shelburne, and the Carriboo bog of Aylesford. With respect to the geological features of these deposits, I may notice: First, that they consist of vegetable matter which has grown on the spot, and has accumulated, because in water-soaked soils the decay of dead vegetable matter proceeds more slowly than the acquisition of new matter by growing vegetation from the air and water. Secondly, The vegetable matter in bogs, forming a black carbonaceous mass, has entered on the first stage of the changes by which it may be converted into coal; and it is not unusual to find in the bottom of such bogs a substance much resembling ordinary bituminous coal. Thirdly, The organic acids produced by the vegetable matter, when long saturated in water, remove from the subsoil of the bogs the oxides of iron and manganese, as well as lime and the other alkaline earths; hence the subsoils of bogs usually consist of bleached whitish sand or clay of a very unproductive character. There are a few exceptions to this in localities where the soil contains a very large proportion of lime. On the other hand, when the underlying rocks contain bi-sulphuret of iron, as is the case in some parts of the slate districts, the sulphuric acid produced from this mineral gives a still greater degree of acidity to the bog, while the iron is sometimes in too great quantity to be removed entirely. Fourthly, The iron and manganese, removed in the manner above mentioned, are deposited, usually in rounded kernels, at the outlets of such bogs, or in the soils through which their waters soak, and become partially exposed to the air. In this way small quantities of bog iron ore and bog manganese ore are formed in the vicinity of many swamps. All these facts respecting bogs have their analogues on a large scale in our ancient rock-formations.

The bogs when drained, and their surface dressed with sand, or sand and lime, to supply the silicious and calcareous matter in which they are deficient, are excellent soils, second only to diked marsh in their productiveness in hay and oats. Portions of bog have already been reclaimed in this way in several of the counties, and there can be no doubt that many tracts of this description, more especially in the less fertile portions of the province, require only the application of skill and industry to render them valuable.

CHAPTER IV.

THE DRIFT, DILUVIUM, OR BOULDER FORMATION.

UNSTRATIFIED DRIFT—TRAVELLED BOULDERS—STRIATED ROCK SURFACES—PEAT UNDER BOULDER CLAY—ORIGIN OF DRIFT—STRATIFIED GRAVELS—REMAINS OF MASTODON.

THE deposits last described are found in the bed or on the margin of the existing waters, and they rest on the ordinary upland soils, which are consequently older than they. These soils and subsoils, which are often of great depth, and which over a great part of the province completely hide the rocks which lie beneath, belong to the formation which we are now to describe. The soils and subsoils of any country, so far at least as they consist of mineral matter, are as a matter of course derived from the waste of the rocks of which that country is composed. Hence we are in no way surprised to find the soil overlying sandstone rocks to be sandy, that over shales and slates to consist in great part of clay, or that overlying limestone to be calcareous; and we may attribute such appearances to the mere waste or decay of the underlying rock, by the action of the air, the water, and the frost. This waste may have been proceeding ever since the country emerged from beneath the deep, and need not necessarily belong to one geological period more than to another. But the case becomes very different where we find the soil to consist of or to contain materials for whose presence we cannot account by any causes now in operation in the locality; and that this is the case with the formation now under consideration, may be inferred from the names which stand at the head of this division of the subject—names which are applicable to the surface deposit over the greater part of the northern temperate and arctic latitudes.

If we examine the materials exposed in ordinary excavations, or on the coasts and river banks, and which extend from the surface down to the solid rocks, we find them to consist of clay or sand intermixed with large stones, or it may be occasionally of large stones with their interstices filled with soil, or possibly in a few localities of rolled gravel, like that found on the beach or in river beds. If our inquiries proceed a little beyond a mere glance at these at first sight not very interesting materials, we may discover that the large stones in the drift are of very different kinds. Some of them, perhaps the greater number, may be of the same kind with the rocks occurring *in situ* in the vicinity. Others are of kinds not found in place except at great distances. It is farther observable that the clay or sand containing large stones, is not arranged in layers, but that its materials are confusedly intermixed. The fine rounded gravel, however, is not only comparatively free from large stones, but it is arranged in beds or layers, often with bands of sand between. By observing these differences, the student of the superficial deposits will soon learn to divide them into two classes, the *till* or *boulder sand and clay*, and the *stratified gravels*.

The *Unstratified Drift* may be viewed as consisting of a base or paste including angular and rounded fragments of rocks. The base varies from a stiff clay to loose sand, and its composition and colour generally depend upon those of the underlying and neighbouring rocks. Thus over sandstones it is arenaceous, over shales argillaceous, and over conglomerates and hard slates pebbly or shingly. The greater number of the stones contained in the drift are usually, like the paste containing them, derived from the neighbouring rock formations. These untravelled fragments are often of large size, and are usually angular, except when they are of very soft material, or of rocks whose corners readily weather away. It is unnecessary to give illustrations of these facts. Any one can observe, that on passing from a granitic district to one composed of slate, or from slate to sandstone, the character of the loose stones changes accordingly. It is also a matter of familiar observation, that in proportion to the hardness or softness of the prevailing rocks, the quantity of these loose stones increases or diminishes. In some of the quartzite and granite districts of the Atlantic coast, the surface seems to be heaped with boulders with only a little soil in their interstices, and every little field, cleared with immense labour, is still half filled with huge white masses popularly known as "elephants." On the other hand, in the districts of soft sandstone and shale, one may travel some distance without seeing a boulder of considerable size.

Though I have called these fragments untravelled, it by no means follows that they are undisturbed. They have been lifted from their original beds, heaped upon each other in every variety of position, and intermixed with sand and clay, in a manner which shows convincingly that the sorting action of running water had nothing to do with the matter; and this applies not only to stones of moderate size, but to masses of ten feet or more in diameter. It is as if a gigantic harrow had been dragged over the surface, tearing up the solid rocks, and mingling their fragments in a rude and unsorted mass.

Beside the untravelled fragments, the drift always contains boulders derived from distant localities, to which in many cases we can trace them; and I shall mention a few instances of this to show how extensive has been this transport of detritus. In the low country of Cumberland there are few boulders, but of the few that appear some belong to the hard rocks of the Cobequid hills to the southward; others may have been derived from the somewhat similar hills of New Brunswick. On the summits of the Cobequid hills and their northern slopes, we find angular fragments of the sandstones of the plain below, not only drifted from their original sites, but elevated several hundreds of feet above them. To the southward and eastward of the Cobequids, throughout Colchester, Northern Hants, and Pictou, fragments from these hills, usually much rounded, are the most abundant travelled boulders, showing that there has been great driftage from this elevated tract. In like manner, the long ridge of trap rocks, extending from Cape Blomidon to Briar Island, has sent off great quantities of boulders across the sandstone valley which bounds it on the south, and up the slopes of the slate and granite hills to the southward of this valley. Well characterized fragments of trap from Blomidon may be seen near the town of Windsor; and I have seen unmistakable fragments of similar rock from Digby neck, on the Tusket river, thirty miles from their original position. On the other hand, numerous boulders of granite have been carried to the northward from the hills of Annapolis, and deposited on the slopes of the opposite trappean ridge; and some of them have been carried round its eastern end, and now lie on the shores of Londonderry and Onslow. So also, while immense numbers of boulders have been scattered over the south coast from the granite and quartz rock ridges immediately inland, many have drifted in the opposite direction, and may be found scattered over the counties of Sydney, Pictou, and Colchester. These facts show that the transport of travelled blocks, though it may here as in other parts of America have been principally from the northward, has by no means been exclusively so; boulders having been carried in various directions, and more especially from the more elevated and rocky districts to the lower grounds in their vicinity.

As might have been expected, the removal of these travelled masses has occasioned important changes of the surface, or, to use the ordinary geological term, there has been very extensive *denudation* in the production of the boulder deposits. A very large proportion of the present features of the surface indeed result from this cause; the ridges of Cumberland, the deep valley of Cornwallis and Annapolis, the great gorges crossing the Cobequid Mountains and the western end of the North Mountains in Annapolis and Digby counties, such eminences as the Greenhill in Pictou county, and Onslow Mountain in Colchester, are due in great part to the removal of soft rocks by denuding agencies of this period, while the harder rocks remained in projecting ridges. On the other hand, it might be shown that many masses of rock which once projected above the surface, have been greatly diminished or entirely removed.

One of the most remarkable effects of the transport of surface materials, is the *scratching and polishing of rock surfaces*, a phenomenon which prevails very extensively over the northern parts of America and Europe, and may be frequently observed in Nova Scotia. Indeed it is the rule rather than the exception, that when a fresh rock-surface is uncovered by the removal of the boulder clay, it is found to be smoothed and marked with striæ, scratches, and furrows, usually in a uniform direction; the whole being evidently the result of the passage of heavy and hard substances over the surface. These scratches or furrows are useful as indicating the direction in which the mass of superficial detritus has been moved; and I have even used this direction with success in tracing useful minerals found in fragments among the drift, to the sources whence they were derived. I give below the directions of the diluvial scratches in a number of localities in different parts of the province.

Point Pleasant, and other places near Halifax, exposure south, very distinct striæ, . . .	S. 20° E. to S. 30° E.
Head of the Basin, exposure south, but in a valley, . .	E. & W. nearly.
La Have River, exposure S.E.	S. 20° W.

Petite River, exposure S. .	S. 20° E.
Bear River, exposure N. . .	S. 30° E.
Rawdon, exposure N. . .	S. 25° E.
The Gore Mountain, exposure N., two sets of striæ, respectively,	S. 65° E. & S. 20° E.
Windsor Road, exposure not noted,	S.S.E.
Gay's River, exposure N. . .	Nearly S. & N.
Musquodoboit Harbour, exposure S.	Nearly S. & N.
Near Pictou, exposure E. in a valley,	Nearly E. & W.
Polson's Lake, summit of a ridge,	Nearly N. & S.
Near Guysboro', exposure not noted,	Nearly S. & N.
Sydney Mines, Cape Breton, exposure S.	S. 30° W.*

The above instances show a tendency to a southerly and south-easterly direction, which accords with the prevailing course throughout Northern America and Europe. Local circumstances have, however, modified this prevailing direction.

The travelled and untravelled boulders are usually intermixed in the drift. In some instances, however, the former appear to be most numerous near the surface of the mass, and their horizontal distribution is also very irregular. In examining coast sections of the drift, we may find for some distance a great abundance of angular blocks, with few travelled boulders, and then we may observe a portion of the shore or bank in which both varieties are equally intermixed, or in which travelled boulders prevail; and we may often observe particular kinds of these last grouped together, as, for instance, a number of blocks of granite, greenstone, sye-

* The above and other courses in this volume are *magnetic*, the average variation being about 18° W.

nite, &c., all lying together, as if they had been removed from their original beds and all deposited together at one operation. On the surface of the country where the woods have been removed, this arrangement is sometimes equally evident; thus hundreds of granite boulders may be seen to cumber one limited spot, while in its neighbourhood they are comparatively rare. It is also well known to the farmers in the more rocky districts, that many spots which appear to be covered with boulders have, when these are removed, a layer of soil comparatively free from stones beneath. These appearances may in some instances result from the action of currents of water, which have in spots carried off the sand or clay, leaving the boulders behind; but in many cases this is manifestly the original arrangement of the material.

Boulders or travelled stones are often found in places where there is no other drift. For example, on bare granite hills, about 500 feet in height, near the St Mary's River, there are large angular blocks of quartzite, derived from the ridges of that material which abound in the district, but are separated from the hills on which the fragments lie by deep valleys.

In Canada and the Northern States, as well as in Scotland, beds of clay containing marine shells are associated with the boulder formation, and it is worthy of remark that these shells are of such species as indicate a colder or more arctic climate than that which at present prevails in those countries. In Nova Scotia I have observed nothing of this kind, and the only evidence of organic life during the boulder period or immediately before it, that I have noticed, is a hardened peaty bed which appears under the boulder clay on the north-west arm of the River of Inhabitants. It rests upon gray clay similar to that which underlies peat bogs, and is overlaid by nearly twenty feet of boulder clay. Pressure has rendered it nearly as hard as coal, though it is somewhat tougher and more earthy than good coal. It has a glossy appearance when rubbed or scratched with a knife, burns with considerable flame, and approaches in its characters to the brown coals or more imperfect varieties of bituminous coal. It contains many small roots and branches, apparently of coniferous trees allied to the spruces. The vegetable matter composing this bed must have flourished before the drift was spread over the province, so that it belongs to some part (probably one of the later parts) of the great tertiary group of rocks of which the drift is the latest member.

If we ask what has been the origin of this great mass of shifted and drifted material, which overspreads the surface not only of the province we are now describing, but the greater part of the land of the northern hemisphere, we raise one of the most vexed questions of modern geology. In reasoning, however, on this subject as regards Nova Scotia, I have the advantage of appealing to causes now in operation within the country, and which are at present admitted by the greater number of modern geological authorities to afford the best explanation of the phenomena. In the first place, it may at once be admitted that no such operations as those which formed the drift are now in progress on the surface of the land, so that the drift is a relic of a past state of things, in so far at least as regards the localities in which it now rests. In the next place, we find, on examining the drift, that it strongly resembles, though on a greater scale, the effects now produced by frost and floating ice. Frost breaks up the surface of the most solid rocks, and throws down cliffs and precipices. Floating ice annually takes up and removes immense quantities of loose stones from the shores, and deposits them in the bottom of the sea or on distant parts of the coasts. Very heavy masses are removed in this way. I have seen in the Strait of Canseau large stones ten feet in diameter, that had been taken from below low water mark and pushed up upon the beach. Stones so large that they had to be removed by blasting, have been taken from the base of the cliffs at the Joggins and deposited off the coal-loading pier, and I have seen resting on the mud flats at the mouth of the Petitcodiac river a boulder at least eight feet in length, that had been floated by the ice down the river. Another testimony to the same fact is furnished by the rapidity with which huge piles of fallen rock are removed by the floating ice from the base of the trap cliffs of the Bay of Fundy. Let us suppose then the surface of our province, while its projecting rocks were still uncovered by surface deposits, exposed for many successive centuries to the action of alternate frosts and thaws, the whole of the untravelled drift might have been accumulated on its surface. Let it then be submerged until its hill-tops should become islands or reefs of rocks in a sea loaded in winter and spring with drift ice, floated along by currents, which like the present arctic current, would set from N. E. to S. W. with various modifications produced by local causes. We have in these causes ample means for accounting for the whole of the appearances, including the travelled blocks and the scratched and polished rock-surfaces. This, however, is only a general explanation. Had we time to follow it into details, many most interesting and complicated facts and processes would be discovered. I mention merely one for an example, as it illustrates the manner in which the land may have subsided beneath the boulder-bearing seas. I have stated that large blocks of sandstone from the plains of Cumberland have been carried to the summits of the Cobequid mountains. When these blocks were carried to their present place, the waters must have reached to the summits of the hills; but at that time the plain from which these blocks came must have been several hundred feet below the sea-level. How then could ice take them from such a depth? We may fancy huge icebergs grounding in this deep water, but they could not float over the hills or ground against their summits. The explanation is that the country was gradually subsiding. While the water was shallow the blocks were drifted against the base of the hills. As the land sunk the ice-fields of successive years gradually pushed them higher, until the summits of the hills were submerged so deeply that the ice could no longer take up the blocks. Most of the apparent anomalies of the drift may be explained in such ways, when the theory of ice-carriage is once admitted.

The stratified sand and gravel rests upon and is newer than the unstratified drift. This may often be seen in coast sections or river banks, and occasionally in road cuttings. I observed some years ago a very pretty illustration of this fact, in a bank on the shore a little to the eastward of Merigomish harbour (Fig. 4.) At this place the lower part of the bank consists of clay and sand with angular stones, principally sandstones. Upon this rests a bed of fine sand and small rounded gravel,

Fig. 4.

Stratified Gravel resting on Drift,—Merigomish.

with layers of coarser pebbles. The gravel is separated from the drift below by a layer of the same sort of angular stones that appear in the drift, showing that the currents which deposited the upper bed have washed away some of the finer portions of the drift before the sand and gravel were thrown down. In this section, as well as in most others that I have examined, the lower part of the stratified gravel is finer than the upper part, and contains more sand.

It will be observed that the great distinction between the beds now under consideration and those last described, is that the former consist of materials sorted and rounded by currents of water, in the manner of the beaches of sand and gravel which may be seen on the coast or in the beds of rivers. In some cases we can trace these pebbles to ancient conglomerate rocks which have furnished them by their decay; but in other instances the pebbles may have been rounded by the waters that deposited them in their present place. In places, however, where old pebble rocks do not occur, we sometimes find, instead of gravel, beds of fine laminated sand. A very remarkable instance of the connexion of superficial gravels with ancient pebble rocks occurs in the county of Pictou. In the coal-formation of this county there occurs a very thick bed of conglomerate, the outcrop of which, owing to its comparative hardness and great mass, forms a high ridge extending from the hill behind New Glasgow across the East and Middle Rivers, and along the south side of the West River, and then crossing the West River reappears in Roger's Hill. The valleys of these three rivers have been cut through this bed, and the material thus removed has been heaped up in hillocks and beds of gravel, along the sides of the streams, on the side toward which the water now flows, which happens to be the north and north-east. Accordingly, along the course of the Albion Mines Railway and the lower parts of the Middle and West Rivers, these gravel beds are everywhere exposed in the road cuttings, and may in some places be seen to rest on the boulder-clay, showing that the cutting of these valleys was completed after the drift was produced. Similar instances of the connexion of gravel with conglomerate occur near Antigonish, and on the sides of the Cobequid mountains, where some of the valleys have at their southern entrances immense tongues of gravel extending out into the plain, as if currents of enormous volume had swept through them from north to south.

The stratified gravels do not, like the older drift, form a continuous sheet spreading over the surface. They occur in mounds and long ridges, sometimes extending for miles over the country. One of the most remarkable of these ridges is the "Boar's Back," which runs along the west side of the Hebert river in Cumberland. It is a narrow ridge, perhaps from ten to twenty feet in height, and cut across in several places by the channels of small brooks. The ground on either side appears low and flat. For eight miles it forms a natural road, rough indeed, but practicable with care to a carriage, the general direction being nearly north and south. What its extent or course may be beyond the points where the road enters on and leaves it I do not know; but it appears to extend from the base of the Cobequid mountains to a ridge of sandstone that crosses the lower part of the Hebert river. It consists of gravel and sand, whether stratified or not I could not ascertain, with a few large boulder-stones. Another very singular ridge of this kind is that running along the west side of Clyde river in Shelburne county. This ridge is higher than that on Hebert river, but like it extends parallel to the river, and forms a natural road, improved by art in such a manner as to form a very tolerable highway. Along a great part of its course it is separated from the river by a low alluvial flat, and on the land side a swamp intervenes between it and the higher ground. These may serve as illustrations of the "boars' backs" and gravel ridges which occur in many other places, and are sometimes accompanied, particularly where they are crossed by gullies, by circular and oval mounds, as regular as if thrown up artificially.

Just as we attribute the formation of the older or boulder drift to the action of water and ice, while the land was subsiding beneath a frozen sea, so we may assign as the cause of the superficial gravels the action of these same waters while the country was being elevated above their level. Many of the mounds of gravel have evidently been formed by currents of water rushing through and scooping out the present valleys. Some of the more regular ridges are apparently of the nature of the gravel beaches which are thrown by the sea across the mouths of bays and coves, and may mark the continuance of the sea-level unchanged for some time in the progress of elevation. Others may have been pressed up by the edges of sheets of ice, in the manner of the ridges along the borders of our present lakes. That the action of ice in some form had not ceased, we have evidence in the large boulders sometimes found on the summits of the gravel ridges.

In the island of Cape Breton the bones of a large elephantine quadruped, probably a species of mastodon, have been found in connexion with the superficial gravel. This gigantic creature probably inhabited our country at the close of the glacial or drift period, and may have been contemporary with some of the present animals, though probably extinct before the introduction of the human race. The existence of this huge quadruped does not imply a tropical or even very warm climate, since in a skeleton found in Warren county, New Jersey, fragments of twigs, found in such a position as to show that they had formed part of the food of the creature, were found by microscopic examination to have belonged to a species of cypress, probably the common white cedar of America; so that the animal probably browsed as the moose does at present, and could live in any wooded region.* One specimen found in the state of New York measured twenty-five feet in length and twelve feet in height. In Nova Scotia the animal must have attained to similar dimensions, for a thigh bone now in the museum of the Mechanics' Institute in Halifax, though apparently somewhat worn, measures three feet eleven inches in length. This huge bone and some

* Lyell, "Manual of Geology."

fragments of a tusk, are the only remains of this animal that I have seen in this province; but I am informed that others have been found, though several of the best specimens have been unfortunately lost by shipwreck. Not having seen the teeth, I can give no opinion as to the species, but presume it must have been the "*Mastodon giganteus*," the species usually found in the United States.

In conclusion of this part of the subject, we may view the drift period as the close of the great Tertiary era of geologists. In that period there was much dry land in the northern hemisphere, and multitudes of large animals now extinct inhabited it, apparently under a climate milder than at present. Great changes, however, took place in the relative positions of land and water, inducing very important changes of climate, which finally became of an almost arctic character over all the present temperate regions. Then the greater part of northern Europe and Asia appear to have subsided beneath the waters of the boulder-bearing semi-arctic ocean, until raised again by the fiat of the Creator to be the abode of man and the animals of the modern earth. This final elevation, marked by the superficial gravels, appears to have fixed the present contour of the country, though the extinction of the mastodon and the phenomena of submerged forests, show that important changes both in inorganic and organic nature have occurred subsequently. We have thus, in tracing back the geological history of Nova Scotia, observed first, certain modern formations now in progress, and depending wholly on the present condition of the country. We have seen in connexion with these, evidences of subsidence of the land over an extensive area in the modern period. A little farther back, we have observed evidences that formerly a large elephantine quadruped now extinct inhabited the province, which we find had at a time still farther back emerged from the bosom of the deep, under which it had long remained, while icebergs and floes were drifting masses of rock over its surface, and scraping and polishing its hills. Lastly, we have found that at a still earlier period it must have been dry land, exposed to the influence of intense frost, yet having in places peat bogs on its surface. This whole history, however, reaches no farther back than the close of the Tertiary period; and by referring to the Table in Chapter II. it will be observed, that between this period and the formation next to be described a great blank occurs, occupied in some other countries by some of the most wonderful monuments of the earth's history.

CHAPTER V.

THE NEW RED SANDSTONE.

GENERAL DISTRIBUTION—RED SANDSTONES—VARIETIES OF TRAP—NEW RED FROM TRURO TO AVON ESTUARY—BLOMIDON TO BRIAR ISLAND.

BETWEEN the drift and the New Red Sandstone, a deposit, probably of the same age with the Permian System of geologists, there is a great hiatus in the geology of Nova Scotia. During all those periods in which the middle and older Tertiaries, the Cretaceous and the Oolitic systems were produced, no rocks appear to have been formed within the area of our province, or if they were formed, they have been swept away. This remark applies not only to Nova Scotia, but to an immense region extending through New Brunswick, Canada, and the Northern United States; and in some directions far beyond the limits of those countries. During those long periods, these regions, thus destitute of the newer secondary and tertiary rocks, may have been in the interior of a great continent, or in the fathomless depths of an ocean where no sediment was being deposited; but whatever their condition, they retain no geological monuments of the lapse of time. In passing then from the Boulder-formation to that which for convenience we may call the *New* Red Sandstone, to distinguish it from rocks of similar character but greater age, the reader may be reminded by a glance at the table in Chapter II., that we are passing at one leap over a great part of the earth's geological history.

The distribution of the New Red Sandstone, as shown on the map, indicates that, when it was deposited, the form and contour of the country already made some approach to those which it still retains. Just as the marsh mud lines the coasts of the Bay of Fundy, so do we find the New Red occupying an inner zone, and appearing to have been deposited in a bay a little wider and longer than the present one. It is indeed to this bay district that in Nova Scotia the New Red has been chiefly confined, and it may have been deposited in circumstances not very dissimilar from those of the present marshes, except that the older deposit is accompanied by evidence that active volcanoes poured out their lavas on the grandest scale in the waters and on the shores of the bay while its sandstones were being formed. While the New Red Sandstone of Nova Scotia is limited to the Bay of Fundy, we have evidence in the wide extent of the same formation in Prince Edward Island, that a similar deposit was in progress in the Gulf of St Lawrence. In the gulf, however, unlike the bay, we do not find the New Red along the coasts, but in an isolated patch separated on all sides from the continent. I may remark here, that the New Red Sandstone, though patches of it are scattered over several parts of North America, is nowhere very extensive. To the southward of Nova Scotia it reappears in Connecticut, where a band extends upward along the valley of the river; and in New Jersey, where another band commences that extends a great distance to the south-east, some isolated patches occurring as far south as North Carolina. Westward of Prince Edward Island, the nearest locality is the Bay de Chaleur, along the north side of which a belt of this formation appears. Beyond this place no similar rock appears until we reach Lake Superior, where we find an extensive deposit of red sandstone, associated with the trap so celebrated on account of its copper deposits. The age, however, of this deposit is doubtful; some geologists maintaining that it is New Red Sandstone, while others assign to it a much older date.*

The aqueous rocks of the New Red Sandstone period in Nova Scotia and Prince Edward Island, are principally coarse and soft red sandstones with a calcareous cement, which causes them to effervesce with acids, and contributes to the fertility of the soils formed from them. In the lower part of the formation, there are conglomerates made up of well-worn pebbles of the harder and older rocks.

The volcanic rocks of this period are of that character known to geologists as *Trap*, and are quite analogous to the products of modern volcanoes; and, like them, consist principally of *Augite*, a dark green or blackish mineral, composed of Silica, Lime, and Magnesia, with iron as a colouring material. Various kinds of trap are distinguished, corresponding to the varieties of modern

* Marcou's Geological Map. Logan's, Jackson's, and Owen's Reports. Possibly the Bay de Chaleur Sandstone may be liable to similar doubts.

lavas. Crystalline or basaltic trap is a black or dark green rock, of a fine crystalline texture, and having on the large scale a strong tendency to assume a rude columnar or basaltic structure. Amygdaloid or almond-cake trap, is full of round or oval cavities or air bubbles, filled with light-coloured minerals introduced by water after the formation of the rock. This represents the vesicular or porous lava which forms the upper surface of lava currents, just as the basaltic trap represents the basaltiform lava which appears in their lower and more central parts. The only difference is, that in the amygdaloid the cavities are filled up, while in the modern lavas they are empty. In some old lavas, however, the cavities are already wholly or partially filled. A third kind of trap, very abundant in Nova Scotia, is Tufa or Tuff, a rock of earthy or sandy appearance, and of gray, greenish, or brown colour. It consists of fine volcanic dust and scoriæ, popularly known as the ashes and cinders of volcanoes, cemented together into a somewhat tough rock. Modern Tufa, quite analogous to that of the trap, is very abundant in volcanic countries, and sometimes sufficiently hard to be quarried as a stone.

As the New Red Sandstone and trap are formations of one period, and differ only in origin, it will be convenient to consider them together. I shall, therefore, proceed to describe these two rocks as they appear in connexion in different parts of Nova Scotia and Prince Edward Island, and then notice their fossil remains and useful or interesting minerals.

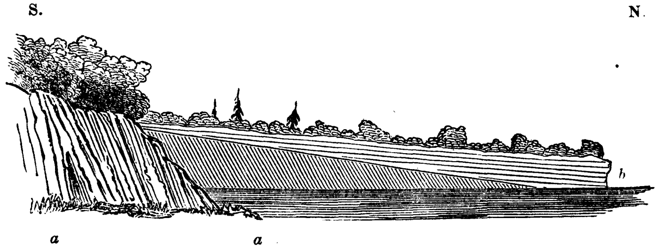
1. *Truro and south side of Cobequid Bay.*

In the valley of the Salmon river, four and a half miles eastward of the village of Truro, the eastern extremity of the New Red Sandstone is seen to rest unconformably on hard reddish brown sandstones and shales, belonging to the lower part of the carboniferous system, and dipping N. 80° E. at an angle of 40°. At this place the overlying formation is nearly horizontal, and consists of soft and rather coarse bright red silicious sandstones. Southward of Truro, at the distance of less than a mile, the horizontal soft red sandstone is seen, in the banks of a brook, to run against hard brownish grits and shales, dipping to the eastward at angles varying from 45° to 50°. Westward of this place, the red sandstones extend in a narrow band, about a mile in width, to the mouth of the Shubenacadie, ten miles distant. This band is bounded on the north by Cobequid Bay, and on the south by highly inclined sandstone, shale, and limestone of the lower carboniferous series. In the coast-section, between Truro and the Shubenacadie, the red sandstone presents the same characters as at the former place, except that, near the Shubenacadie, some of the beds, which like most of the red sandstones of Truro have a calcareous cement, show a tendency to arrangement in large concretionary balls.

West of the mouth of the Shubenacadie, the red sandstone ceases to form a continuous belt, but occurs in several patches, especially at Salter's Head, Barncote, and Walton. At the latter place, it is seen to rest on the edges of sandstones and other rocks of the lower carboniferous system, affording a very fine example of that *unconformable* superposition, which in geology proves the underlying formation to have been elevated and disturbed before the overlying beds were deposited upon it. This appearance is represented in Fig. 5, and was thus described by the writer in a letter supplementary

Fig 5.

SECTION ON THE WEST SIDE OF THE MOUTH OF PETITE RIVER.



(*a*) Carboniferous Strata, highly inclined. (*b*) New Red Sandstone.

to his paper on the New Red Sandstone of Nova Scotia, and communicated to the Geological Society in 1852.

"I had in the past summer an opportunity of examining these beds at Walton (Petite) and other places, and was much gratified by finding that the New Red might be traced, as a narrow and occasionally interrupted band, from the mouth of the Shubenacadie nearly to the mouth of the Avon; thus connecting as far as possible the distinct patches of New Red described in my former paper. At some points also I found very distinct coast-sections, showing the unconformable superposition of the New Red on the Lower Carboniferous beds. A good instance of this occurs at Petite river.

"Near the mouth of the river, the Lower Cariboniferous formation appears with the same characters observed at Windsor and on the Shubenacadie. It includes a large body of gypsum, extensively quarried for exportation, and a bed of limestone with veins of oxide of manganese. In the neighbourhood of these beds, the softer

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rocks have been denuded and do not appear. Still nearer the mouth of the river, however, there is a distinct section, showing black shales, with calcareous bands, dipping at a high angle to the south, and underlying the beds above mentioned. In a short space these beds become contorted, and then dip steeply to the north.

"Succeeding these black shales, in ascending order, the Lower Carboniferous rocks are seen in the section. These beds probably underlie the gypsum and limestone, which would recur on the north side of the anticlinal formed by the black shales if the section extended sufficiently far. Before reaching the extremity of the point on the east side of the river, however, the edges of the beds sink to the level of the sea, and the lower members of the New Red are unconformably superimposed upon them. It is a somewhat instructive fact that the beds of the underlying series are at this place both redder and softer than the overlying New Red Sandstone."

I notice this section particularly, because it gives a clear conception of the manner in which the New Red rests on the older Carboniferous beds, wherever it is in contact with them.

2. *Blomidon to Briar Island.*

Westward of Walton, the estuary of the Avon river and Minas basin, make a very wide gap in the New Red Sandstone. On the western side of Minas basin, however, this formation attains its greatest width and grandest proportions; and as this coast affords the finest opportunity in the province for studying all the members of the formation and their mutual relations, I shall describe it in detail with the aid of the section, Fig. 6.

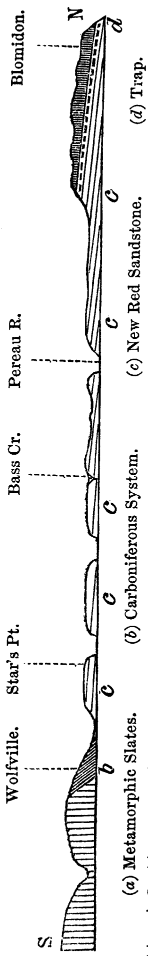


Fig. 6.—SECTION FROM HORTON TO CAPE BLOMIDON.

Blomidon is the eastern extremity of a long band of trappean rocks, forming an elevated ridge, named in the greater part of its length the "North Mountains." This ridge is about 123 miles in length, including two insular portions at its western extremity, and does not exceed five miles in breadth, except near Cape Blomidon, where a narrow promontory, terminating in Cape Split, extends to the northward. The trap of the North Mountains presents to the Bay of Fundy a range of high cliffs, and is bounded on the inland side by soft red sandstones, which form a long valley separating the trappean rocks from another and more extensive hilly district occupied principally by metamorphic slates and granite. The trap has protected the softer sandstones from the waves and tides of the bay, and probably also from older denuding agents; and where it terminates, the shore at once recedes to the southward, forming the western side of Minas Basin, and affording a cross section of the North Mountains and the valley of Cornwallis.

At Cape Blomidon, the cliff, which in some parts is 400 feet in height, is composed of red sandstone surmounted by trap. The sandstone is soft, arranged in beds of various degrees of coarseness, and is variegated by greenish bands and blotches. It contains veins of selenite and fibrous gypsum, the latter usually parallel to the containing beds, but sometimes crossing them obliquely. I found no fossils in it: it dips to the north-west at an angle of 16°. Resting on the sandstone, and appearing to dip with it to the north-west, is a thick bed of amygdaloidal trap, varying in colour from gray to dull red, but in general of grayish tints. It is full of cavities and fissures; and these, as well as its vesicles, are filled or coated with quartz, in different states, and with various zeolites, to be noticed hereafter, especially heulandite, analcime, natrolite, stilbite, and apophyllite, often in large and beautiful masses of crystals. In its lower part there are some portions which are scarcely vesicular, and often appear to contain quartz sand like that of the subjacent sandstone. Above the bed of amygdaloid is a still thicker stratum of crystalline basaltic trap, having a rude columnar structure.

The columnar trap of Blomidon, in consequence of its hardness and vertical joints, presents a perpendicular wall extending along the top of the precipice. The amygdaloid beneath, being friable and much fissured, falls away in a slope from the base of this wall, and the sandstone in some places forms a continuation of this slope, or is altogether concealed by the fallen fragments of trap. In other places the sandstone has been cut into a nearly vertical cliff, above which is a terrace of fragments of amygdaloid.

Northward of Cape Blomidon, the north-westerly dips of the sandstone and trap cause the base of the former to descend to the sea-level, the columnar trap, which here appears to be of increased thickness, still presenting a lofty cliff. Southward of the cape, on the other hand, the amygdaloid and basalt thin out, until the red sandstones occupy the whole of the cliff. It thus appears that the trap at Blomidon is a conformable bed, resting on the sandstone, exactly as in some places on the opposite shore, to be described hereafter.

The coast-section between Blomidon and Horton, as seen near Pereau river and Bass Creek, and at Star's Point, Long Island and Bout Island, exhibits red sandstones, with north-west dips at angles of about 15°, and precisely similar in mineral character to those of Blomidon, except that near Bass Creek some of them contain layers of small pebbles of quartz, slate, granite, and trap. The whole of these sandstones underlie those of Blomidon, and resemble those which occupy the long valley of Cornwallis and the Annapolis river, westward of this section. In this valley, the red sandstone, in consequence of its soft and friable nature, is rarely well exposed; but in a few places in Cornwallis, where I observed it, it has the same dip as on the coast. The comparatively high level of the sandstone, where it underlies the trap, shows that the present form of this valley is in great part due to denudation; and the trap itself must have suffered from this cause, since fragments of it and of the quartzose minerals which it contains, are frequent in the valley of Cornwallis, and along the base of the slate hills to the southward.

We may now consider the relations of the red sandstone of Cornwallis to the other formations bounding it on the south. Near Kentville, seven miles westward of the direct line of section from Blomidon to Horton, the red sandstone with its usual north-west dip, rests against clay-slate having a high dip to the N.N.E., and belonging to a series of similar rocks apparently equivalents of the Silurian system. In tracing the boundary of the slate eastward of this place, along the south side of Cornwallis river, its junction with the red sandstone is not again observed; and at Wolfville the slates support hard gray sandstones, composed of the materials of granite, with some beds of brownish sandstone. These rocks were observed in one place to dip to the northeast, and in another to the N.N.W. They are separated from the red sandstones of Bout and Long Island, and Star's Point, by a wide expanse of marsh, and by the estuary of the Cornwallis river. In Lower Horton, and between that place and Halfway river, gray sandstones, similar to those of Wolfville, are seen to support black shales and dark sandstones, with *Lepidodendra* and other fossil plants of carboniferous forms, and dipping to the N.E., N., and N.W. These beds continue to the mouth of the Avon estuary, where they form the cliffs of Horton Bluff, at the northern end of which they are seen dipping to the south. They are then concealed by boulder-clay, which with marsh forms the shore for nearly a mile. Beyond this, in a small point called Oak Island, are seen a few beds of coarse red sandstone with some finer red beds and grayish bands. These rocks dip to the N.N.W., and form a continuation, and the eastern extremity, of the new red sandstone of the Horton Islands and Cornwallis.

In describing this section, I have merely copied my notes upon it, and have purposely refrained from drawing any inferences or giving any explanations. To begin with Blomidon—the crystalline trap at its summit, which rises abruptly in huge irregular columns, is an ancient current of molten rock or lava, which has flowed over and cooled upon the surface on which it now rests. It slopes gently toward the north-west, as if it had flowed toward the bay, but there is no volcanic dike or other evidence of the ejection of lava from beneath on that side, and it is more than probable that the orifice from which it was poured forth, was to the westward along the range of which Blomidon is the eastern extremity, or northward toward Cape Split. From the appearance of the mountain-top that rises above the vertical cliff, there may have been more than one overflow of the volcanic matter. Before this great bed of basaltic trap flowed forth, the surface on which it rests had been thickly covered with volcanic ashes and scoriæ, which, consolidated by pressure, now form the thick bed of amygdaloid and tufa intervening between the columnar trap and the red sandstone. This is precisely what we find to be the case in modern volcanic eruptions. The first violent explosions in such cases usually eject immense quantities of dust and fragments of old lavas, which are blown or ejected to great distances, or if they fall into the sea, as was most probably the case at Blomidon, are scattered in layers over its bottom. Over these ejected scoriæ and ashes the lava currents which issue subsequently are poured. We need not be surprised that we do not now perceive any regular volcanic mountain or vent at Blomidon, for independently of the action the waters may have exerted on it when being formed, we know that great denudation has taken place in the drift-period, and under the wasting action of the present frosts and tides. The minerals mentioned as occurring in the trap are all either silica or silicates,—that is, compounds of silica with the alkalies potash and soda, or the earths, as alumina, lime, &c. They are produced by the solvent action of water, which, percolating through the trap, dissolves these materials, and redeposits them in fissures and cavities. Below the amygdaloid, we have a thick series of beds of red sandstone—mechanical detritus deposited by water, and probably in great part derived from the wear and tear of the sandstones of the carboniferous system. The gypsum veins which traverse it were probably deposited by waters which had dissolved that mineral, in passing through the great gypsum-beds which occur in the older system last mentioned.

The history of this fine precipice is then shortly as follows. In the New Red era, thick beds of sandstone were deposited off the coasts of Horton, just as the red mud and sand of the flats are now deposited. Volcanic phenomena on a great scale, however, broke forth from beneath the waters, scoriæ and dust were thrown out, and spread around in thick beds, and currents of lava were poured forth. Subsequently the whole mass was elevated, to be again submerged under the boulder-bearing sea, by which, and the present atmospheric and aqueous agencies, it was worn and wasted into its present form. Still the work of decay goes on; for yearly the frosts loosen immense masses from its brow, and dash them to the beach, to be removed by the ice and the tides, and scattered over the bottom of the bay. The rains and melting snows also cut huge furrows down its front. These agencies of destruction as yet, however, only add to the magnificence of this noblest of all our sea-cliffs. The dark basaltic wall crowned with thick woods, the terrace of amygdaloid with a luxuriant growth of light green shrubs and young trees that rapidly spring up on its rich and moist surface, the precipice of bright red sandstone always clean and fresh,

PART OF CAPE BLOMIDON. 1846.

(New Red Sandstone & Trap)

and contrasting strongly with the trap above and with the trees and bushes that straggle down its sides, and nod over its deep ravines, constitute a combination of forms and colours equally striking if seen in the distance from the hills of Horton or the shore of Parrsboro', or more nearly from the sea or the stony beach at its base. Blomidon is a scene never to be forgotten by a traveller who has wandered around its shores or clambered on its giddy precipices.

From the shore of Blomidon, we may follow the trap formation in a continuous ridge without a break to Annapolis Gut. On the north side, the trap slopes down in rounded and abrupt eminences into the Red Sandstone valley. On its summit it is somewhat level, though divided into a number of long rolling ridges, probably the effect of denuding agents on the edges of beds of trap of unequal hardness. The bay shore presents to the sea a range of cliffs and precipices often overhanging or vertical, or rolled down into shapeless heaps of rubbish by the frost and the undermining action of the waves. Huge landslips occur every spring from these causes, covering acres of the shore with their ruins, and affording a rich harvest to the mineralogist who may visit the shore after one of these falls. The amount of debris annually thrown down and removed in this way is enormous. The cliffs are usually composed of alternate layers of soft and hard trap and tufa, they are traversed by innumerable fissures, and the general dip is seaward. In addition to these circumstances, the ice annually removes large quantities of fragments from the shore, so that a cliff does not long continue to be protected by the masses that have fallen from it. Hence the whole shore wastes rapidly, with the exception of those places where beds of hard basaltic trap run down to the sea level, and form inclined planes against which the sea rages in vain.

A very remarkable deviation from the ordinary regularity of the coast-line of the trap occurs at Cape Split, which forms a prolongation of the Blomidon shore to the north-westward. The dip of the Blomidon basalt gradually brings it down to the sea-level, and toward Cape Split it either thickens, or portions which are retired from the cliff at Blomidon come forward into the shore precipices, for toward the cape a cliff more than 300 feet in height, seems to be composed of compact and columnar trap, which extends in a promontory and series of islands and reefs far out into the bay. The appearances at this place render it possible that a trappean dike or dikes, indicating the point or line of ejection of the great basaltic bed of Blomidon, may appear in these cliffs toward Cape Split. I have not, however, been able to study them so closely as to ascertain decisively whether this is the case. There seems no reason to doubt at least, that the line from the summit of Blomidon to Cape Split marks the direction of one of the greatest lava streams of the region.

At the extremity of the long continuous range extending westward from Blomidon, in the cliff forming the east side of Annapolis Gut, we find the trap, as at the former place, forming a thick bed resting on the red sandstone, and dipping to the northward; and there can be no doubt, from the appearances observed at several places along the coast, that the same arrangement prevails throughout the entire ridge.

Annapolis Gut is a deep channel separating the trap of the promontory of Granville from the western prolongation of the formation. This channel forms the only outlet of Annapolis Basin and the rivers emptying into it. It is of great depth, and the tides rush through it with terrible rapidity. The trap on its west side is more largely developed than on the Granville side. It attains a greater width and height, and contains a larger mass of compact and basaltic trap. This circumstance, in connexion with the narrowing of the valley by a spur of the metamorphic rocks on the south, has probably caused the currents of the drift period to excavate the present outlet. Had it not been for these circumstances, the waters of the Annapolis river would probably have flowed into St Mary's Bay, and the Annapolis basin, probably the finest sheet of salt water in the province, and its remarkable and picturesque outlet, would not have existed. The sandstone near the town of Digby is somewhat hard, and contains concretions of transparent calc spar. It passes under the southern edge of the trap, but cannot be seen toward the centre of the ridge, where the precipitous side of the "Gut" consists of compact and basaltic trap extending downward to the water-level. In one place, I observed basalt with its pillars nearly horizontal,—an evidence that here a dike of molten rock had been ejected from beneath. Toward the entrance of the gut on the Digby side, the coast becomes low, and amygdaloid is seen in low cliffs and on the slopes of the hills, while sheets of compact trap run downward into the sea with scarcely any abrupt cliff or bank.

In Digby Neck, the sandstone is well exposed on the side fronting St Mary's Bay, and compact and amygdaloidal trap rest upon it, and dip northward toward the Bay of Fundy. This long promontory, though only from two to three miles in width, consists of two ridges, one forming the cliffs that front St Mary's Bay, the other sloping toward the Bay of Fundy; while between them is a narrow and almost level valley, with several little lakes and ponds arranged in a line along its bottom. The rock in this valley appears to be amygdaloid, and it is probably owing to this circumstance that the valley has been scooped out, while the edges of the beds of more compact trap remain as ridges. This at least is the explanation which appears most probable from the structure of all parts of the ridge that I have visited, except the very singular and romantic spot named Sandy Cove. At this place a deep cove penetrates about one-fourth across the ridge from the south, between precipitous cliffs of trap resting on amygdaloid, and apparently with a southerly dip; or, at all events, without that decided dip to the north which prevails over the greater part of this trappean ridge. Opposite the southern cove, there is on the north side of the ridge a shallower cove, and between is a little lake, on either side of which rise lofty beetling cliffs of basaltic trap, which appear to be parts of a thick bed dipping to the northward. I have marked in my notes the query—Can this be a volcanic focus? and I find that the same thought has occurred to other geologists who have visited the spot. It may have been so; but it is perhaps more probable that the ridge has here been cracked across by a fissure caused by earthquake disturbances; and that the currents of the boulder-formation period have passed through and widened the chasm. Whatever the causes of its present appearance, Sandy Cove is more like something a poet or painter might dream of, than like an actual reality in our usually tame province of Nova Scotia.

Though the trap ridge is very narrow at Digby Neck, it appears that this rock occupies a considerable breadth beneath the waters of the Bay of Fundy. I have already mentioned that the "Neck" consists of two ridges with a valley between. Now under water there are three similar ridges, the outer being nine miles distant from the shore. They are thus described by Mr Perley in his Report on the Fisheries of New Brunswick; and his statements were corroborated by information which I obtained from gentlemen resident on this coast.

"From Black Rock down to Briar Island, along the whole south shore, there are three fishing banks or ledges, lying parallel to the shore, outside each other; their respective distances from the coast have acquired for them the designations of the three mile ledge—the five mile ledge—and the nine mile ledge. On these ledges there are sixty fathoms of water, but on the crown of each ledge, thirty fathoms only. The three mile ledge, and the five mile ledge, extend quite down to Briar Island; but the nine mile ledge can only be traced down the bay, about fourteen miles below Digby Gut, abreast of Trout Cove, where it ends in deep water. Below Digby Gut, the three mile ledge and five mile ledge are composed of hard gravel and red clay; above the gut, the three mile ledge has a rough, rocky bottom, on which anchors are frequently lost. Each of these ledges is about a mile in width, the outer one something more; between them the bottom is soft mud."

The trap of Digby Neck is remarkable for the large quantity of jasper and other coloured varieties of quartz contained in it. Red jasper is especially abundant, amethyst, stilbite, and laumonite are also abundant. I have collected all these minerals near Sandy Cove; as well as micaceous specular iron ore, a mineral which I have not observed elsewhere in the trap district, though it abounds in our more ancient igneous and altered rocks, and is also a not infrequent product of modern volcanic action; the iron being apparently sublimed in a state of vapour from the intensely heated mass of molten rock beneath. This is probably its origin at Sandy Cove, where it occurs in brilliant little crystalline plates embedded in a quartzose matrix, and projecting from the sides of cavities in the fissures of the trap. Its occurrence here lends some countenance to the conjecture already stated, that a focus of igneous activity may have been in or near this place. It is not in sufficient quantity to be of importance for mining purposes.

At the extremity of Digby Neck, we find another deep transverse ravine cut through the ridge, and separating Long Island, which geologically is a perfect continuation of the Neck. The sides of this strait, which is named Petite Passage, as far as I examined them, consist principally of amygdaloid, the cavities of which have been lined with bright green chlorite before they have been filled with crystalline zeolitic matter.

The water of Petite Passage is beautifully clear, the tides rush through it with great force, and its rocky bottom is covered with seaweeds; the finer and more beautiful varieties of which are very abundant on this outlying tract of rocky coast. It is probably the abundance of these seaweeds on the "ledges" before mentioned, that supports the marine creatures that attract to these coasts the cod, torsk, pollack, haddock, halibut, and herring that abound in summer, and furnish a comfortable subsistence to the numerous fishermen who inhabit Long Island and Briar Island. The great

Albecore or King Mackarel, *Thynnus Vulgaris?* the Sea Wolf, *Anarrhicas Lupus;* and the Sturgeon, *Accipenser Oxyrinchus*, are also caught in these waters and in St Mary's Bay, but are not much valued by the fishermen.

On reaching the extremity of Long Island, another strait, the Grand Passage, appears. On the opposite side of this, we see the thriving village of Westport, on Briar Island the *ultima thule* of Nova Scotia in this direction, and one of the most active and intelligent fishing communities in the province. Briar Island is the extreme western end of the trappean ridge, which is, however, prolonged beyond the land in a submarine ledge. It consists entirely of basaltic trap, very regularly divided into columns, which may be seen both as a pavement on many parts of the beach, and in lofty precipices which rise to their greatest height on the south-west side of the island, where they form a perpendicular wall several hundred feet in height, and adorned with buttresses, outlying towers, and pinnacles, such as basaltic cliffs alone can produce in their full perfection. I was so fortunate as to be detained several days at Briar Island by a south-west gale, and had the pleasure of seeing the Atlantic swell bursting in all its grandeur on these iron-bound shores.

The red sandstone is seen to underlie the trap of Digby Neck for several miles below the head of St Mary's Bay, but beyond this I did not again observe it. Gesner states, however, that a small patch of it can be observed at low tide beneath the trap of Briar Island. This interesting fact I had no opportunity of verifying, owing to the stormy state of the weather during my visit.

CHAPTER VI.

THE NEW RED SANDSTONE—*Continued.*

TRURO TO CAPE D'OR—GENERAL REMARKS—MINERALS OF THE NEW RED SANDSTONE AND TRAP.

3. *North Side of Cobequid Bay and Minas Basin and Channel.*

RECOMMENCING at Truro, we may now consider the stripe of new red sandstone with occasional masses of trap, which extends with several interruptions as far as Cape d'Or. Northward of Truro, the red sandstone meets and overlies unconformably the carboniferous grits, shales, limestone, and gypsum of the North river and Onslow mountain. Its boundary in this direction is about three miles distant from the bay, and it occupies the low country; the carboniferous rocks rising from under its edges into hills of considerable elevation. From the North river it extends in a band about three miles in width to De Bert river, where an apparently insulated patch of lower carboniferous rocks projects through it. These last appear at the bridge, and consist of limestone, with fossil shells characteristic of the lower carboniferous period, gypsum, and hard brownish sandstone. They dip at a high angle to the north-east, while the new red sandstone, which laps around them, dips at a small angle to the south-west. This limestone and gypsum, as well as other rocks of the same age, were long believed to belong to the new red sandstone period, and it was only after their true age had been ascertained by careful comparison of a number of sections, and the identification of the fossil remains with those of the carboniferous period in other countries, that their true geological position was appreciated. This very locality at the De Bert river, owing to the similarity of the lower carboniferous sandstones to those of the new red, and to the circumstance that the former have been ground down and their debris mixed up with the latter, is at first sight one of the most deceptive in the province, and might readily lead a geologist, unacquainted with other more distinct sections, into an error on this subject.

As the section at this place is remarkably obscure, I copy from my notes the following memoranda of the appearances. On the south side of the river, near the bridge, there are gray and brown shales, red sandstone, red grit, and conglomerate, with high dips and disturbed. These are evidently lower carboniferous, and quite different from the horizontal soft red sandstones which appear lower down on the same bank. On the north side, at the end of the bridge, are dark red grit and conglomerate, grayish conglomerate, marly and shaly beds with gray calcareous concretions, and a vein of calcareous spar. They dip N.E. and N.N.E. 38°. The limestone and gypsum seen a little below the bridge, are evidently associated with these beds, the whole being lower carboniferous, as indicated by the fossils of the limestone. In the road-cutting, soft red sandstone and conglomerate overlie these beds, and though they have a steep false bedding, I believe they are new red and unconformable. In the same road-cuttings, these upper beds are seen to be made up of the debris of the lower, with which they are confusedly intermixed at their confines, the underlying marls in some places rising like veins into the sandstone above. At Folly river the new red is soft and fine grained, with greenish stains and layers, and has a very slight northerly dip. In the point opposite the village, sandstones, apparently the continuation of the other formation seen at the bridge, dip to the N.E. at a very high angle.

Within this islet of lower carboniferous rock, the new red sandstone extends up the Folly river, which runs into the same estuary with the De Bert, for about five miles. Its dip increases until it amounts to 50°, and the lowest beds rest against the disturbed carboniferous rocks which occupy the bed of the river between this place and the base of the Cobequid mountains. Near their junction with the older rocks, the red sandstones become coarse and pebbly.

Westward of Folly river, the belt of red sandstone gradually decreases in width, and begins to contain in its lower part thick beds of conglomerate, made up of pebbles derived from the older rocks to the northward. Near Portapique river, and somewhat removed from the coast, there is an eminence that I have not visited, but was informed by a gentleman, very familiar with this part of the country, that it consists of trap. If so, this is the first appearance of this rock in this direction.

Economy Point, as well as a detached reef named the Brick Kilns lying off the point, consists of new red sandstone, which here has in consequence a considerable breadth. It has a slight dip to the south. In the banks of Economy river, the red sandstone and conglomerate which, near the coast, dip to the southward at a low angle, undulate as they approach a hill of hard lower carboniferous rocks at no great distance from the shore. Behind these they again appear with a south-west dip, and are again succeeded by lower carboniferous rocks which continue to the base of the hills. The ridge of older rock which here divides the red sandstone, is probably a point or promontory connected with the mass of the carboniferous rocks to the westward.

In Gerrish's mountain, six miles west of Economy river, the red sandstone and conglomerate are overlaid by amygdaloidal trap, and having been protected by it from denudation, rise into an eminence nearly 400 feet high. At Indian Point, the southern extremity of Gerrish's mountain, the trap and red sandstone form a bold precipitous cliff, and are continued along the picturesque rocky chain of the Five Islands, in two of which the red sandstone is seen to underlie the trap.

The isolated trap eminences at this place are probably the remains of a continuous lava current, and it is interesting that the direction of the chain of islets corresponds with that of the great trap ridge on the opposite side of the bay. To a traveller who has passed along the level shores of Londonderry and Onslow, and toward the close of day ascends the steep side of Gerrish's mountain, the view which greets him at the summit is of the most grand and striking character. The rocky chain of the Five Islands, and the pretty inlet and settlement on the shore within them, lie at his feet. In front are the waters of Minas Basin stretching far to the westward. On the one hand is the rugged and picturesque trappean shore extending toward Parrsboro', with the Cobequid mountains ranged behind it. On the other, Blomidon and Cape Split tower in the distance. I may remark here, that for grandeur and beauty of coast scenery, this part of Minas Basin and the Minas Channel are not surpassed by any part of the eastern coast of North America.

It will be seen, on consulting the map, that at the Five Islands three great geological formations approach each other, so that within a very limited space the trap, the new red, the carboniferous system, and the older metamorphic rocks may be studied, and specimens of their characteristic minerals obtained. Hence, at various times, this locality has had the reputation of producing useful minerals of different descriptions. The latest instance of this led to the formation of a copper mining company in London, which, after a very fair promise of success, was broken up, owing to a deficiency of the ore, which on trial was found by no means to warrant the reports that had been published respecting it. The trap which forms the summit of Gerrish's mountain is a huge bed resting on red sandstone, on which at the high cliff of Indian Point it is seen to rest. The trap at this place is traversed by a number of narrow and irregular veins of magnetic iron ore, mixed with the gray sulphuret and oxide of copper. Specimens of this substance were sent to me, many years since, by the late George Duncan, Esq. of Truro, and I was somewhat struck by the singular appearance and composition of the mineral, which was stated to be found in great quantity. From my knowledge of the superficial character of the trap, and the smallness and irregularity of the metallic veins found in it, I rather discouraged Mr Duncan from speculating on it, though some specimens seemed sufficiently rich to be useful as copper ores. It appears, however, that a very favourable report was given by an English mining engineer, and operations were commenced in consequence, though it almost immediately became apparent that they were hopeless.

Between Five Islands and Swan Creek, ten miles distant, an excellent coast-section, rising in many places into lofty cliffs, shows the new red sandstone and trap, as well as the underlying carboniferous strata. As this section is an interesting specimen of the complicated appearances that may result from the eruption of volcanic rocks through stratified deposits, I shall give a description of it taken nearly verbatim from my notes.

At the mouth of Harrington river, opposite the Five Islands, the carboniferous rocks approach the shore very closely; and as seen in the west side of the river, consist of black shales and dark-coloured sandstones with *Poacites* and other fossil plants. They dip at high angles to the south, and are met by the new red sandstone dipping gently to the southward. The sandstones of the newer formation here contain little conglomerate, and are variegated by numerous greenish bands and blotches. They occupy the shore for some distance, and then contain a thick bed of trap conglomerate, consisting of large partially rounded fragments of amygdaloidal and compact trap, united by a hard brownish argillaceous cement. At a short distance westward, another bed of trap conglomerate of the same kind appears in the cliff. It is overlaid by a bed of dark clay, filled with angular fragments of black shale constituting a kind of breccia. The sandstone underlying this bed of trap contains small nodules of selenite and narrow veins of reddish fibrous gypsum. No other volcanic rocks occur in the coast-section near these trap conglomerates. Westward of this place, the section is occupied for about three miles by soft red sandstones with greenish bands, dipping generally to the south-west: some of them are divisible into very thin layers, whilst others are compact and form beds several feet in thickness.

Near Moose river, the red sandstones meet black shales and hard gray sandstones of the carboniferous system, containing *Poacites*, *Ferns*, and *Lepidodendra*.*

At this place the junction of the two groups of rocks was not, at the time of my visit, well exposed in the cliff, and had the appearance of a fault; but as seen in the horizontal section on the beach, the red sandstone with a south-west dip seems to overlie unconformably the carboniferous strata, dipping at a high angle to the E.N.E. On the west side of Moose river the carboniferous strata include three large masses of trap which have altered the grits and shales in contact with them, causing them to assume reddish colours. Beyond the last of these masses of trap, the shales and grits, there dipping to the north and north-east, have some red sandstone resting on their edges, and are succeeded by another great mass of trap forming a lofty cliff, and in part at least resting on soft red sandstone which it must have overflowed when in a fluid state. At the western side of this mass, or rather bed of trap, its upper surface is seen to dip to the W. S. W., and is conformably overlaid by red sandstones similar to those already described. These continue with various dips to a cove where there

* These fossil plants will be described in treating of the coal-measures.

is a break in the section, westward of which the coast exhibits the interesting and complicated appearances which I have endeavoured to represent in Fig. 7.

The lower part of the cliff, on the western side of the cove above mentioned, consists of hard, black, and reddish shales and grits, like some of those seen near Moose river, with a steep dip to the E.N.E. Resting on the edges of these are a few beds of red conglomerate and sandstone with greenish bands, dipping to the south-west, and apparently a remnant of more extensive beds. An enormous mass of trap conglomerate forms a high cliff towering above this little patch of sandstone, and is seen a little farther on to contain a wedge-shaped bed of red sandstone, and at its western extremity rests on red sandstone mixed with fragments of trap.* Here the trap conglomerate seems to be cut off by a fault, and abuts

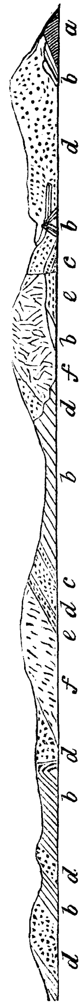


Fig. 7.—COAST-SECTION EAST OF SWAN CREEK.

(a) Shales and Sandstone of Carboniferous System dip E. N. E.
(b) New Red Sandstone dips to S. W. (c) New Red Sandstone with fragments of Trap.
(d) Trap Conglomerate and Breccia. (e) Amygdaloidal Trap. (f) Crystalline Trap.

* This section was examined in 1846. When I revisited the place in 1850, the front of this mass of trap conglomerate had fallen, and formed a huge slope of fragments.

against a great trappean mass, composed in ascending order of amygdaloidal trap, a wedge of red sandstone extending over part of the surface of the amygdaloid, a great bed of crystalline trap, and a bed of trap conglomerate. The western side of this mass rests on an apparently denuded surface of soft red sandstones, with S. S.W. dip. These are overlaid by another trappean mass, consisting of beds which appear to dip conformably with the underlying sandstones. At its western side it abuts against greatly disturbed red sandstones succeeded by other red sandstones dipping to the southward, and extending as far as Swan Creek.

On the west side of Swan Creek, the soft red and variegated sandstones are seen to dip to the north at an angle of 30°, and are underlaid by a bed of trap conglomerate, which rests against disturbed strata of a composition different from any previously occurring in this section. They consist of laminated, compact, and brecciated gray limestone, a bed of white gypsum, hard reddish purple and gray marls and sandstones, some of them with disseminated crystals of specular iron ore. I saw no fossils in these beds, but as they are identical in mineral character with some parts of the gypsiferous member of the carboniferous group, and have evidently been disturbed and altered before the deposition of the overlying trap conglomerate and red sandstone, I have no doubt that they belong to the carboniferous system, the sandstones and shales of which, with some trappean rocks, occupy the cliff between this place and Partridge Island five and a half miles distant. The new red sandstone in the vicinity of Swan Creek appears to form a small synclinal trough, occupying an indentation in the carboniferous rocks, and probably extending only a short distance westward of the mouth of the creek. The two islands near Swan Creek are detached masses of trap, resting on or rising through red sandstones, which at low tide are seen to extend between them and the shore. The red sandstone and trap, occurring in the section between Five Islands and Swan Creek, appears to be a very narrow band, extending parallel to the coast; and as the section is nearly in the general direction of the strike of the formation, it is probable that some of the trappean masses above described are portions of beds disconnected by faults and denudation.

Many beautiful crystallized minerals occur in the trap rocks of the sections described. The masses near Moose river contain cavities coated with opaque white varieties of quartz, in stalactitic and other imperfectly crystalline forms. Opposite the Two Islands, the fissures of the trap are lined with fine crystals of analcime and natrolite; and the fissures and vacant spaces of the trap conglomerate in the same neighbourhood contain a reddish variety of chabasie in rhombohedrons, often of large size.

At Clarke's Head, immediately west of Swan Creek, are well-characterized lower carboniferous rocks, including beds of limestone and gypsum, with some igneous rocks of porphyritic character, and probably much older than the new red sandstone period. On the top of the cliff, a bed of compact trap is seen to rest on the edges of the disturbed lower carboniferous rocks, over which it has flowed as a lava stream.

The trap conglomerate or breccia, noticed in describing the above section, is a rock of very singular character. It consists of large fragments, often more than a foot in diameter, of amygdaloid, cemented together by a hard brownish substance. The boulder-like fragments of trap which make up this rock have probably been blown out of a volcanic orifice, and then rolled into beds by the sea, and finally cemented by a paste made up of fine volcanic mud or ashes.

Beyond Clarke's Head, the coast extending toward Cape Chiegnecto is occupied by carboniferous rocks, for the most part in a very much disturbed condition, and it is only here and there that we meet with a small patch of new red, and its overlying trap, the remnants of a formation once continuous throughout the whole distance.

The first of these isolated patches is Partridge Island, a high rock of trap resting at its west side on red sandstone. Though called an island, it is connected with the shore, which consists of lower carboniferous sandstones and shales in a vertical and contorted condition, by a shingle-beach. The island itself presents a high cliff to the bay, and slopes downward on the land side. In approaching it from the east, we see a cliff of columnar trap extending from the shore to the summit of the rock. By scrambling at low tide around the south side, we find that this, like the basalt of Blomidon, is a thick irregular bed, and that amygdaloid and tufa succeed it in descending order. On the western side these last rocks occupy nearly the whole of the cliff, and may, when examined from a distance, be seen to consist of several beds distinguishable by different shades of colour. In some lights this difference is very perceptible. On this side the basaltic trap still appears, but it forms only a thin bed, capping the amygdaloid and tufa. Under all these beds, and in the north-west corner of the island, the sandstone peeps forth, dipping to the south-east.

The trap of Partridge Island contains a variety of interesting crystallized minerals. A honey-yellow variety of stilbite, crystallized in fine sheaf-like aggregations of crystals, is especially abundant, forming veins running up the face of the cliff. Being one of the most accessible and easily explored portions of the formation, this place has been much ransacked by mineralogists and amateurs; still large quantities of fine specimens may generally be seen going to waste on its beach. Amethyst, agate, chabazite, heulandite, apophyllite, and calc spar, may also be studied in some of their most beautiful forms at Partridge Island. The whole of these minerals have been introduced by the action of water, trickling through the numerous fissures of the porous amygdaloid and tufa, rocks which perhaps more than any others, are fitted to yield to water thus permeating them, the materials of crystallized silicious compounds.

Westward of Partridge Island, vertical and contorted carboniferous rocks occupy the shore as far as Cape Sharp, three miles distant. This promontory, which, like Partridge Island, presents a precipitous front to the bay, and slopes toward the land side, consists of trap resting on red sandstone. Here, however, trap conglomerate takes the place of the finer tufaceous matter seen at Partridge Island. It will be observed that though the red sandstone is not at these places seen very distinctly to rest on the carboniferous rocks, the former underlies the trap at a gentle angle, and dips southwards, or from the latter, while these are contorted and disturbed in the most extreme manner, serving at least to confirm the evidence, noticed at other places, of the later date of the new red. These contorted carboniferous sandstones and shales must have formed a coast-line, at the time when the red sand was washing in the sea, and the trap and scoriae being belched forth from submarine vents.

Beyond Cape Sharp, with the exception of the isolated mass of Spencer's Island, which I have not visited, we see nothing of the trap or red sandstone till we reach Cape d'Or, the last and noblest mass on this coast. At Cape d'Or, as at the Five Islands, a great mass of trap rests on slightly inclined red sandstone, and this again on disturbed carboniferous rocks, while behind and from beneath these last, still older slates rise into mountain ridges. Cape d'Or thus forms a great salient mass standing out into the bay, and separated from the old slate-hills behind by a valley occupied by the red sandstone and carboniferous shales. Cape d'Or differs from most of the trappean masses which have been described in the arrangement of its component parts. The upper part of the cliff consists of amygdaloid and tufa, often of a brownish colour, while beneath is a more compact trap, showing a tendency to a columnar structure. The whole forms a toppling cliff, more shattered and unstable in its aspect than usual.

Cape d'Or derives its name from the native copper which is found in masses, varying from several pounds in weight down to the most minute grains, in the veins and fissures which traverse the trap. It is sometimes wedged into these fissures, along with a hard brown jasper, or occupies the centre of narrow veins of quartz and calc spar. At first sight, these masses and grains of pure copper appear to have been molten into the fissures in which we find them. On more careful consideration of all the circumstances, and those of the associated minerals, it seems more probable that the metal has been deposited from an aqueous solution of some salt of copper, in a manner similar to that of the electrotype process. Why this should have occurred in trap rocks more especially does not appear very obvious; and, indeed, when we take a piece of native copper from Lake Superior, or Cape d'Or, with the various calcareous and silicious minerals which accompany it, nothing can be more difficult than to account on chemical principles for these assemblages of substances, either by aqueous or igneous causes. Nature's chemistry is often thus inscrutable in its details, for the behaviour of substances, when brought into contact with each other in the bowels of the earth, is often very different from that which they display in the laboratory; and, besides, nature's processes are not limited by time, and long continued chemical actions often produce effects which would hardly be inferred from experiments which are limited for their performance to hours or days.

The copper of Cape d'Or is not likely ever to become of mining importance, as it does not appear in large quantity in any one portion of the mass, and this latter is itself not of very great extent. The valuable discoveries, however, which have been made on the shores of Lake Superior, have in late years caused increased importance to be attached to the appearance of copper in trap rocks, and perhaps this and other cupriferous localities in the trap of Nova Scotia, may deserve a more careful examination than they have yet received.

The only remaining portion of the new red sandstone and trap formation is the little insulated spot of Isle Haut, lying off Cape Chiegnecto. I have not landed on this island; but, viewed from the sea, it appears to present nearly on all sides lofty cliffs of trap.

4. *General Remarks on the New Red of Nova Scotia.*

It will be observed, that in the notes referring to the coast-sections of the new red sandstone, I have given especial attention to its relations to the older rocks, especially those of the carboniferous system. I have done so, because, until very recently, much doubt existed as to the precise limits of this formation. The earlier writers on the geology of the province associated it with the red sandstones and gypsums of the carboniferous period, and described the whole as new red; and it was not until the first visit of Sir Charles Lyell that the great beds of gypsum and limestone of Windsor, the Shubenacadie, and other places, with their associated sandstones and marls, were recognised as lower carboniferous. Even after Sir Charles had published his results, these were dissented from both by Mr Logan and Dr Gesner, though both these geologists subsequently convinced themselves, and admitted that they had been in error; and the latter even went so far as to believe that the red sandstones of Blomidon and Cornwallis were also carboniferous. It then became a question whether there were really any rocks of the new red period in the province, and to determine this point, the writer undertook, in 1846, a careful examination of the red sandstone and trap on both sides of the bay, the results of which were published in the Proceedings of the Geological Society of London.* In this paper, the relations of the new red to the older formations in this province were for the first time accurately defined, by

* Journal of Geological Society, iv. p. 50.

ascertaining its structure, and its actual superposition on carboniferous strata, in the cliffs on the north side of Cobequid Bay and Minas Basin, and applying the facts thus obtained to the larger area of new red on the south side of the bay, in the manner indicated by the following quotation :—

"It appears from the facts above stated, that the red sandstones of Cornwallis and Horton, though not seen in contact with the carboniferous rocks, extend parallel to their disturbed strata with uniform north-west dips, and passing beyond them with the same dip, rest unconformably on the older slaty series. This arrangement, I think, satisfactorily proves that these red sandstones and the overlying trap are really newer than the carboniferous shales of Horton, and unconformable to them.

"Eastward of the estuary of the Avon, the country as far as the Shubenacadie River is occupied by a deposit of reddish, gray, and purple sandstones and marls, with large beds of gypsum and limestones abounding in marine shells. This gypsiferous series is much fractured and disturbed, and is in many places associated with dark shales containing fossil plants, like those of Horton Bluff, and thin seams of coal. This association of the gypsiferous series with dark fossiliferous shales, occurs at Halfway River, where coarse brown and gray sandstones, with imperfect casts of fossil trunks of trees, and a thick bed of anhydrite and common gypsum, rest conformably on the continuation of the dark beds of Horton Bluff. The carboniferous date of this gypsiferous series has been fully established by Mr Lyell; and though it contains red sandstones with veins of gypsum like those of Blomidon, these never extend to so great a thickness as that of the Cornwallis sandstones, without alternating with fossiliferous shales, or limestones, or with beds of gypsum. For this reason, in connexion with the undisturbed condition of the Cornwallis sandstones, their apparent unconformability to the carboniferous shales of Horton, and their identity in mineral character and association with trappean rocks, with the red sandstones of Swan Creek and Five Islands, I have no hesitation in separating them from the gypsiferous series and including them in the new red sandstone formation."

From the same paper, I quote the following general statements as to the age and mode of formation of the new red sandstone and trap, as affording in the most condensed form the conclusions at which I have arrived :—

" I am not aware that any rocks equivalent in age to the new red sandstones which have been described, occur in any other part of Nova Scotia. Red sandstones not unlike those of Cornwallis and Truro, occur in some parts of the newer coal-formation, as seen on the shores of the Gulf of St Lawrence ; but they alternate with beds of shale and gray sandstone, containing fossil plants of carboniferous species. Prince Edward Island, in the Gulf of St Lawrence, is chiefly composed of soft red sandstones, little disturbed, and similar in mineral character to the new red sandstone of Nova Scotia ; but they contain in their lower part silicified wood and other vegetable fossils, which I have not been able to distinguish from some found in the newer coal-formation. It is however probable that these red sandstones of Prince Edward Island may be post-carboniferous. It is not improbable that the new red sandstone of Connecticut, and some other parts of the United States, which is believed to be a Triassic deposit, may be of the same age with the formation above described. At present, however, from the want of fossils in the new red sandstone of Nova Scotia, it must be regarded as a post-carboniferous deposit of uncertain age.

"The new red sandstones now described appear to have been deposited in an arm of the sea, somewhat resembling in its general form the southern part of the present Bay of Fundy, but rather longer and wider. This ancient bay was bounded by disturbed carboniferous and Silurian strata; and the detritus which it received was probably chiefly derived from the softer strata of the carboniferous system. The arenaceous nature of the new red sandstone, as compared with the character of these older deposits, indicates that the ancient bay must have been traversed by currents, probably tidal like those of the modern bay, which washed away the argillaceous matter so as to prevent the accumulation of muddy sediment. When we consider the large amount of land in the vicinity of the waters in which the new red sandstone was deposited, the deficiency of organic remains in its beds is somewhat surprising, though this is perhaps to be attributed rather to the materials of the deposit and the mode of its accumulation, than to any deficiency of vegetable or animal life at the period in question.

"The volcanic action which manifested itself in the bed and on the margin of the bay of the new red sandstone, is one of the most remarkable features of the period. It has brought to the surface great quantities of melted rock, without disturbing or altering the soft arenaceous beds through which it has been poured, and whose surface it has overflowed. The masses thus accumulated on the surface have greatly modified the features of the districts in which they occur; especially the great ridge extending westward from Cape Blomidon. It is worthy of note, that this ridge, probably marking the site of a line of vents of the new red sandstone period, and occurring in a depression between two ancient hilly districts, so nearly coincides in direction with these older lines of disturbance. The trap rocks associated with the new red sandstone do not precisely coincide in mineral character with any that I have observed in other parts of Nova Scotia, though it is possible that some of the igneous rocks which have penetrated and disturbed the carboniferous rocks of various parts of this province, may belong to the new red standstone period, or are of a date not long anterior to it."

The red sandstone formation affords fine loamy friable soils, especially adapted to the culture of fruit and of the potato. The red sandstone valleys of Annapolis and King's are celebrated for their apple orchards, which furnish large quantities of excellent fruit for exportation to the other parts of the colonies, and even to the United States and Great Britain. The same districts are well adapted to the growth of Indian corn, large quantities of which are annually produced; and in those years in which the potato has failed over nearly the whole of America, it has remained uninjured in the red sandy loams of Cornwallis, the farmers of which have in consequence realized large sums by supplying the markets of the New England States. The calcareous matter which serves as a cement to the sandstone, and the alkalis derived from the fragments of trap which have been scattered through the soil in the drift period, add much to the fertility of these districts.

The agricultural capabilities of the trap are very different from those of the red sandstone. The soil, formed of decomposed trap, is very rich in the mineral ingredients most necessary to cultivated plants. It produces in its natural state a most luxuriant growth of timber, and yields excellent crops when recently reclaimed from the forest; but, perhaps from its porous and permeable texture, it is said not long to retain its fertility. I fear, however, that very bad methods of farming have generally been applied to it. The situation and exposure of the trap are singularly different from those of its contemporary the red sandstone. The latter usually appears in low and sheltered valleys. The trap, on the other hand, forms steep acclivities and high table-lands, exposed to the full force of the storms and changes of an extreme and variable climate; while its ranges of rugged cliffs, with their cascades, their terrible land-slips, and the wild beating of the winds and waves upon their bare fronts, present nature in an aspect altogether different from that which she wears in the quiet valleys of the red sandstone. These differences are, even in this new country, not without their influence on the mental and moral tone of the inhabitants of these dissimilar districts.

5. *Minerals of the New Red Sandstone and Trap.*

The red sandstone of this formation does not contain any valuable repositories of useful minerals. It frequently includes small veins of foliated and fibrous gypsum, and in one locality, near Cornwallis Bridge, I have observed in it a bed of impure manganese ore. These things are, however, of too small dimensions to be of any practical value. The sandstone itself is usually too soft and perishable to form a useful building-stone. Blocks and slabs of it are, however, quarried for fire-places and chimneys, and are said to be well adapted to this use.

The trap contains some small veins of metallic minerals, not of mining importance; but it abounds in the finely crystallized minerals usually contained in the ancient volcanic rocks, and the long range of coast-line which it occupies, and the very rapid waste which it is undergoing, place these within reach of the collector in almost unexampled abundance. As these minerals are of much interest to mineralogists, and the trap formation of Nova Scotia has become somewhat celebrated for the abundance and fineness of the specimens which it affords, I give below a catalogue of the mineral species that I have collected, with references to the localities from which I have specimens in my cabinet, and which I believe to be the most productive of fine specimens. Many other localities, however, are mentioned by Messrs Jackson and Alger, and Dr Gesner, who have devoted especial attention to these beautiful productions. I may remark, however, that interesting specimens may be found in almost all parts of the trap coasts, by inquiring for the spots in which land-slips have most recently occurred.

Magnetic Iron Ore—in octahedrons and massive; Partridge Island, North Mountains of King's.

Specular Iron Ore—in tabular crystals; Sandy Cove.

Native Copper—in irregular masses; Cape d'Or, Briar Island, and Peter's Point.

Gray Sulphuret of Copper, *Green Carbonate of Copper*, *Oxide of Copper*, associated with Magnetic Iron, at Indian Point, also Cape d'Or; not in fine specimens.

Quartz—occurs in a great variety of beautiful forms, among which are Amethyst and Transparent Quartz in six-sided pyramids, Agate, Chalcedony, Carnelian, and Jasper. The best localities for these minerals are Blomidon, Scott's Bay, Digby Neck, and Partridge Island. A fine variety of Moss Agate occurs at the Two Islands, and a sort of Quartz Sinter in imperfect crystals and beautiful coralloidal forms in the neighbouring promontory of M'Kay's Head. Large quantities of fine agates and jaspers, applicable to ornamental purposes, may be found at Cape Blomidon and Digby Neck; and the amethyst of the same localities is sometimes in sufficiently large crystals to admit of being cut for ring-stones, seals, &c.

Opal—occurs at a few localities, in the plain variety of semi-opal; and very frequently, in the form of white chalky Cacholong, forms the basis of fine crystallizations of amethyst, having lined the cavities of the trap before the latter was deposited.

Heulandite—Hydrous Silicate of Alumina and Lime, in fine rhombic prisms, colourless and light flesh colour; at Blomidon, Black Rock, Partridge Island, &c. Minute yellow crystals are found at Two Islands.

Stilbite—Hydrous Silicate of Alumina, Lime and Soda, or Potash, in radiated and sheaf-like aggregations of crystals of honey-yellow and brown colours; at Partridge Island, Sandy Cove, Blomidon, Black Rock, &c. Fine groups of white crystals are found at Black Rock in King's County and its vicinity.

Mezotype.—The variety or species *Natrolite*, the Hydrous Silicate of alumina and soda, is found in small prismatic crystals and in radiated masses of crystals, at Blomidon, Two Islands, M'Kay's Head, Scott's Bay, &c. The variety *Scolecite*, or Hydrous Silicate of alumina and lime, is found at the same localities, also in radiating and prismatic forms.

Laumonite—Hydrous Silicate of Alumina and Lime, in whitish and light red prismatic crystals; at Peter's Point, Black Rock, Sandy Cove, &c. This mineral, very beautiful when freshly taken from the rock, loses water and becomes opaque and brittle when exposed to air and light. I have found that this change takes place very rapidly when the specimens are exposed to sunlight, and is much retarded by keeping them in darkness. Immersion in gum-water is also a preventive.

Chabazite—Hydrous Silicate of Alumina, Lime, Soda, and Potash. The flesh red, brownish red, purplish red, and yellowish red varieties, which have been named *Acadiolite*, are found abundantly at Two Islands in trap conglomerate. Their red colour is due to the peroxide of iron which abounds in the cement of the conglomerate and the neighbouring red sandstone. Grayish and white varieties are found at the same place, also at Cape d'Or and Digby Neck. The usual form is the primary rhombohedron; the six-sided pyramid occurs rarely at Cape Blomidon.

Analcime—Hydrous Silicate of Alumina, Soda, and Lime. Trapezohedrons of white and dull reddish colours, occur at Blomidon, Two Islands, M'Kay's Head, &c.

Thomsonite—Hydrous Silicate of Alumina, Lime, and Soda or Potash. I have a small specimen in radiating crystals from the North Mountains of King's County.

Prehnite—Hydrous Silicate of Alumina, Lime, and Iron. I have found specimens of this mineral at Clarke's Head in porphyritic rocks near the trap, but possibly of greater age.

Apophyllite—Hydrous Silicate of Lime and Potash is found at a number of places, but in none very plentifully. Green and white crystals, aggregated in plates or in square prisms, occur at Blomidon, Peter's Point, Two Islands, and Cape d'Or. The finest specimens that I have seen are from the latter place, and present rosette-shaped groups of crystals. They were collected by the late Professor Chipman of Acadia College, and are now, I believe, in the museum of that institution.

Calcareous Spar—Carbonate of Lime is found in fine rhombohedral crystals of white and yellowish colours, and also in the imperfect scalenohedrons known as Dogtooth spar, at Partridge Island, Black Rock, Two Islands, &c.

CHAPTER VII.

THE NEW RED SANDSTONE—*Continued.*

PRINCE EDWARD ISLAND — AGE OF ITS SANDSTONES — FOSSIL PLANTS — REPTILIAN REMAINS — USEFUL MINERALS AND SOIL.

Prince Edward Island, which stretches for 125 miles along the northern coast of Nova Scotia and New Brunswick, has everywhere a low and undulating surface, and consists almost entirely of soft red sandstone and arenaceous shale, much resembling the new red of Nova Scotia, and like it having the component particles of the rock united by a calcareous cement. In some places the calcareous matter has been in sufficient abundance to form bands of impure limestone, usually thin and arenaceous. Over the greater part of the island these beds dip at small angles to the northward, with, however, large undulations to the south, which probably cause the same beds to be repeated in the sections on the opposite sides of the island. This is the general character of the island in all parts of it that I have explored, with the exception of a few limited spots on the south side, which present brown and gray sandstones and shales, not unlike some of the upper parts of the coal-formation of Nova Scotia, and containing a few fossil plants. These are apparently the lowest and oldest beds in the island; and the determination of their true geological age is important as affording data for ascertaining that of the red sandstone. I shall therefore give a somewhat detailed account of these beds as they appear at Orwell or Gallows Point on the south coast, about ten miles east of Charlottetown.

In approaching this place the red sandstone forms long undulations sloping gently toward the shore, and the coast displays a series of low points, terminated by red sandstones, which, though not hard, have better resisted the wearing action of the waves than the softer strata which have occupied the intermediate creeks. Passing through Cherry Valley, the country has the same appearance until we enter the by-road to Orwell or Gallows Point, when the soil loses its bright red colour, and assumes a grayish tint, and more argillaceous composition, indicating to the geological traveller a change in the composition of the rocks beneath. On reaching the extremity of the Cape, a good section of a considerable variety of rocks may be seen. Their dip is to the E. S. E. by compass (variation about 19 deg. W.) at an angle of only 6 degrees; consequently in proceeding along the shore to the westward, lower and older rocks appear cropping out from beneath those which overlie them. Commencing with those which are higher in order, red and brown sandstone of soft and rather coarse texture occupy a considerable portion of the shore, projecting in low reefs into the sea, and rising to the height of a few yards in a water-worn cliff. Beneath these appear harder gray sandstones, containing gray and brown impure limestone, in beds a few inches in thickness. One of these beds contains a number of fragments of fossil plants, in a very imperfect state of preservation. Beneath these strata is a bed of sandstone, containing small nodules of red ochre, and in one place the impression of a large fossil tree, whose wood has disappeared, leaving a mould which has been filled with ochreous clay. Proceeding in the same direction, we find beds of considerable thickness consisting of gray and brown clay, apparently without coal or fossils. Beneath these are several beds of brownish sandstone of various qualities, one stratum appearing to be sufficiently hard for building purposes. Embedded in one of these layers appear some large fossil trees, one of them nearly three feet in diameter; they are prostrate and much flattened by pressure, and the place once occupied by their wood is now filled with a hard dark-coloured silicious stone, which, when polished in thin slices, and examined by the microscope, displays the structure of the original wood. These trees appear to have been partially decomposed before they were submitted to the petrifying process, and the rents caused by decay are now filled with red-coloured crystals of Sulphate of Barytes. In some of the specimens the fissures are coated with silicious crystals, and portions of some of the trunks consist of a soft carbonaceous ironstone retaining the woody structure. These fossil trees carry back our thoughts to a period when Prince Edward Island was a tract of submarine sand, in which drift trees were embedded and preserved, and which has since been indurated and partially elevated above the level of the sea. In another of these sandstone beds are the remains of a large tree compressed to the thickness of an inch, and converted into friable shining coal, coloured in some places with green carbonate of copper.

These beds must belong either to the very newest portions of the coal-formation, which in some particulars they closely resemble, or to the lower part of the new red sandstone; and in either case the sandstones of the greater part of Prince Edward Island will be new red. Unfortunately I could not observe whether the latter are superimposed conformably or unconformably on the lower beds, and the fossils are hardly sufficiently well characterized to indicate to which epoch they belong. With the view of obtaining from them all the information they are capable of affording, I have examined the fossil wood of this locality, and some specimens found lying loose on the surface at Des Sables and other places in the island, with the following results.

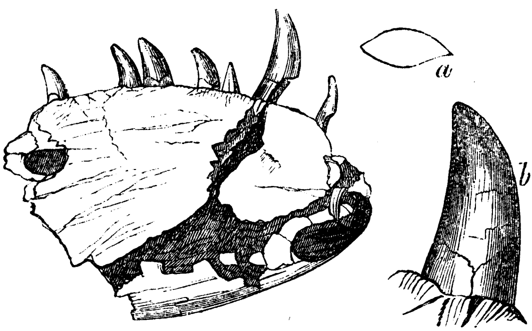
Thin slices of the specimens from Orwell Point show under the microscope in the transverse direction a dense tissue of quadrangular cells, arranged in rows, with numerous but narrow medullary rays. Longitudinal slices in the direction of the medullary rays show elongated parallel cells, with traces of hexagonal discs on the walls of the cells, there being two rows of discs only in each cell. These characters are those of coniferous wood (that of the pine tribe), and of that particular type of coniferous trees which appears in the northern hemisphere only in the palæozoic and mesozoic rocks; though in the southern hemisphere this peculiar structure of the wood is still found in the Araucarian pines of Australasia. The specimens from other parts of Prince Edward Island show similar structures, some of them even more distinctly.

On comparing these specimens with a large number of slices of coniferous wood from various parts of the coal-formation of Nova Scotia and New Brunswick, I find that the latter are wider or more open in the cellular tissue, and with usually more than two rows of discs on each cell. The wood from Prince Edward Island, therefore, though of a type which may be carboniferous, does not appear to be quite identical with any species found in the coal-formation of the opposite coast. Such wood might readily occur either in the upper coal-formation or in the next geological formation in ascending order, the *Permian System* of geologists.

A much more interesting fossil, which greatly aids in fixing the geological age of the red sandstones of Prince Edward Island, has recently been discovered. It is a portion of the jaw of a large *carnivorous reptile*, apparently closely allied to the *Thecodontosaurus* of the English new red sandstone. This creature must have rivalled in dimensions the modern alligators, and belonged to a more perfect or higher type of structure, represented in the present world only by lizards of moderate or small dimensions. It was, in short, one of that giant *reptile aristocracy* which constituted the highest animal type in the middle or secondary period of geological time, which in consequence has long been known as the peculiar "age of reptiles."

The specimen was found by Mr D. M'Leod of New London, on the north side of the island, in the bottom of a well, at the depth of twenty-one feet nine inches, and embedded in the ordinary soft red sandstone of that part of the island. The discoverer was desirous of disposing of the specimen; and the writer being convinced that it would prove of great interest to naturalists, if examined and described by a competent anatomist, offered to negotiate its sale. By the advice of Sir Charles Lyell, then in America, it was offered to the Academy of Natural Sciences, Philadelphia; for which it was finally purchased for the sum of thirty dollars. It was described and figured in the Proceedings of the Society by Dr Leidy, from whose elaborate paper I extract the following description, which, with the aid of Fig. 8, will serve to give some idea of its character.

Fig. 8.



Outline of Jaw of Bathygnathus Borealis.
(*a*) Cross section of Second tooth, nat. size. (*b*) Fifth tooth, nat. size.

"The specimen consists of the right dental bone, considerally broken, attached by its inner surface to a mass of matrix of a red granular sandstone, with large, soft angular red chalk-like stones embedded in it.* The fossil has seven large teeth protruding beyond the alveolar margin of the jaw; and it is hard, brittle, and cream-coloured, and stands out in beautiful relief from

* These are probably concretions.—J. W. D.

its dark red matrix. The jaw indicates a lacertian reptile, and in comparison with that of other known extinct and recent genera, is remarkable for its great depth in relation to its length.

"The depth of the dental bone is five inches, whilst its length in the perfect condition appears not to have exceeded seven and a quarter inches; for in the specimen the middle part of the posterior border is so thin and scale-like, that I am disposed to think it here came in contact with the supra-angular and other neighbouring bones.

"The teeth, in their relation to the dental bone, are placed on the inner side, and rest against the alveolar border, which rises in a parapet external to them. Whether this parapet is supported by abutments between the teeth, as in *Megalosaurus*, I cannot clearly ascertain, from the inner side of the jaw being so closely adherent to the matrix. The dental bone, if it be considered complete in its length in the specimen, is capable of containing a series of twelve teeth.

"As the teeth were worn away or broken off, they were replaced by others produced at their inner side, as is indicated in the specimen by a young tooth, which is situated internal to and is concealed by the largest mature tooth. The enamelled crowns of the fully protruded teeth are exserted at their base for several lines above the alveolar border of the jaw. They are compressed, conoidal, and recurved; but compared with those of *Megalosaurus* they are not so broad, compressed, nor recurved, and they are more convex externally, and are less so internally. They resemble much in form those of the recent *Monitor ornatus*, but are less convex internally. The anterior and posterior acute margins of the crowns are minutely crenulated; and the crenulations commence just below the tip, and descend as far as the enamelled base."

Dr Leidy then proceeds to describe the teeth minutely, remarking that the first in the series is narrow, and not crenulated, and that it is separated from the second by a space sufficiently large to have held another tooth. "The second tooth seen in the figure is the largest and longest of the series; and its enamelled crown when perfect was about an inch and three quarters long by seven lines in breadth at the base. Its fang can be seen in the wide fissure of the jaw, descending two inches from the alveolar border; and being broken, it is observed to be hollow as far as the enamelled crown." The third tooth has not fully protruded, and the fourth, fifth, and sixth, have nearly the same size and form, and are highly perfect piercing and cutting instruments, with sharp and finely crenulated edges. The space between the fourth and fifth tooth is sufficient to contain one additional tooth, and that between the sixth and seventh is sufficient for two, and has in it a young tooth just appearing above the jaw. There is an impression of an eighth tooth on the matrix. The whole jaw may thus when perfectly filled have accommodated twelve teeth on each side of the mouth; in predaceous reptiles, however, the teeth are often broken and are renewed, so that in adult animals they are never uniform or complete.

From the extraordinary depth of the dental bone relatively to its length, and from its northern locality, Dr Leidy has named the animal to which it belonged *Bathygnathus Borealis*. He adds: "This interesting fossil is the second authentic discovery of saurian bones in the new red sandstone of North America; the first being those found near Hossac's Creek, in Lehigh county, Pennsylvania, by Dr Joel Y. Shelley, and described by my friend Mr Isaac Lea, under the name of *Clepsysaurus Pennsylvanicus.*"

The remains of this ancient reptile must have been drifted by the sea, and embedded in the sand now forming the red sandstone of New London. Probably its bones, after the decay of the body, were scattered over the bottom, to be buried under the next layers of sand spread over it. What information can we derive from the fragment which has been handed down to our time, respecting the structure and habits of the creature, and the age of the rock in which it was embedded? The teeth prove decisively that the animal to which they belonged was fitted for capturing and devouring other animals. It is difficult to imagine an instrument better fitted for cutting and tearing asunder than a jaw furnished with these sharp and serrated teeth. The size of the teeth, and the shortness and depth of the jaw, indicate an amount of power sufficient for the destruction of large animals; perhaps fishes, smaller reptiles, or even clumsy and gigantic wading birds, all of which are known to have existed as far back as the new red period. Among living carnivorous reptiles, those which like the crocodile are clumsy and less agile in their movements, have elongated snouts to enable them the more easily to secure their prey; those which like the serpents can move with extreme rapidity, have comparatively short jaws. We may therefore infer that this creature was furnished with means of very rapid movement, either on land or water. It could spring or dart on its prey. If we had the remains of its extremities, we could determine what its means of movement were, and whether the sea or the land was its sphere of activity. Without these nothing very certain can be determined on these subjects. The apparent thinness and density of the bone, however, and its width of surface, convey the impression that it was intended to combine great strength with great lightness, and therefore that it belonged to a creature of terrestrial habits. Probably considerations of this kind, though he does not state his reasons, induced Dr Leidy to hazard the conjecture, "Was this animal probably not one of the bipeds which made the so-called bird-tracks of the new red sandstone of the valley of the Connecticut?" This conjecture of an eminent anatomist, itself shows how singular and anomalous among reptiles is this fossil fragment.

Had this fossil been specifically identical with any reptile whose remains have been found in other countries, the age of whose rocks has been determined, it might have given conclusive evidence as to the true geological age of the red sandstones of New London. It is, however, a new species of a new genus, quite distinct therefore from any species found elsewhere. Still it gives some important testimony. It belongs to a group of large and highly organized carnivorous reptiles now extinct, and which occupied in the secondary period of geology a place afterwards taken by the carnivorous mammalia. No reptiles of equal grandeur and perfection have existed since the beginning of the tertiary period; and so far as we know, none were created before the very close of the palæozoic period. Between these eras, therefore, we may place our fossil; but this gives a very wide range. There is, however, a difference of *facies* or general appearance between the reptiles of different parts of this long reptilian dynasty, which enables us to distinguish between them, just as an antiquary might distinguish a coat of armour of the time of John of Gaunt from one of the time of Henry the Seventh. Now, as already hinted, the reptile in question appears to have most nearly resembled the *Thecodontosaurus* and *Palæosaurus*, reptiles of the lower new red or *Permian* system of Europe, than any other known animals; hence it confirms the view generally adopted on other grounds, that this is the age of the Prince Edward Island new red, and its corresponding formation in Nova Scotia. I only add, that the occurrence of this family of reptiles in rocks so old, is one of the geological objections to the so-called "development" theory of some popular writers, whose zeal to dispense with acts of creation outruns their discretion. "This family of reptiles is allied to the living *monitor*, and its appearance in a primary or palæozoic formation," observes Mr Owen, "is opposed to the doctrine of the progressive development of reptiles from fish, or from simpler to more complex forms; for if they existed at the present day, these monitors would take rank at the head of the lacertian order."*

The red sandstone of Prince Edward Island is not known to contain any useful minerals except limestone, which occurs in thin beds in several places. Indications, apparently of no economic value, of ores of copper and manganese occur in a few places. The red sandstone everywhere supports a fine, friable, loose, loamy soil, which renders Prince Edward Island one of the finest agricultural districts in the lower provinces—a

* Lyell's Manual of Geology.

distinction which well compensates the want of valuable minerals. I have not observed in any of my excursions in the island, any traces of igneous action; but Dr Gesner, in the report of a survey undertaken for the provincial Government, mentions the occurrence of a limited mass or dike of trap on Hog Island, an isolated spot which I have not visited, in Richmond Bay; and which I have accordingly coloured in the map with the tint appropriate to that rock. This fact, though not of any importance in establishing the age of the formation, establishes an additional analogy between it and the new red of Nova Scotia.

CHAPTER VIII.

THE CARBONIFEROUS SYSTEM.

GENERAL REMARKS—SYNOPTICAL TABLE—GEOGRAPHICAL ARRANGEMENT—CARBONIFEROUS DISTRICT OF CUMBERLAND—SOUTH JOGGINS SECTION.

I HAVE had frequent occasion to state that the lower beds of the new red sandstone rest on the edges of the upturned strata of the great geological series now to be described. In entering, therefore, on the carboniferous system, we go one whole period back in the history of the earth, to a time when the rocks that formed the shore of the red sandstone sea were themselves being deposited in the form of sediment, in waters which washed the sides of the Cobequid hills, and the other old metamorphic ranges of the province.

The carboniferous system is of inestimable importance in an economical point of view, from the number and value of its useful minerals. It is also of exceeding interest to the geologist, in consequence of the singular and interesting monuments which it contains of the changes of the earth's surface, and of the character of its inhabitants, during a long and important period.

None of the geological formations surpasses it in either of these respects; and in Nova Scotia and the neighbouring colonies there is none which approaches to an equality with it. It is also a very thick group of beds, and these are very varied in their character. For this reason, I shall commence my description with a synoptical table of its various members, as they have now been ascertained in Nova Scotia. An examination of this table will enable the reader much more clearly to comprehend the statements hereafter to be made.

SYNOPSIS OF THE CARBONIFEROUS ROCKS OF NOVA SCOTIA.

UPPER OR NEWER COAL-FORMATION.

Grayish and reddish sandstones and shales; with beds of conglomerate, and a few thin beds of limestone and coal, the latter not of economic importance.—Thickness 3000 feet or more.

Characteristic Fossils.—*Coniferous Wood*, *Calamites*, *Ferns*, *&c.*

Localities.—Cumberland north of the Cobequid mountains, Northern Colchester, Pictou. Well exposed in the Joggins coast, and in the coast of Northumberland Strait west of Pictou Harbour.

LOWER OR OLDER COAL-FORMATION.

Gray and dark-coloured sandstones and shales, with a few reddish and brown beds; valuable beds of coal and ironstone; beds of bituminous limestone, and numerous underlays with *Stigmaria*. Thickness 4000 feet or more.

Characteristic Fossils.—*Stigmaria*, *Sigillaria*, *Lepidodendron*, *Poacites*, *Calamites*, *Ferns*, *&c.* Erect trees *in situ.* Remains of Ganoid Fishes, *Cypris*, *Modiola*, and Reptiles of three species.

Localities.—Cumberland north of Cobequid mountains; Pictou, especially East River; Port Hood, Inhabitants Basin, and other places in Inverness and Richmond; Eastern part of Cape Breton; parts of Colchester south of Cobequid mountains. Finest exposures South Joggins, and near Sydney, Cape Breton.

LOWER CARBONIFEROUS OR GYPSIFEROUS FORMATION.

Great thickness of reddish and gray sandstones and shales, especially in upper part; conglomerates, especially in lower part; thick beds of limestone with marine shells, and of gypsum. Thickness 6000 feet or more.

Characteristic Fossils.—*Productus*, *Terebratula*, *Encrinus*, *Madrepores*, and other marine remains in the limestones. *Coniferous Wood*, *Lepidodendron*, *Poacites*, *&c.*, in shales and sandstones. Scales of Ganoid Fishes very abundant in shales associated with lowest beds, in which are also small coaly seams and bituminous beds.

Localities.—Northern Cumberland, Pictou, Colchester, Hants, Musquodoboit in Halifax county, Guysboro' in part, parts of Inverness, Richmond, Cape Breton, and Victoria.

The actual superposition and arrangement of all this great thickness of beds, are ascertained by the examination of coast and river sections, in which portions of the series are seen tilted up, so that they can, by proceeding in the direction toward or from which they incline, be seen to rest on each other. There is one coast-section in the province so perfect that nearly the whole series is exposed in it. On the other hand, there are large areas in which the lower portion alone exists, and perhaps never was covered by the upper portions; and there are other areas in which the upper members have covered up the lower, so that they appear only in a few comparatively limited spots.

The area occupied by carboniferous rocks in Nova Scotia and New Brunswick is very extensive; and in Nova Scotia it is divided by ridges of the older metamorphic rocks into portions which may for convenience be considered separately. These are—

1. The Cumberland Carboniferous district, bounded on the south by the Cobequid hills, and continuous on the north-west with the great Carboniferous area of New Brunswick, which will be considered along with it.

2. The Carboniferous district of Hants and Colchester, including the long band of carboniferous rocks extending along the south side of the Cobequids, and that reaching along the valley of the Musquodoboit river.

3. The Carboniferous district of Pictou, bounded on the south and east by metamorphic hills, and connected on the west with the Cumberland district and that last mentioned.

4. The Carboniferous district of Sydney county, bounded by two spurs of the metamorphic hills.

5. The long stripe of Carboniferous rocks extending from the Strait of Canseau westward through the county of Guysboro'.

6. The Carboniferous district of Richmond county, and southern Inverness.

7. The Carboniferous district of Inverness and Victoria counties.

8. The Carboniferous district of Cape Breton county.

1. *Carboniferous Districts of Cumberland.*

The rocks of the great Cumberland carboniferous area have a general trough-shaped arrangement, which in the western part of the county at least appears to be very regular. (See Fig. 1.) On the south side, all along the base of the Cobequids, we find conglomerates and other lower carboniferous rocks dipping to the north, and forming the southern edge of the trough. Resting on these are the beds of the coal-formation, still dipping to the northward. Toward the centre of the county, we find the rocks of the upper coal-formation slightly inclined and finally dipping to the south, to form part of the northern side of the trough. Proceeding onward, we find the repetition of the older coal-formation and lower carboniferous series with southerly dips. The latter extends into New Brunswick, where it turns over and dips to the northward, underlying the great carboniferous plain of that province. In crossing the county of Cumberland, this regular arrangement of the beds is evidenced by the long parallel ridges that cross the country from east to west, and which are produced by the outcropping edges of beds of firm sandstone, that have resisted wasting agencies better than the softer beds that occur between them. On the western coast of the county, the cliffs fronting Chiegnecto Bay and Cumberland Basin, and which have been cut and are kept clean and fresh by the same agencies which we have already noticed in treating of the trap and new red sandstone coasts, furnish the finest and most complete section of the carboniferous rocks in Nova Scotia, and one of the finest in the world; and on this account I shall commence with its description, as affording the best guide to the understanding of the more obscure and complicated parts of the formation.

This remarkable section, now well known to geologists as the South Joggins section, extends across almost the whole north side of the Cumberland trough, and exhibits its beds in a continuous series, dipping S. 25° W. at an angle of 19°; so that in proceeding along the coast from north to south, for a distance of about ten miles, we constantly find newer and newer beds, and these may be seen both in a bold cliff and in a clean shore, which at low tide extends to a distance of 200 yards from its base. We thus see a series of beds amounting to more than 14,000 feet in vertical thickness, and extending from the marine limestones of the lower carboniferous series to the top of the coal-formation. In the cliff and on the beach, more than *seventy* seams of coal may be seen, with their roof-shales and underclays, and erect plants appear at as many distinct levels; while the action of the waves and of the tide, which rises to the height of forty feet, prevents the collection of *debris* at the foot of the cliff, and continually exposes new and fresh surfaces of rock.

In describing this remarkable section, I shall take as guides Mr Logan's elaborate section of the whole of the coast, including 14,570 feet 11 inches of vertical thickness, and a re-examination of 2800 feet of the most interesting part of the section, made by Sir Charles

VIEW ON THE JOGGINS SHORE. 1853.

Erect tree & fragments of Lepidodendron & Stigmaria in the foreground.

(Coal Formation)

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Lyell and the writer in 1852 and 1853, and published in the proceedings of the Geological Society of London for the latter year. I shall proceed in the *ascending* order, or from the older to the newer beds, and shall interpret each new appearance as it occurs. In this way I hope to give to the attentive reader a more accurate idea of the structure and mode of formation of a coal-field than he could obtain in any other way, except by an examination of the actual coast-section described.

The oldest beds of the lower carboniferous series do not appear in the coast-section, but may be studied at Napan river and other places near Amherst. They consist of sandstones and marly clays, including thick beds of limestone and gypsum. The mode of formation of this last rock I shall not now notice, as better opportunities will occur hereafter. Respecting the limestones, I may remark, that they are marine deposits, formed in an open sea, tenanted by various kinds of shell-fish, &c., the remains of which still exist in the limestone. They are principally bivalves of a family (the *Brachiopoda*), once very abundant, but in the modern world represented by very few species; and the most abundant shell of this kind in these limestones is the *Producta Scotica*, a finely striated species, having one valve very convex externally, and the other very concave. It is found in rocks of the same age in Great Britain. There is also a Nautilus, nearly resembling in form the Nautilus of recent tropical seas, but smaller in size; and there are numerous fragments of *Encrinites*, a tribe of creatures allied to modern star-fishes, but furnished with a stem by which they were attached to the bottom, while their radiating arms extended on all sides in quest of prey. These limestones must have been formed in a sea whose waves lashed the slopes of the Cobequid mountains and ground up the pebbles of old rocks which now form conglomerates on their flanks, while beds of shells were accumulating in its more quiet depths. Its northern boundary may have been the silurian and metamorphic rocks of Lower Canada and Labrador.

The limestones above described dip to the southward; and if we proceed across the country in the direction of their strike, we find them again with the same fossils on the Hebert river near Minudie; and in the opposite or eastern direction, at several places nearly in a line between the Nepan and Pugwash Harbour on the shore of Northumberland Strait, where the limestone with its characteristic marine fossils is largely developed. Leaving in the meantime the rocks that lie to the northward of and under this limestone, we may take that part of it which appears near Minudie as the base of the Joggins section. Following its direction across from Hebert river to the Joggins coast, we find there that it is overlaid conformably by a great series of sandstones and shales, which we shall now proceed to describe, just as we should see them if walking along the coast; and if this process should seem at all tedious to the reader, I beg him to remember, that this finely exposed series of beds furnishes the key which will enable us to understand the whole structure of the coal-formation of Nova Scotia and New Brunswick; and farther, that this key to facts so important both in geology and in reference to the economical value of the coal-fields, is now for the first time brought in a complete form before the general reader.

Commencing at Seaman's Brook in Mill Cove, and taking Mr Logan's carefully detailed section as our guide, we see in the low cliff and in the shore-reefs beds of reddish and gray sandstone, alternating with reddish shales or beds of hardened and laminated clay. In a few places we find among these beds layers of gypsum and of a coarse sandy limestone. In several of the gray beds there are fragments of trunks and branches of trees, converted into coal, and resembling what they certainly once were, drift trees embedded in sandbanks. Associated with these remains, we find in four of the beds small quantities of the gray sulphuret and green carbonate of copper, minerals introduced into these beds by waters holding sulphate of copper in solution, which the carbonaceous matter of the fossil wood has deoxidized and thereby caused its deposition. Such appearances are not infrequent in beds containing fossil plants, but they have not hitherto been found to afford sufficient quantities of copper to be of any practical value. I may also remark here, in connexion with the occurrence of fossil plants in gray rather than red beds, that in the coal-formation, as in the modern marshes and peat-bogs already described, the presence of vegetable matter has often destroyed the red colour of beds tinged with peroxide of iron, and hence the fossils are in some sense the cause of the gray colour of the beds in which they are found. Beds of the kinds just described occupy the shore to a distance equal to 2308 feet, as ascertained by the careful measurements of each bed made by Mr Logan. I may remind the reader, that as these beds dip to the south-west, we are constantly proceeding from older to newer beds.

In the succeeding 3240 feet of beds we find a similar series, with some additional features indicating our approach to the great masses of fossil vegetables entombed in the true coal-measures which overlie them. There are here nine seams of coal, all very thin, their total thickness being only ten inches; and under each seam we observe a bed of clay or crumbling argillaceous sandstone, with remains of roots belonging to plants to be noticed hereafter, and which had much to do with the accumulation of the coal. We find also among this thick series of sandstones and shales, several bands of hard black limestone, yielding a bituminous and almost animal smell when rubbed or struck, and containing abundance of little diamond-shaped plates with smooth and polished surfaces, which if we are acquainted with the animals of the coal period, we recognise as the scales of a singular tribe of fish, the Ganoids, of which numerous species abounded in the carboniferous period, but which are now represented in America only by the bony pikes of the Canadian lakes. There is also in this part of the section a far greater prevalence of gray sandstones than in the part previously noticed, and in these gray sandstones are immense quantities of fossil plants, most of them trunks of trees confusedly intermingled and flattened more or less by pressure; others long cylindrical reed-like stems (*Calamites*), or immense creeping roots dotted all over with pits from which their rootlets sprang (*Stigmariæ*). In most of these fossils the bark is converted into hard shining coal, but the wood has decayed away, and the hollow cavity left within the bark, has been filled with sand now hardened into stone like that without. This is a distinct process from petrifaction properly so called, in which the minute cells of the wood become so filled with mineral matter that the minutest parts of the structure are preserved. Some of the gray sandstones of this part of the section are of great thickness, and in them are the most important quarries of the Joggins grindstones, which are exported to all parts of the United States. These grindstones have been formed from beds of sand deposited in such a manner that the grains are of nearly uniform fineness, and these grains have been cemented together with just sufficient firmness to give cohesion to the stone, and yet to permit its particles to be gradually rubbed off by the contact of steel. A piece of grindstone may appear to be a very simple matter, but it is very rarely that rocks are so constituted as perfectly to fulfil these conditions, and hence the great demand for the Joggins stone.

This part of the section suggests many interesting inquiries respecting the mode of formation of some of its beds, but I postpone these till we arrive at those portions which show coal-measures, properly so called, on a somewhat larger scale.

Proceeding along the coast, we find that the strata last described are overlaid by a series amounting to 2082 feet in vertical thickness, and differing from the last group of beds in containing fewer gray sandstones, no coal-seams or bituminous limestones, and comparatively few fossil plants, and these but imperfectly preserved. This series then consists in great part of reddish shales and reddish and gray sandstones. These and indeed the greater part of the rocks composing the part of the section we have examined, must originally have consisted of beds of reddish sand and mud, spread over the bed of that ancient carboniferous sea once tenanted by the shells of the Napan limestone, much in the same manner that layers of mud are now deposited in the Bay of Fundy.

We have now, after passing over beds amounting altogether to the enormous thickness of 7636 feet, reached the commencement of the true coal measures, or that part of the section which was examined in detail by Sir Charles Lyell and the writer in 1852 and 1853. Owing to the comparative softness of the rocks of the last group described, they have in many places been worn down nearly to the level of the beach, so that they cannot be very distinctly observed. Fortunately, however, just where the section becomes most interesting, the beds rise into a high cliff, and every one can be measured, and its mineral character and fossil contents observed, by any person who is content to labour diligently, and who is not too apprehensive that he may be buried under the falling cliffs, which, especially in the spring and in stormy weather, often send down very threatening showers of stones and sometimes terrible landslips. This portion of the section then I shall give in detail, as one of the best specimens in the world of that wonderful series of fossiliferous beds constituting the great coal-measures of the carboniferous period. In doing so, I shall first copy the section as it appears in my notes, and nearly as published in the Proceedings of the Geological Society, and shall then describe and interpret its more interesting and important features. In order to give the beds in their natural order, it is necessary to proceed in the sectional list in *descending* order. For the purposes of description, it is, however, better to proceed as we have hitherto done from older to newer beds. For this reason the numbers of the groups into which the section is divided proceed *from below upward.* I may also explain that this division into groups of beds is to some extent arbitrary; though the endeavour has been made to bring together in each group a series of beds somewhat similar in character and origin.

Section of part of the Coal-measures of the South Joggins, Nova Scotia, in descending order. Strike S. 65° E. Magnetic; Dip S. 25° W. 19°.

(The asterisks denote the ancient soil beds, with roots.)

Group XXIX.

On the western side of M'Cairn's Brook, which is about three-fourths of a mile S.W. from the Coal Pier, the coast-section shows a great thickness of gray sandstones, with gray and chocolate shales; in which were observed five small coal-seams with underclays, and erect trees at two levels.

East of M'Cairn's Brook is a thick bed of gray sandstone (grindstone) with prostrate Coniferous trees. Under this are gray and chocolate shales and gray sandstone with erect trees at two levels. Then follows a space of about 100 paces without section.

XXVIII.

	ft.	in.
Shale and sandstone, chocolate and gray	90	0
Shale and sandstone, chocolate and gray. In one of the beds an erect stump, converted into coaly matter	35	0

	ft.	in.
*Sandstone and gray shale. Stigmaria rootlets	4	6
Shale, chocolate and gray	25	0
*Sandstone, gray. Stools of Stigmaria .	3	0
Shale, gray. Upper part full of Stigmaria rootlets	20	0
Shales and flags, gray, and in part calcareous. Vegetable fragments and fish-scales .	15	0
Shale, hard gray	6	0

XXVII.

Shale, calcareo-bituminous. Shells of Modiola	1	0
Coal	1	0
*Underclay, resting on sandstone and shale. Rootlets	10	0
Sandstone, coarse gray. Irregularly bedded	6	0
*Underclay, arenaceous. Stools of Stigmaria and an erect stump	3	6
Shale, gray	6	0
*Sandstone and shale. Irregularly bedded. One bed has Stigmaria rootlets	8	0
Shale, gray, with ironstone balls . .	2	8
*Sandstone, gray. Rootlets of Stigmaria .	2	3
Shale, gray. An erect tree rooted in bed below	20	0
*Bituminous limestone. Rootlets of Stigmaria, Modiola, Cypris	0	2
Shale, carbonaceous, with ironstone balls. Poacites, &c.	0	9
*Underclay. Rootlets of Stigmaria .	0	10
Coal, shaly	1	0
*Underclay. Indistinct rootlets . .	1	2

	ft.	in.
*Sandstone, gray argillaceous, passing downward into shale and bituminous shale. An erect tree; Stigmaria roots	3	0
Coal	0	1
*Underclay. Rootlets	0	10
Sandstone, gray. Erect Calamites and Stigmaria rootlets descending from bed above	1	5
Shale, gray, pyritous. Numerous flattened plants	4	6
Coal, very pyritous	0	8
Shale, bituminous and pyritous. Coaly layers, Poacites, Ulodendron	4	0
Coal, with much mineral charcoal . .	0	8
*Underclay, hard and arenaceous. Stigmaria rootlets	3	0

XXVI.

Shales, chocolate and gray, with sandstone bands, ripple-marks and coaly vegetable fragments on some of the sandstones. An erect tree. Reptilian foot-prints and rain-marks .	66	0

XXV.

Shale, gray. Modiola in lower part, fewer towards the top	2	0
Limestone, black bituminous. Fish-scales, Coprolites, Modiola, Spirorbis, attached to carbonized trunks	2	0
Coal, impure. Sigillaria, &c., with Spirorbis attached; Modiola	0	1
*Underclay. Stigmaria rootlets . .	1	0

	ft.	in.
Shale, ironstone nodules, and coaly seams *Coal*, impure, two inches *Underclay. Many rootlets of Stigmaria Shale. Ironstone nodules	5	9
Coal	0	5
*Sandstone, gray. Many rootlets of Stigmaria	2	0
Shale, gray	5	0
*Sandstone, gray. Rootlets of Stigmaria	1	3

XXIV.

Sandstone, gray, alternating with chocolate and gray shales. Prostrate carbonized trunks. Fish-scales	45	0
Shales, chocolate and gray, alternating with even bands of gray sandstone. On some of the sandstones scratches of driftwood	75	0

XXIII.

Shale, gray, passing into black. Modiola in lower part	0	6
Shale, calcareo-bituminous. Modiola, Cypris, Fish-scales	0	10
Coal and bituminous shale. Poacites, Sigillaria, Spirorbis, Fish-scales, Cypris	0	8
Underclay. Rootlets of Stigmaria	3	9
Sandstone, gray. Rootlets	4	6
Shale and sandstone	8	0
*Underclay, hard and sandy below. Roots and rootlets of Stigmaria	1	6
Coal impure. Full of Poacites	0	1
Shale and argillaceous sandstone. Plants with Spirorbis, rain-marks?	7	0

	ft.	in.
Sandstone and arenaceous shale. Erect Calamites in five feet of upper part; an erect coaly tree passes through these beds and the sandstone below	8	0
Sandstone, gray. Erect coaly tree as above	7	0
*Shale, gray. Roots of coaly tree spread in this bed	4	0
Sandstone, gray	4	0
Shale, gray. Prostrate and erect Sigillaria and Lepidodendron, Poacites, Asterophyllites, Ferns, Modiola, Spirorbis on surface of fossil plants, Stigmaria and rootlets . .	0	6
COAL, *main seam*, worked by the General Mining Association	3	6
Shale or underclay. Thins out in working to N.E.	1	6
COAL, worked with main seam	1	6
*Underclay and shale with bands of sandstone	20	0
*Sandstone and clay. Stigmaria stools; on the surface of this bed a thin film of coaly matter. [*Coal Mine Pier here.*]	2	6
Sandstone and shale. Irregular beds .	5	0
Shale, gray, with bands of sandstone and ironstone	4	0
Sandstone, gray. Two erect stumps, one of them a Sigillaria with Stigmaria roots, erect Calamites	2	0
*Shale, gray and ironstone. Roots and rootlets of erect stumps	6	6
Coal, impure. Much Poacites . .	0	0½
Shale, gray	0	11½
Coal and bituminous shale. Prostrate trunks and mineral charcoal . . .	0	0½

	ft.	in.
*Sandstone with clay parting. Stigmaria rootlets and prostrate Sigillaria above the clay parting	3	6
Sandstone and shales with ironstone .	12	0
Ironstone-band. Sigillaria, Favularia, Poacites, Ferns, &c.; Spirorbis attached to many of these plants	0	3
*Underclays. Rootlets of Stigmaria and carbonized plants	2	0
Coal, impure	0	1
*Sandstone, argillaceous. Stools and rootlets of Stigmaria	2	6
*Sandstone alternating with shales. In one bed Stigmaria stools and an erect tree. In another Ulodendron and other trees, prostrate, with Spirorbis attached	10	0
*Shale, gray, passing downwards into underclay. Poacites, Lepidophylla, &c.; an erect tree, Stigmaria rootlets in lower part . .	3	10
Coal	0	3
*Underclay. Rootlets	0	5
COAL and bituminous shale, in several alternations. Lepidodendron, Ulodendron, Poacites, Lepidophylla. (This is called the Queen's Vein.")	1	9
*Shale, gray. Poacites in upper part. In lower part an underclay with remains of erect stumps	4	4
Coal	1	0
*Underclay, black, bituminous, slickensided, resting on hard arenaceous understone. Stools and rootlets of Stigmaria	3	0

XXII.

	ft.	in.
Shales, red and chocolate, with sandstone in uneven beds. Two erect stumps in one of the sandstones, ironstone in the shales .	93	0
Sandstone and shales, chiefly gray. Erect Calamites, and an erect stump in one of the beds	11	6

XXI.

	ft.	in.
Shale, gray, passing into black. Poacites, Sigillaria, Calamites, coaly trunks, and an erect stump	14	6
Coal	0	8
*Underclay. Rootlets and coaly matter, 4½ inches to	0	2
Coal	0	2
*Underclay and shale, pyritous. Stigmaria, small erect stems or roots, coaly layers	14	0
Sandstone and shale. Very irregularly bedded	3	0
Shale and ironstone nodules. Two erect stems	3	0
Sandstone and shales. Carbonized wood and Poacites	8	0
Shales, chocolate and gray. Ironstone nodules. [*Brook here.*]	12	0

XX.

	ft.	in.
***Shales, chocolate and gray, and gray sandstones irregularly bedded. Stigmaria rootlets in three of the sandstones	90	0

XIX.

	ft.	in.
Sandstone, gray, laminated. Erect Calamites	15	0

	ft.	in.
*Shale, gray and chocolate. Roots of Calamites	7	0
Coaly layer. Carbonized flattened trunks	0	2
*Underclay. Roots and rootlets of Stigmaria	2	0
Sandstone, gray, with chocolate and gray shale. Very irregularly bedded, carbonized trunks, Artisia, rain-marks?	30	0
*Shale, gray. Erect stump, Stigmaria roots, one root traced six feet	3	6
Coal and bituminous shale. Poacites with Spirorbis, erect and inclined Calamites stand on surface of this coal	1	0
*Underclay	2	4
Bituminous shale and coal. Poacites and coaly trunks	0	10
*Understone, hard, arenaceous. Many rootlets of Stigmaria	1	6
Sandstone	7	0
**Shale, including two underclays with thin coaly seams. Sigillaria, Poacites, Stigmaria rootlets	15	0

XVIII.

*Shales and sandstones. One sandstone has Stigmaria rootlets	25	0
Sandstone, and red and gray shales. Irregularly bedded, sun-cracks, erect Calamites in one bed	60	0
Sandstone, and chocolate and gray shale .	15	0

XVII.

*Shale, gray and chocolate. Sun-cracked surface, and a stool of Stigmaria . . .	14	0

	ft.	in.
Coal. In roof, Poacites with Spirorbis .	0	8
*Underclay passing into arenaceous shales	15	0

XVI.

Sandstone, gray. Prostrate carbonized trunks and vegetable fragments. Forms a high reef at end of Coal Mine Point; has been quarried for grindstone	25	0

XV.

*Shales and bluish sandstone. Two erect fluted stumps. One has Stigmaria roots .	18	0
Coal and bituminous shale. Stigmaria, Sigillaria, Calamites, Lepidodendron, Poacites	1	2
*Underclay. Rootlets . . . . . } **Shale, including two thin coals and underclays . . . . }	8	10
*Sandstone, gray argillaceous. Erect trees and Calamites, Stigmaria and rootlets. Reptilian remains and land shell in one of the erect trees	9	0
Coal. Erect coaly tree (Conifer?) at its surface	0	6
*Underclay. Rootlets	2	0
Sandstone and shales. Prostrate Sigillaria, erect Calamites	21	0
Coal	0	4
*Underclay. Rootlets	2	0

XIV.

**Sandstones in thick beds, alternating with shales. In one bed an erect stump springing from shale with Poacites; lower, a coaly bed

	ft.	in.
with Stigmaria underclay; still lower, a sandstone with erect Calamites rooted in shale, and immediately below this another erect stump	110	0
Sandstones, gray. Sigillaria, Lepidodendron, Ulodendron, Artisia, &c. . . .	20	0

XIII.

*Shale, including a 4-inch coal with underclay. In the shale above the coal is a fine ribbed erect tree, two feet diameter, four feet of height seen. Its roots are well marked (*Stigmaria ficoides*). The coal contains Spirorbis, Modiola, and Cypris; and its underclay has rootlets of Stigmaria	10	0
Sandstones. Fine ripple-marks . .	6	0
Shales and sandstones. Irregularly bedded	12	0
Sandstone. Ripples, coaly fragments, Calamites	10	0
Shale and sandstone	10	0
Shale, calcareo-bituminous, resting on bituminous limestone. Modiola, Coprolites, Fish-scales, Cypris	5	0
Coal. Prostrate Sigillaria	0	1
*Underclay. Rootlets of Stigmaria .	2	0
Sandstone. Ripples, and coaly fragments	6	0
Shaly clay	13	0
Bituminous limestone. Cypris, Modiola, Coprolites	3	0
COAL, with three clay partings . .	2	9
*Underclay. Rootlets of Stigmaria .	1	6
Sandstone, gray. Two erect trees, one a Sigillaria	5	0

	ft.	in.
Clay	6	0
Sandstone. An erect fluted tree; erect Calamites rooted one foot above roots of tree. Also an erect coaly tree penetrating this and clay above	8	0
Shale, gray and black, passing into bituminous limestone, with coaly bands. Modiola	10	0
Coal	0	10
*Underclay. Stigmaria rootlets . .	1	0
**Sandstones and shales. Stigmaria rootlets at two or three levels	30	0
Shales, coarse and fine. An erect tree; also Poacites with Spirorbis	8	0
Coal	0	5
*Bituminous limestone. Stigmaria roots and rootlets, Modiola, Coprolites, Cypris . .	0	4
Coal	0	7
*Underclay	1	6

XII.

	ft.	in.
*Sandstones and shales, including a 6-inch coal and several underclays. Erect trees at five levels. One of the trees four feet in diameter, and irregularly ribbed; rooted in shale, with rootlets	80	0

XI.

	ft.	in.
Shale, passing into bituminous limestone, with coaly layers. Cypris, Coprolites, Spirorbis, Modiola	8	0

	ft.	in.
*Clay, pyritous, with coaly bands. Stigmaria rootlets	20	0
Sandstone	5	0
Shale, with ironstone, passing into bituminous shale	20	0
COAL and bituminous shale. Poacites, Lepidophylla	5	0
*Underclay, resting on shale, with ironstone. Stigmaria rootlets	6	0
Shale, arenaceous. Stems, Calamites, Poacites, Lycopodium ?, Modiola	0	3
Coal	0	5
Shale and coaly layers	4	0
Coal and shale	0	4
Shale	0	9
Coal	0	2
Shale	0	10
Ironstone and bituminous limestone. Poacites, Spirorbis, Cypris	0	3
*Underclay and shale. Rootlets of Stigmaria	4	0
COAL	4	0
*Underclay, pyritous, passing into sandstone. Rootlets of Stigmaria	1	6
Sandstone and shale. Six large erect trees, one of them 15 feet in height, erect Calamites	30	0
Coal and bituminous shale	5	0
*Underclay. Stigmaria rootlets . .	2	0

X.

Sandstone. Large erect tree . . .	8	0
**Shale, with bands of gray sandstone, a few		

	ft.	in.
thin layers of coal, with underclays. Poacites, Ferns, &c. abound in the shales .	60	0
***Shale, cholocate, with gray sandstone. Contain three thin coaly bands, with underclays and roof-shales, about	500	0
*Shale, gray, and sandstone. In upper part, an understone, with Stigmaria rootlets, and an erect tree, Ferns, Poacites . . .	82	0

IX.

Sandstone, gray, and shale. In lower part an erect tree extending 2 feet into these beds, and 3 feet into bed below . .	10	0
Shale	12	0
*Bituminous limestone. Stigmaria stools and rootlets; at bottom a thin coaly layer, with prostrate trunks and attached Spirorbis .	1	2
*Underclay. Rootlets and remains of erect stumps	2	6
Coal	0	3
*Underclay	3	0
Gray sandstone and shale. Stigmaria rootlets	6	0
Shale, with coaly layers	8	0
Sandstone, argillaceous, and shale . .	6	0
Bituminous limestone. Rootlets, Fish-scales, Cypris . . . . ?	2	0
Coal and bituminous shale . . .	0	9
*Underclay	2	0
Coal and bituminous shale . . .	0	8
*Under-clay. Stigmaria rootlets . .	1	3
Bituminous limestone. Rootlets; Cypris .	0	4
Shale	0	3

	ft.	in.
Coal	0	1
*Underclay. Stigmaria rootlets . .	8	0

VIII.

Sandstone	5	0
Sandstone and chocolate shales . .	70	0

VII.

Shale, calcareo-bituminous, and bituminous limestone. Modiola, Cypris, &c. . .	5	0
Coal, full of minute spines	0	4
*Underclay, passing into chocolate shale. Rootlets	3	0

VI.

*Shales, chocolate and sandstone. Near bottom an erect tree rooted in hard arenaceous underclay. Stigmaria rootlets	38	0
Shales, chocolate and gray, and sandstones .	63	0
Sandstone, gray, with false stratification. Trunks of trees	15	0

V.

Shale, chocolate above, gray below. Thin coaly layers in bottom, Poacites . . .	15	0
*Bituminous limestone. Rootlets, Cypris .	0	5
Underclay. Rootlets	2	0

IV.

Sandstones and shales	30	0
Sandstone, gray. Erect Calamites, flattened trunks	8	0

	ft.	in.
Shales, chocolate and gray. An erect tree (ribbed)	40	0

III.

	ft.	in.
Bituminous limestone. Cypris, Modiola, Coprolites, Fish-scales	0	5
Bituminous shale	0	4
Bituminous limestone. Cypris, Modiola, &c.	0	3
Bituminous shale	0	11
Coal	0	3
Bituminous shale	0	11
Coal	0	3
Bituminous shale	0	7
Bituminous limestone, earthy. Coprolites, Modiola, Fish-scales, Cypris	0	10
Bituminous limestone, with coaly layers	0	7
Shale and ironstone balls	7	0
Bituminous limestone, calcareo-bituminous shale, and coaly layer. Fish-scales, Cypris, &c.	3	0
Shale, gray	3	6
Coal and bituminous shale. Modiola	0	3
*Underclay. Rootlets of Stigmaria	1	6
Shale, arenaceous, and ironstone balls. Rootlets	5	0
Sandstone, gray	4	0
Shale, gray	4	0
Shale, black	0	6
Bituminous limestone. Modiola, Cypris, Coprolites	0	7
Coal	0	5
*Underclay, passing into chocolate shale. Rootlets of Stigmaria	8	0

	ft.	in.
II.		
Shales, chocolate and gray, and sandstones	45	0
I.		
Sandstone, gray. An erect tree (Lepidodendron ?) 8 inches diameter, 4 feet high; erect Calamites	12	0
Shale, gray	16	0
Bituminous limestone, Modiola, Cypris, Fish-scales, Spirorbis	0	4
Shale, gray	9	0
Bituminous limestone. Modiola, Fish-scales, Cypris	0	6
Shale, gray	2	6
Bituminous limestone and calcareo-bituminous shale. Modiola, Fish-scales, Cypris .	3	0
Shale, gray	1	6
Calcareo-bituminous shale. Modiola, Fish-scales, Cypris, Poacites	0	6
Shale, gray	6	0
Bituminous limestone. Cypris, &c. .	0	3
Shale, black	0	7
Coal	0	6
*Bituminous limestone. Cypris, Stigmaria rootlets	0	2
Coal	0	0½
*Underclay. Stigmaria rootlets . .	4	0
Shales and sandstones, red and chocolate (not measured).		
Total thickness,	2819	2

CHAPTER IX.

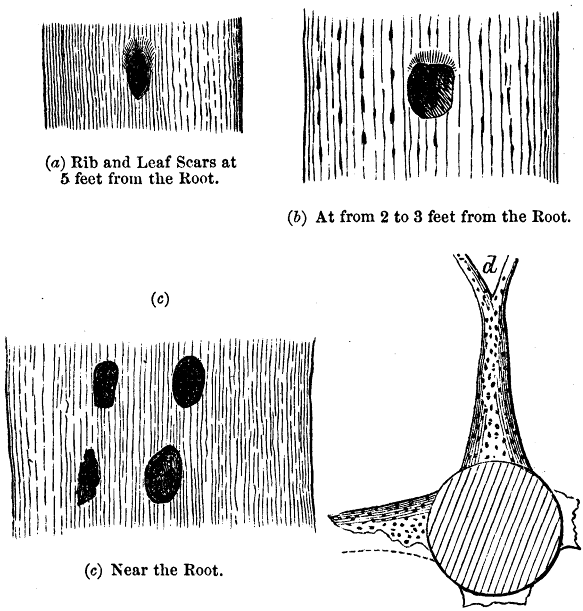
THE CARBONIFEROUS SYSTEM—*Continued.*

CUMBERLAND COAL-FIELD, *continued*—EXPLANATION OF JOGGINS SECTION—EASTERN COAST OF CUMBERLAND—USEFUL MINERALS OF CUMBERLAND—SOILS.

IN the last line but one from the bottom of the section, in the preceding chapter, the reader will observe the words "Underclay—stigmaria rootlets," and over this underclay is a small seam of coal. An underclay is technically the bed of clay which underlies a coal seam; but it has now become a general term for a *fossil soil*, or a bed which once formed a terrestrial surface, and supported trees and other plants; because we generally find these coal underclays, like the subsoils of many modern peat-bogs, to contain roots and trunks of trees which aided in the accumulation of the vegetable matter of the coal. The underclay in question is accordingly penetrated by innumerable long rootlets, now in a coaly state, but retaining enough of their form to enable us to recognise them as belonging to a very peculiar root, the *stigmaria*, of very frequent occurrence in the coal-measures, and at one time supposed to have been a swamp plant of anomalous form, but now known to have been the root of an equally singular tree, the *sigillaria*, found in the same deposits (Fig. 9). The *stigmaria* has

Fig. 9.—*Ribs, Leaf Scars, and Stigmaria Roots of Sigillaria—South Joggins.*

(*a*) (*b*)



(*a*) Rib and Leaf Scars at 5 feet from the Root.

(*b*) At from 2 to 3 feet from the Root.

(*c*)

(*c*) Near the Root.

(*d*) Stump with Roots, viewed from above.

derived its name from the regularly arranged pits of spots left by its rootlets, which proceeded from it on all sides. The *sigillaria* has been named from the rows or leaf scars which extend up its trunk, which in some species is curiously ribbed or fluted. One of the most remarkable peculiarities of the stigmaria rooted trees was the very regular arrangement of their roots, which are four at their departure from the trunk, and divide at equal distances successively into eight, sixteen, and thirty-two branches, each giving off, on all sides, an immense number of rootlets, stretching into the beds around, in a manner which shows that they must have been soft sand and mud at the time when these roots and rootlets spread through them.

It is evident that when we find a bed of clay now hardened into stone, and containing the roots and rootlets of these plants in their natural position, we can infer, 1st, that such beds must once have been in a very soft condition; 2dly, that the roots found in them were not drifted, but grew in their present positions; in short, that these ancient roots are in similar circumstances with those of the recent trees that underlie the Amherst marshes. In corroboration of this, we shall find, in farther examination of this section, that while some of these fossil soils support coals, others support erect trunks of trees connected with their roots and still in their natural position.

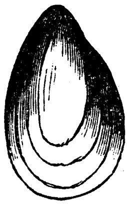
Believing the underclays to have been soils, we find similar reasons to conclude that the coal seams were originally vegetable matter, which accumulated in the manner of peat; and on examining the coal minutely, we often find distinct evidences that it is composed in part of woody fragments, sometimes retaining their structure in sufficient perfection to enable the kind of wood to which they belonged to be ascertained. These appearances are most distinctly seen in the coarser and more impure coals, and in the bands of clay and ironstone which occur within the coal seams. In the more pure coals, the vegetable matter has sometimes been reduced by chemical change and pressure into an almost homogeneous mass.

Here, then, at the commencement of the section, we have a soil four feet in depth, and supporting a layer of vegetable mould which has been compressed into half an inch of coal. Above the coal rests a very different description of rock, one of those hard dark-coloured limestones already referred to. It is filled with innumerable little shells of a minute crustaceous animal, the *Cypris*, the modern representatives of which reside in countless numbers in ponds and in river estuaries. Our coal bog therefore became, from some cause, probably subsidence, a pond or lagoon, in which cyprides and other aquatic animals must have existed for some time before their remains could accumulate in sufficient quantity to form these two inches of hard bituminous limestone. The cypris-inhabited waters, however, were dried up, and on the rich marly soil grew another forest, whose rootlets may be seen finely preserved in the limestone; and the result was a thicker seam of coal than the first, again inundated and covered by a considerable thickness of shales and bituminous limestones, in which we find not only the *Cypris* but the scales of small fishes, bivalve shells (*Modiolæ*) allied to the common mussel, and a small whorled shell (*Spirorbis*) resembling those now found adhering to the seaweeds of the shore (the common *Spirorbis Spirillum*) Fig. 10. The bituminous

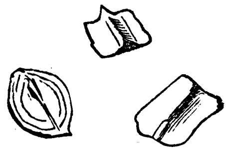
Fig. 10.—*Fossils from Bituminous Limestone—Joggins.*

Cypris (*a*) *natural size.* *Spirorbis* (*a*) *natural size.*

Fig. 10—Continued.



Modiola.



Ganoid Scales.

limestones containing these remains, alternate with shales indicating that irruptions of mud partially filled up, at different times, the waters in which calcareous beds were being gradually accumulated by the growth and death of animals. In the highest of these beds of mud, which probably restored the whole area to the state of a swamp, trees took root and were buried by an irruption of sand, in which they as well as an undergrowth of *Calamites* still stand in an erect position.

I have dwelt at some length on this first group, as its appearances will help to explain others that succeed. It is evident that when read in the light of modern geology, they tell a very intelligible tale, and show us that the circumstances in which these coal-rocks were formed were similar to those which we have found to exist on a small scale in the modern marshes of the Bay of Fundy ; and also to those more extensive changes which occur in the deltas of great rivers, such as the Mississippi and the Ganges, in which low alluvial flats have often been alternately covered by water and by a dense swamp-vegetation. Let the reader also observe, that in this one group of the Joggins beds, only about 56 feet in thickness, we have at least three successive soil-surfaces, two of them sufficiently permanent to permit the accumulation on them of peaty vegetable soils; and four feet nine inches of calcareous beds, mostly made up of animal remains. The lapse of time required for the accumulation of this group alone must thus have been vastly greater than that necessary for the production of the modern marsh-formation with its one fossil soil. It will also be observed that these beds carry our thoughts back to a period when this province was covered by a strange and now extinct vegetation, and when its physical condition resembled that of the Great Dismal Swamp, the Everglades of Florida, or the Delta of the Mississippi.

One appearance only in this group requires farther explanation before we proceed to the next. One of the sandstones at the top of the group exhibited in 1853 a tree standing out from the cliff, as a pillar of hard sandstone spreading out at the base, and beside it were numerous calamites, also represented by sandstone casts, and like the tree standing at right angles to the beds, which are now inclined at an angle of 19 degrees, but which must have been horizontal when these plants grew and were entombed. The manner in which the plants were preserved in their present state and position can easily be understood. Imagine a forest of trees and a tall brake of reed-like plants growing together on a swampy flat. The flat is inundated and overspread with sand to the depth of four feet. The plants are thus killed and their dead tops project for some time above the sand. At length they decay and are broken off, and eventually the wood decays, leaving only a hollow cylinder of bark. Sand is now washed into the perpendicular pipes produced by the decay of the trunks and stems, forming casts of them. The whole is now buried up by succeeding deposits and becomes hardened into stone, and so remains until tilted up, elevated above the water level, and exposed by the action of the tides and waves.

The stump observed in the particular bed now under consideration is named in the section a *Lepidodendron*, with a note of interrogation to show that its surface was not so well preserved as to make it certain that it belonged to that genus. The Lepidodendra were tall and graceful trees, intermediate in their structure between the pines and the humble club-mosses (*Lycopodia*) of our modern woods. Their trunks were marked by diamond-shaped leaf-scars, and their branches and twigs were thickly clothed with long lance-shaped leaves like those of the pine tribe, and bore large cones at their extremities. These trees did not send up straight trunks with numerous small branches, like the pines, but branched out by the continuous division of the trunk and limbs into pairs of branches, in the manner in which standard pear-trees are often trained in this country, by constantly cutting out the main ascending twig and allowing two lateral branches to grow in its place. The Lepidodendra must have been among the most beautiful trees of the coal-period, and their roots appear to have been constructed on the same regular type with those of the *Sigillaria.* Mr Brown of Sydney has described some fine examples of this from the coal-field of Cape Breton.

Group II. is a barren series of sandstones and shales, representing beds of sand and mud conveyed by water over the last terrestrial surface of the first group. For aught that the section shows to the contrary, these forty-five feet of sand and mud may have been rapidly deposited. It is quite likely that the formation of the half-inch bed of coal in the former group may have occupied a longer time than the deposition of the whole of these beds. The reader will note here that the absolute thickness of any bed or mass of beds is no measure of the time occupied in their formation. A layer of sand may be spread over a wide surface by a single storm or inundation, but it requires time to accumulate even a very inconsiderable amount of organic matter by the slow growth of animals or plants.

The next group is very similar to No. I. It shows that the locality was again for a very long period alternately a swamp and a lagoon. I say for a very long time, for much of this group consists of bituminous limestone, Modiola shale, and coal, all beds requiring a very long lapse of time for their growth. There is every reason, for example, to believe that the three feet bed of bituminous limestone, nearly in the middle of the group, consists mainly of the remains of *Cyprides*, fish, and other aquatic creatures, accumulated by the slow growth of successive generations; and if we have any idea of the growth of modern beds of this kind, we will be disposed to measure the growth of this limestone by centuries.

Group IV. is comparatively barren of organic remains, and consists of coarse mechanical detritus; and it will be observed that throughout the section groups of beds of this kind alternate with others composed of fine silt and organic matter. There were, in other words, long-continued swamp and lagoon periods, alternating with periods in which the waters of the sea or turbid streams were bearing in sand and mud. We have here, however, two surfaces which had sufficient permanence, as land or swamp soils, to support trees and *Calamites.*

In Group V. we have a recurrence on a small scale of the conditions of Group III.

Group VI. is another great series of sandstones and chocolate-coloured shales. It has, however, one erect tree, probably a *Sigillaria,* rooted in an underclay with stigmaria rootlets; and in the lowest sandstone there is a great mass of prostrate trunks of trees, imperfectly preserved, probably the wreck of some land-flood, or the drift-wood from a forest-clad coast.

In Group VII. there are but three beds in an order which we shall find frequently repeated in the section. First, we have an underclay, a soil on which grew a small bed of vegetable matter represented by four inches of coal. This terrestrial surface was overflowed by water, for a very long time inhabited by *Modiola* and *Cypris.* This, it will be observed, implies subsidence of a terrestrial surface and its long submergence, and I may remark once for all that the appearances of the whole section imply continuous subsidence, only occasionally interrupted by elevatory movements. The succeeding group marks the filling of the quiet waters tenanted by *Modiolæ,* with thick deposits of clay and sand.

Group IX. is a fine series of underclays and coals, alternating with *Modiola* beds. It contains nine distinct soil-surfaces, the highest supporting an erect tree, which appears as a ribbed sandstone cast, five feet six inches high, nine inches in diameter at the top, and fifteen at the base, where the roots began to separate. This tree being harder than the enclosing beds, at the time of my visit, stood out boldly at the base of the cliff, nearly three-fourths of its diameter, and the bases of three of its four main roots being exposed. Five of the underclays support coals, and in three instances bituminous limestones have been converted into soils, none of which, however, support coals. The last of these bituminous limestones is a very remarkable bed. First we have an underclay; this was submerged, and *Spirorbis* attached its little shell to the decaying trunks, which finally fell prostrate, and formed a carbonaceous bottom, over which multitudes of little crustaceans (*Cypris*) swam and crept, and on which fourteen inches of calcareous and carbonaceous matter were gradually collected. Then this bed of organic matter was elevated into a soil, and large trees, with Stigmaria roots, grew on its surface. These were buried under thick beds of clay and sand, and it is in the latter that the erect tree already mentioned occurs; its roots, however, are about nine feet above the surface of the limestone, and belong to a later and higher terrestrial surface, which cannot be distinguished from the clay of similar character above and below.

The Xth Group contains a vast thickness of sandstones and shales, the latter chiefly of chocolate colours, which, as they afforded few facts of interest, were not measured in detail. This group points to a long-continued interruption of the swamp-deposits previously in progress. During the greater part of the time occupied in the formation of these beds, the locality must have been a sandy or muddy sea-bottom, receiving much mechanical detritus, or an expanse of flats of reddish mud and brown or gray sand, covered by the tides. There are, however, some evidences of terrestrial conditions. In the lowest beds is a large erect stump, filled with laminated clay after the complete decay of its wood. In the clay filling it were abundance of fern leaves, *Poacites*, *Lepidophylla*, a few plants with attached *Spirorbis*, and a shell of *Modiola*. This tree was rooted in a thick underclay full of rootlets of *Stigmaria*. Higher up there are several thin coaly bands, with underclays; many of the shales abound in leaves of Ferns and *Poacites*, probably drifted, and the highest sandstone showed a large erect tree.

Group XI. commences with a soil resting immediately on the truncated top of the tree last mentioned. On this soil was formed a deep swamp, now represented by five feet of coal and bituminous shale in alternate bands. Large quantities of clay and sand buried this swamp, but not in such a manner as to preclude the growth of trees, many of which were entombed in the erect position. In these sandstones and shales, no less than six erect trees were observed at different levels, the lowest being rooted in the shale forming the coal-roof; fifteen feet of the trunk of one of these trees still remain; two others were respectively five and six feet high. Erect *Calamites* were also observed. The soil which was formed on the surface of these beds supports one of the thickest coal-beds in the section, marking a long and undisturbed accumulation of vegetable matter. It was covered by clay, which became a Stigmaria soil, and was then submerged for a sufficient time to allow the formation of a small bed containing *Cypris* and *Spirorbis*. Above this we find a series of beds indicating swamp conditions, alternating with aqueous drift and deposition, and finally again giving place, for a long period, to the quiet estuary or lagoon, inhabited by *Modiola* and ganoid fish, and receiving little mechanical sediment. We have here, as in some previous groups, three distinct conditions of the surface:—first, terrestrial surfaces more or less permanent; secondly, undisturbed marine or brackish water conditions; thirdly, intervening between these the deposition, probably with considerable rapidity, of sandy and muddy sediment. We may also observe that, admitting the *Stigmaria* to be roots of trees, there are five distinct forest soils without any remains of the trees except their roots; and we shall find throughout the section that the forest soils are much more frequently preserved than the forests themselves.

The XIIth Group, eighty feet in thickness, consists of sandstones and shales, with few vegetable remains. There are, however, several underclays, and one thin coal, and erect stumps appear at five distinct levels. One of them is the largest tree observed in the section: it measured four feet in diameter, and was five feet in height. Its surface was irregularly ribbed, and it was rooted in clay containing Stigmaria rootlets. Its roots, however, were too imperfectly preserved to show the markings of *Stigmaria*. In this group we have probably the margin of alluvial deposits gradually spreading over the Modiola-inhabited waters of the last group, and occasionally presenting dry surfaces for a time sufficiently long to admit of the growth of trees of great size.

In the large series of beds included in Group XIII., there are no less than thirteen distinct forest surfaces, marked by underclays or erect trees, and five periods of submergence indicated by beds with *Modiola*, &c., and three of them, at least, of very long duration. It will be observed that, in three instances, the order of succession is underclay—coal—bituminous limestone. This arrangement, so common in other parts of the section, seems to show a connexion other than accidental between the long periods of terrestrial repose required for the growth of coal, and those of quiet submergence necessary for the growth of Modiola beds. Perhaps the submerged coal-swamp was the most fitting habitat for *Modiola* and its associates; and these sunken swamp areas may have been so protected by thick margins of jungle as to resist for a long time the influx of turbid waters.

In ascending through Group XIII., the first object of interest is a band of bituminous limestone with *Modiola*, *Coprolites*, and *Cypris*, which forms the roof of one coal and the underclay of another, evincing important changes of level with scarcely any sedimentary deposition. Above the upper coal, however, we have an erect plant, only four inches in diameter, surrounded by arenaceous shale, and, in the finer clay surrounding its base, *Poacites* with attached *Spirorbis*, which probably, like some of its modern congeners, could grow rapidly, and with equal facility, either on drifting or stationary plants. Still higher in this group, and immediately above a thick bed of bituminous limestone and Modiola shale, is a very curious association of erect plants. An erect tree, converted into coal, springs from the surface of the shale, and passes through fourteen feet of sandstone and shale. Apparently from the same level there rises an erect ribbed tree, probably a *Sigillaria*, in the state of a stony cast, which, however, extends only to the top of the sandstone. In the sandstone, and rooted about a foot above the base of the erect trees, are a number of erect *Calamites*. In this case the forest-soil has been covered by about a foot of argillaceous sand, on which a brake of *Calamites* sprung up. Further accumulations of sand buried them, and covered the trunks of the trees to the depth of eight feet. By this time the *Sigillaria* was quite decayed, and its bark became a hollow cylinder, reaching only to the surface of the sand, and ultimately filled with it. The other tree still stood above the surface, until six feet of mud were deposited, when its top being broken off, it also completely disappeared beneath the accumulating sediment; and being softened and crushed by the lateral pressure of the surrounding mass, it was finally converted into an irregular coaly pillar, retaining no distinct traces either of the external form or internal structure of the original plant. The structure of similar trees, to be noticed further on, renders it likely that this coaly tree is the remains of one of the *Araucarian Pines*, which, it appears, flourished in the coal-swamps in company with the *Sigillariæ*. The surface of the clay which buried this remarkable tree became itself an underclay or soil; and in the sandstone resting upon it were found casts of two erect trees, one of them five feet in height, and a *Sigillaria* with distinctly marked leaf-scars. The tops of these trees have been entirely removed, and their hollow stems filled with sand, before the deposition of a bed of mud resting upon them, and which is now the underclay of a bed of coal. This coal was next submerged under the conditions required for bituminous limestone and Modiola shale. The Modiola waters were then filled up with clay and sand, the latter ripple-marked, and with drifted vegetable fragments. Another soil was formed above these beds, and on it we find an inch of coal, with flattened *Sigillariæ*, which probably once grew on the underclay. This terrestrial surface was succeeded, as usual, by waters swarming with *Modiolæ* and fish, and on these were spread out beds of sand and mud, with ripple-marks, drift-trees, and evidences of partial denudation by currents. A terrestrial surface was again restored, and four inches of coal were accumulated; but the waters again prevailed, and in the coal itself we find *Modiola*, *Cypris*, and plants covered with *Spirorbis*, indicating that these creatures took possession while the vegetable matter was still recent, and probably much of it in an erect position. A terrestrial surface was, however, soon restored; for in the shale which covers the coal there is a fine ribbed stump, two feet in diameter, and displaying on its roots the markings of the true *Stigmaria ficoides*, as well as the rootlets *in situ* in the shale. This is the first instance we have here yet met with of the distinct connexion of an erect ribbed stem with its Stigmaria roots. The causes of the difficulty of observing the roots and stem in connexion will be stated in the sequel.

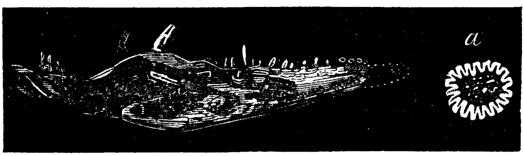
The next group is probably the result of somewhat rapid mechanical deposition. Its lowest bed is a thick sandstone, deposited by currents which have undermined wooded banks, or passed through recently submerged forests, for it contains numbers of trunks of different trees, retaining their bark and surface markings. In the succeeding 110 feet of sandstone and shale, I have noted but one underclay, supporting only a thin carbonaceous layer, which may, however, have been a soil for a long time. There are, however, erect trees and *Calamites* at three levels; and one of the trees springs from a shale loaded with *Poacites* which may have grown around its base.

Here we may pause for a little, to note the appearance of some of the new vegetable remains to which we have been introduced. We have found a Sigillaria with distinct markings, namely its sides marked by bold ribs, having the effect of the flutings of a Grecian column, and these ribs dotted with vertical rows of leaf scars. We have also seen a distinct instance of a Sigillaria attached to its Stigmaria roots still spreading through the soil. (See Fig. 9, page 145.) Let us now endeavour to form an idea of the trees of this singular genus. Imagine a tall branchless trunk, perhaps two feet in diameter, and thirty feet in height. (One has been traced to the length of forty feet in the roof of the Joggins main coal-seam.) The trunk is covered with a thick bark, very smooth, and ribbed regularly, and is clothed to the summit with a dense mass of leaves, probably of lengthened and grass-like forms. Such trees must have formed dense groves in the swamps of the coal-period. They have nothing closely analogous to them among living plants. There were a number of species of Sigillaria, differing somewhat in their ribs and leaf-scars, and probably also in their leaves. The *Favularia* and some other genera were nearly related; and the *Ulodendron*, a plant whose remains occur with the *Sigillaria*, was allied to the *Lepidodendron*, but wanted its graceful branching stem, while it had rows of stiff cones planted on the sides of its trunk, and its general aspect, when clothed with its long leaves, somewhat broader than those of *Lepidodendron*, must have much resembled that of the *Sigillaria*. *Lepidophylla* were the leaves of *Ulodendron* or *Lepidodendron*.

We have also met with the *Poacites*, long striated leaves resembling those of gigantic plants of Iris or Indian corn, and sometimes five or six inches in breadth, and half as many feet in length. They probably formed an undergrowth under and around the Sigillaria woods. We have also met with an erect coniferous tree, and erect *Calamites*, but shall reserve our notice of these for better instances farther on.

Group XV. is one of the most interesting in the section, in consequence of the discovery in it, in 1852, by Sir Charles Lyell and the writer, of the bones of a reptile, *Dendrerpeton Acadianum* (Fig. 11), those of an-

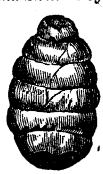
Fig. 11.—*Jaw of Dendrerpeton Acadianum.*



(*a*) Cross Section of Tooth (magnified).

other small reptile, and the shell of a land snail (*Pupa?*) (Fig. 12). These remains are of great interest, as they

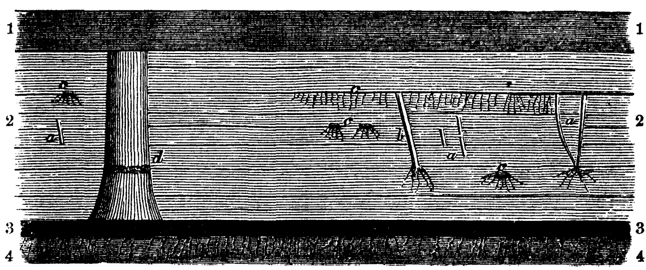
Fig. 12.—*Fossil Land Shell—Joggins Coal-Measures.*



Magnified three diameters.

are the first reptilian animals found fossil in the carboniferous rocks of America, and the only land snail whose remains have ever been found in rocks of that age; in fact, the only evidence yet obtained of the existence of animals of that tribe at so early a period. These interesting remains were all found in the interior of an erect tree, mingled with the sand, decayed wood, and fragments of plants which had fallen into it after it became hollow. The bed of argillaceous sandstone, nine feet in thickness, which enclosed this tree, contains a number of erect plants (Fig 13). Three erect trees in the form of sandstone casts and erect calamites were observed in it, with many Stigmaria roots. There was also a tree not in the form of a cast, but of a mass of coaly fragments surrounded by a broken and partly crushed cylinder of bark; the whole being evidently the remains of a trunk which has been reduced to little more than a pile of decayed pieces of wood before the sand was deposited; consequently it must have been

Fig. 13.—*Section of Middle Part of* Group XV. *in which the Dendrerpeton and Land-shells have been found.*



1. Underclay, with rootlets of *Stigmaria,* resting on gray shale, with two thin coaly seams.
2. Gray sandstone, with erect trees, Calamites, and other stems : 9 feet.
3. Coal, with erect tree on its surface : 6 inches.
4. Underclay, with *Stigmaria* rootlets.

(*a*) Calamites. (*c*) Stigmaria roots.
(*b*) Stem of plant undetermined. (*d*) Erect trunk, 9 feet high.

either an older or more perishable plant than those which stand as pillars of sandstone. The wood of this tree shows, in the cross section, a cellular tissue, precisely similar to that of the Coniferæ; the longitudinal section shows only elongated cells, but is very badly preserved. A tree of this description is not likely to have been more perishable than the *Sigillariæ*, which, in the same situation, remained until nine feet of sandy mud had accumulated. I suspect, therefore, that this stump may be the remains of a coniferous forest, which preceded the *Sigillariæ* in this locality, and of which only decaying stumps remained at the time when the latter were buried by sediment. This is the more likely, as the appearances indicate that this tree was in a complete state of decay at the very commencement of the sandy deposit.

The history of this group will thus be as follows:—(1.) The Stigmaria underclay shows the existence of a Sigillaria forest, on the soil of which was collected sufficient vegetable matter to form six inches of coal, which probably represents a peaty bog several feet in thickness. (2.) On this peaty soil grew the trees represented by the stump of mineral charcoal mentioned above, and which were probably coniferous. This tree, being about one foot in diameter, must have required about fifty years for its growth to that size. It was then killed, perhaps by the inundation of the bog. (3.) During the decay of the tree last mentioned, *Sigillariæ* grew around it to the diameter of two feet, when they were overwhelmed by sediment, which buried their roots to the depth of about eighteen inches. At this level *Calamites* and another *Sigillaria* began to grow, the former attaining a diameter of four inches, the latter a diameter of about one foot. (4.) These plants were in their turn embedded in somewhat coarser sediment, but so gradually that trees with Stigmarian roots grew at two higher levels before the accumulation of mud and sand attained the depth of nine feet, at which depth the original large *Sigillariæ*, that had grown immediately over the coal, were broken off, and their hollow trunks filled with sand. Before being filled with sand, these trees, while hollow, must for some time have projected from a swamp or terrestrial surface, such as that which immediately succeeds them in ascending order; and it is no doubt to this circumstance that we owe the occurrence, in one of them, of reptilian remains and land-shells, as well as many vegetable fragments, such as *Calamites*, *Poacites*, and a *Lepidostrobus*, evidently introduced before the sedimentary matter, and forming just such a mass as might be supposed likely to fall into an open hole in a forest or swamp. (5.) The remaining beds of this group evidence the continuation of swamp conditions for a long time after the trees last noticed were completely buried. They include, in a thickness of twenty-eight feet, three underclays supporting coaly beds, and one with erect stumps; one of them with Stigmarian roots and ribbed. One of the coaly beds, which alternates with laminæ of shale, is filled with flattened trunks of *Sigillaria* and *Lepidodendron*, which probably grew on the surfaces on which they now lie, and indicate how small a thickness of coaly matter may mark the time required for the growth and decay of many successive forests.

On the whole, we can scarcely err in affirming that the habitat of the *Dendrerpeton Acadianum* and its associates was a peaty and muddy swamp, occasionally or periodically inundated, and in which growing trees and

Calamite brakes were being gradually buried in sediment, while others were taking root at higher levels, just as now happens in the alluvial flats of large rivers.

Group XVI. consists of one thick bed of gray sandstone with prostrate carbonized trunks. The sandstone is highly silicious, and of the kind used for grindstones. It is the result of the complete submergence of the swamps of the last group, and their invasion by sand-bearing currents.

The next Group commences with the growth of *Calamites* on the surface of the great sand-bed last noticed, after which there was the formation of an underclay and coal, the latter being afterwards inundated, and the plants at its surface overgrown with *Spirorbis.* In the shale covering this coal, about fourteen feet above its surface, is a bed with shrinkage cracks, and containing a stool of *Stigmaria*, one of the roots of which was traced 9½ feet. Its rootlets were attached, so that it can scarcely have been a drift-stump; and if now *in situ*, it must have grown on a mud-bank alternately inundated and dry, like the present salt-marshes of the Bay of Fundy.

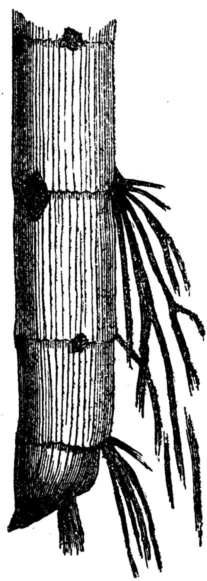
Group XVIII is a series of sandstones and shales, less perfectly exposed than most other parts of the section. Chocolate colours prevail among the shales, and there are few fossils. One of the beds, however, has its surface covered with casts of shrinkage-cracks, such as are now formed on mud left dry by the neap tides; and there are also erect *Calamites* in one bed and a Stigmaria underclay.

The next group is of much greater interest, showing seven soil-surfaces, with a variety of sedimentary deposits. Two of the coals in this group contain on their surfaces of deposition well-preserved remains of the plants (*Sigillaria*, *Poacites*, *&c.*) which must have grown on their underclays. The thick mass of sandstone and shale in the centre of the group is also very curious, as it evidently represents the side of a trench or gully cut by water in a series of mud-beds, and then filled up with a confused mass of drift-trees and sand. By far the most interesting feature in the group is, however, the fine brake of erect *Calamites* in the highest bed. The next bed above the confused mass already mentioned, is an underclay, on which grew a forest, whose only remains are two inches of coaly matter, made up of flattened trunks converted into coal. This forest must have been entirely destroyed by violence or decay, before the next bed, which is a shale seven feet thick, was deposited. On the surface of this shale grew a great brake of *Calamites*, which were buried under sand, in such a manner that their forms and position were perfectly preserved: they stand in groups in the cliff just as they grew, some of them being five inches in diameter, and eight feet high; and at that height they have been broken off without any decrease of their diameter. In one place twelve stems were counted in eight feet measured along the face of the cliff. From the base of the cliff to low-water mark, they could everywhere be seen abundantly along the continuation of the ledge of sandstone. This bed and others of similar character at the Joggins, have given us much information respecting the nature and mode of growth of these plants, which I may pause here to notice in detail.

The Calamites were tall cylindrical stems, with a hard outer bark, and were either hollow or filled with cellular matter. The stems were regularly marked with longitudinal striæ or furrows and cross joints, sometimes showing the marks of the attachment of the leaves, which were verticillate, or in whorls around the stem, and long and needle-like (Figs. 14 and 15). The general habit of growth thus resembled the *Equisetum* or Mare's-tail of modern marshes, and probably these

Fig. 15.—*Leaves of Calamite.*

Fig. 14.—*Erect Calamite, with Roots.*

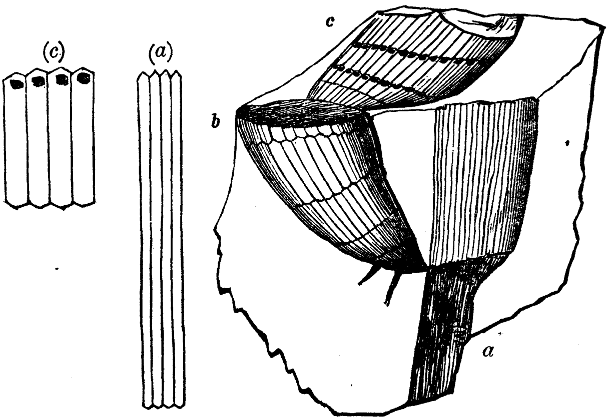


One-sixth natural size.

plants are also allied to the Calamite in structure. Calamites grew on wet mud and sand flats, and also in swamps; and they appear to have been especially adapted to take root in and clothe and mat together soft sludgy material recently deposited or in process of deposition. When the seed or spore of a Calamite had taken root (and it is not unlikely that, like the very remarkable spores of the *Equiseta*, their seeds had wings which expanded to waft them through the air when dry, and closed instantly when they touched the damp soil), it probably produced a little low whorl of leaves surrounding one small joint, from which another and another, widening in size, arose, producing a cylindrical stem, tapering to a point at the base. To strengthen the unstable base, the lower joints, especially if the mud had been accumulating around the plant, shot out long roots instead of leaves, while secondary stems grew out of the sides at the surface of the soil, and in time there was a stool of Calamites, with tufts of long roots stretching downwards, like an immense brush, into the mud (Fig. 16. See also Fig. 14). When Calamites thus grew on inundated flats, they would, by causing the water to stagnate, favour the elevation of the surface by new deposits, so that their stems gradually became buried; but this only favoured their growth, for they continually pushed out new stems, while the old buried ones shot out bunches of roots instead of regular whorls of leaves. These peculiarities have caused much dispute among botanists, some of whom have even fancied that the whole stem served as a root. All the apparent anomalies were, however, wise contrivances to fit the plant for its office in nature.

One peculiarity in these beds well illustrates the fact,

Fig. 16.—*Erect Calamites, showing the Mode of Growth of New Stems, and Forms of the Ribs.*



Natural size. Half natural size.

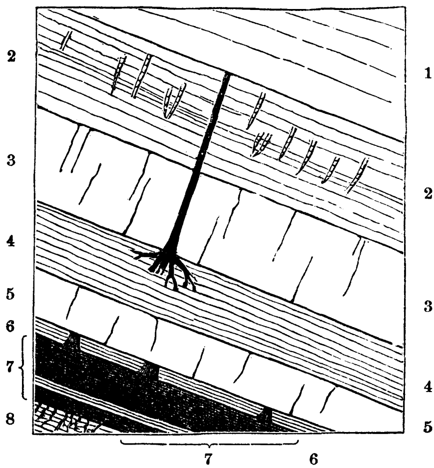
already mentioned, that the thickness of beds is no certain criterion of the time occupied in their formation. The bed of sandstone, eight feet in thickness, enveloping the Calamites, must have been deposited in a few years at most. The underlying coal, two inches thick, is all that marks the growth, submergence, and decay of a forest.

We may pass over the next three groups without particular notice; because, though interesting if they occurred alone, they show nothing different from what we have observed elsewhere.

Group XXIII. is a great and continuous series of swamp and estuary deposits, including the most important beds of coal in the section, and a large number of well-marked terrestrial surfaces. It commences with a black bituminous underclay, a soil probably of long continuance and filled with rootlets. It supports a foot of coal, above which we find two other coals with underclays, and one of them with a shale roof full of prostrate plants. Then we have an underclay capped by shale with fossil leaves, but no coal. Above this we have an interruption of the previous conditions, by the deposition of sand, on the surfaces of which drift-plants were scattered, and became tenanted by the little worms whose shells we have referred to *Spirorbis*. On these sandstones Stigmaria again took root, and one bed is filled, from the cliff to low-water mark, with well-preserved stools of these singular roots, each with four main divisions, branching dichotomously. A single inch of impure coal was the result of this thick growth of trees. Above this accumulated a thick boggy underclay, on which a varied and beautiful forest has grown, which was overturned or uprooted, and now lies prostrate in a thin band of ironstone and shale. In the ironstone of this band are three species of *Sigillaria*, a *Favularia*, and great multitudes of *Poacites*, and other leaves. All these fossils had *Spirorbis* attached. They no doubt mark the site of a submerged and fallen forest, which but for the abundant deposition of fine mud and carbonate of iron, which followed its submergence after an interval sufficiently long for the growth of *Spirorbis*, would have appeared as a thin coaly layer. Above this, after an interval occupied by shales and sandstone with one thin coal, we find a thin coaly layer almost entirely composed of *Poacites*. No roots appear in the underlying shale, and we may therefore doubt whether these leaves grew *in situ*, or were scattered over the bottom of water. On this coal is a thick clay supporting two interesting erect stumps. From the clay in which they are rooted they pass upward, through a sandstone two feet in thickness, into a shale with ironstone bands above. The smaller stump is fluted, but without leaf-scars. Its roots are concealed under the beach. It is filled with sandstone to the height of seven inches above the level of the sandstone without, indicating that this bed must have suffered from denudation, after having contributed materials toward the filling of the stump. It is probable that the sand within the bark was originally lower than that without. If so, the sandstone may have lost much more than seven inches; and of this, but for the presence of this stump, there would have been no evidence. The neighbouring tree, though rooted at the same level, is brought by the dip of the beds to a sufficient height to allow its roots to be seen. It has originally been of the same height with the other, but the upper part has been removed. In this stump we see that while the sandstone within has extended higher than that without, it has also descended lower, though not quite to the bottom, this being filled with clay. We thus find that after the tree became hollow, and while its top continued to stand at least three feet above the surface, it was partly filled with a deposit from muddy water. The mud within was, however, much lower than that without when the sand began to be deposited, and filled the greater part of the stump. The roots of this tree had stigmaria markings, and the rootlets could be seen penetrating the shale beneath. Portions of the surface of the trunk showed the markings of a broad ribbed *Sigillaria*, with oval leaf-scars on the ligneous surface. The roots descend somewhat rapidly into the clay, and perhaps even reach the coaly layer below. The overlying shales bend downward into the upper part of these stumps, indicating that the material within was more compressible than that without. Perhaps this is due to the compression of woody matter remaining in the bottom of the cavity left by the decay of the trunk. The circumstances in which these stumps were preserved, strikingly illustrate the strength and durability of the bark of *Sigillaria*. Above this bed there are about thirty feet of shales with ironstone bands, and sandstones including a few thin layers of coal, and apparently several underclays; but the coal railway and pier prevent them from being well seen. On these rests the main coal, the only one now worked. The main coal and a layer of clay six inches thick overlying it, have supported a forest of *Sigillariæ*, some of which remain as erect stumps, others are prostrate. Very fine specimens have been extracted from this bed in working the coal. Their surfaces are often covered with *Spirorbis*. This forest was buried under eight feet of sand and clay; and from the surface of the latter springs an erect tree, which extends upward to the height of fifteen feet, and is then abruptly broken off. The rocks enclosing it are sandstone and arenaceous shale. (Fig. 17.) This tree, like one previously mentioned, is now a pillar of coaly matter, without distinct external markings, and compressed by lateral pressure. Its preservation in this manner shows that it was composed of durable wood, but by no means proves that it differed from those trees which are found in the state of stony casts. An erect tree, the wood of which had time to decay before it was buried by detritus, would appear as a cast in sand or clay. The same tree, if broken off and buried before

Fig. 17.

Beds overlying Joggins Main Coal, with erect Tree and Calamites.



1. Shale and sandstone. Plants with Spirorbis attached; Rain-marks (?)
2. Sandstone and shale: 8 feet. Erect Calamites.
3. Gray sandstone: 7 feet.
4. Gray shale: 4 feet.
5. Gray sandstone: 4 feet.

(3–5: An erect coniferous(?) tree, rooted on the shale, passes up through 15 feet of the sandstones and shale.)

6. Gray shale: 6 inches. Prostrate and erect trees, with rootlets; leaves; Modiola; and Spirorbis on the plants.
7. Main coal seam: 5 feet coal in 2 seams.
8. Underclay, with rootlets.

the decay of its wood, might appear as a pillar of coal. This tree is, however, proved, by portions of its wood which retain their structure, to have been coniferous.

After deposits of sand had extended to the height of at least ten feet above the root of this tree, and while its top projected above the surface, calamites grew around, attaining a diameter of $1\frac{3}{4}$ inch, and a height of at least five feet. They are very numerous, and though perhaps a different species from those in the great calamite bed before mentioned, grew in the same manner. They were buried by five feet of sand and arenaceous mud, after which their tops and that of the erect tree were removed or decayed, and the sands next succeeding contain only drift vegetable fragments, having spirorbis attached to them. Above these is an inch of coal, loaded with poacites, and it is to be observed that this is the second instance of thin coals of this kind without stigmaria underclays. Immediately above this is a sandy soil with stigmaria and rootlets, but without coal or erect trees. Shales and sandstones succeed; and above these we have a very thick underclay full of rootlets. This soil, after the growth upon it of coaly matter, and a forest or successive forests of sigillaria, was submerged in such circumstances that scarcely any mechanical detritus was deposited upon it. The trees remained erect in the bottom of clear waters, inhabited by fishes and cypris, until spirorbis attached itself to their trunks. They at length fell and sunk to the bottom; and with the vegetable soil, form a bed of impure coal eight inches in thickness, and abounding in scales of fishes and trunks covered with spirorbis. Long after the forest had disappeared these aquatic conditions continued, and ten inches of calcareo-bituminous shale with modiola, fish-scales, and cypris were deposited, as usual passing upward into barren gray shale. This is a fine instance of an order of succession which we had frequent occasion to notice in the earlier part of the section.

In the next group the waters retain their dominion, though probably diminishing in depth, in consequence of the deposition of detrital matter. The sandstones of this group are very uniform and evenly bedded as compared with those in the last, and present no indications of vicinity to shores or water-courses, except in the presence of drift-wood and of singular scratches and furrows on the surfaces of the shales, fine casts of which have been taken by the overlying sand. Scratches and marks of this kind are very frequent in the coal-formation. They occur on a grand scale in the Pictou freestone quarries, and are also very abundant near Tatamagouche. Many of them might very easily be included in the convenient tribe of *Fucoides*, that is remains of sea-weeds, but their want of uniformity in everything except direction, their want of organic matter, and occurrence in beds containing drift-wood, make it most probable that they were scratches produced by the roots and branches of trees borne over the surface by currents of water, and similar to those which may be seen on the inundated mud-flats of wooded countries. Such marks are usually straight, like diluvial striæ, but when stumps or tree-tops ground and are borne off, the most fantastic markings are produced, partly by the eddying of the current around the obstacles opposed to it.

In group XXV. we have a dense series of fossil soils with thin coaly layers. It terminates upwards in bituminous limestone with its usual fossils and resting on coal. This is a case precisely similar to that which terminates our 23d group, except that in this last case the conditions favourable to the formation of bituminous limestone probably continued longer.

The next is another barren group of chocolate and gray shales, with gray sandstone occasionally rippled, and with fragments of drift-wood. This is the filling up of the modiola-inhabited waters, in the manner already so frequently noticed. In one of its beds I observed a series of footprints probably of a small reptile.

Group XXVII. is another succession of underclays and small coaly layers. It is remarkable for the very pyritous character of many of its beds, an indication of the action of sea-water. The most remarkable part of this group is that represented in Fig. 18. It includes a bed of erect calamites and an erect tree with distinct

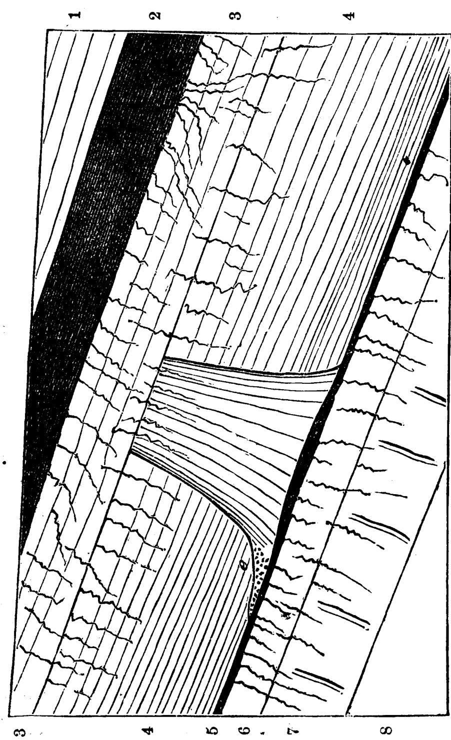


Fig. 18.—*Section from the lower part of* Group XXVII.

1. Shale. 2. Shaly coal: 1 foot. 3. Underclay with rootlets: 1 ft. 2 in. 4. Gray sandstone passing downwards into shale: 3 ft. Erect tree with Stigmaria roots (*e*), on the coal. 5. Coal: 1 inch. 6. Underclay with roots: 10 inches. 7. Gray sandstone: 1 ft. 5 in. Stigmaria rootlets continued from the bed above; erect Calamites. 8. Gray shale, with pyrites. Flattened plants.

stigmaria roots. The underclays are here so crowded on the erect plants, that the rootlets of one underclay pass downward among the erect calamites, and the rootlets of another pass beside and within the cast of the erect tree, the surface markings of which they have helped to obliterate by passing downward immediately within the bark. The calamites are rooted in shale, and the erect tree in an ordinary underclay, supporting a thin layer of coal which rises a little immediately under the stump, being there either protected from pressure or increased by the addition of woody matter derived from the trunk. This stump, it will be observed, expands rapidly toward its base. This group terminates upward in a muscle-bed resting on coal.

Above these beds there occurred sandstones and shales with decreasing evidences of swamp conditions, and abundance of drift-trees and other vegetable remains. In one of the sandstones was a fossil tree petrified by calcareous matter, and showing coniferous structure of the Araucarian type on the cellular tissue. The section extends with southerly dip for several miles beyond the highest bed noted in the section.

The whole series of events in the preceding historical sketch has depended on the following conditions:—"Gradual and long-continued subsidence with occasional elevatory movements, going on in an extensive alluvial tract teeming with vegetable life and receiving large supplies of fine detrital matter. On the one hand, subsidence tended to restore the original dominion of the waters. On the other hand, elevation, silting up, and vegetable and animal growth built up successive surfaces of dry land. For a very long period these opposing forces were alternately victorious, without effecting any very decided or permanent conquest; and it is very probable that the locality of our section was, during this period, near the margin of the alluvial tract in question, where the various changes of the conflict were more sensibly felt and more easily recorded than nearer the open sea or farther inland."

The portion of the section above described in detail, includes a thickness of 2819 feet of the central part of the coal-formation. The whole series, however, as examined by Mr Logan, and extending along the coast about seven miles in a direct line, includes a vertical thickness of 14,570 feet, summed up as follows, in the paper on the Joggins Coal-measures already often referred to.*

"Nos. 1 and 2.—Gray, drab, and reddish yellow sandstones and conglomerates; and dark red, chocolate, and gray argillaceous and arenaceous shales. Large drift-plants, and in lower part erect calamites, 2267 feet.

("This corresponds with the 'Newer or Upper Coal Formation of Pictou.')

"No. 3.—Gray and reddish sandstones, gray and reddish shales, with carbonaceous shales, underclays, and 22 seams of coal. Erect plants at two levels, 2134 feet 1 inch.

"No. 4.—Gray, drab, and reddish sandstones; gray, reddish, and chocolate shales, gray beds greatly preponderating; carbonaceous shales, bituminous limestones, underclays, and 45 seams of coal. Erect

* See Chapter I. for reference to this Paper, in which many additional facts will be found.

plants at eighteen levels; shells (*Modiola*) and fish-scales, ... 2539 feet.

"No. 5.—Reddish and gray sandstones and red and greenish shales, red beds greatly preponderating; some beds with calcareous concretions. Remains of carbonized plants, . . . 2082 feet.

"No. 6.—Gray, drab, and reddish sandstones, constituting nearly two-thirds of the whole; gray and reddish shales, carbonaceous shales, underclays, and bituminous limestones; 9 seams of coal. Upright plants at one level; great quantities of drift-plants, shells (*Modiola*), and fish-scales, 3240 feet 9 in.

("Nos. 3, 4, 5, and 6 contain the equivalents of the productive coal measures of Pictou and Sydney, and in part of the sandstones which separate them from the lower carboniferous series.)

"Nos. 7 and 8.—Reddish and gray sandstone, red conglomerate, red and chocolate shales, concretionary limestone, and two beds of gypsum. Remains of plants, ... 2308 feet.

("Below these beds, and separated from them by a space equal to 300 feet of vertical thickness, is a thick bed of limestone, with shells of *Productus Lyelli*, and other fossils of the lower carboniferous series. This, with the overlying conglomerate, gypsum, red shale, and sandstone, is equivalent to the lower carboniferous or gypsiferous series of Windsor, Shubenacadie, Pictou, Plaister Cove, &c., as established by Sir C. Lyell.)

"The entire section contains 76 beds of coal and 90 distinct Stigmaria underclays. All the coals except two rest on Stigmaria underclays; and there are 16 Stigmaria underclays without coals. Erect plants were observed at 22 levels. There are 24 bituminous limestones, 17 of which are immediately connected with seams of coal.

"The portion of the section examined by Sir C. Lyell and Mr Dawson in 1852, and by Mr Dawson in 1853, includes *the lower part of No.* 3 *and the whole of No.* 4."

Beyond the extremity of Mr Logan's section, the beds become nearly horizontal and then rise with dips to the northward, which probably continue to the base of the metamorphic hills toward Cape Chiegnecto. On this part of the coast the Joggins section should be repeated with a reverse dip, but the beds are not quite so well exposed. Nevertheless, I anticipate very interesting results from the study of this part of the section and its comparison with that of the Joggins shore.

It is impossible to contemplate this vast series of deposits, without been forcibly impressed with the great lapse of time and variety of change which it indicates; and a glance at the table of formations in the introduction to this work, will show how small a portion of the whole geological history of the earth is represented by the coal-measures. It is to be borne in mind also that this section represents the structure of the whole plain of Cumberland, and in a less precise manner that of the whole carboniferous areas of Nova Scotia and New Brunswick, with great tracts composed of similar rocks but not elevated above the bed of the present seas. I do not wish it to be understood, however, that all the changes represented by the Joggins beds extended continuously over large areas. On the contrary, I believe that had we visited Cumberland during the coal-period, we might, by changing our position a few miles, have passed from a sandy shore to a peaty swamp, or to the margin of an estuary or lagoon; but I believe that in each locality these changes succeeded each other in a similar manner, and that the great alternations between terrestial growth and marine deposition extended over very wide areas. Had we visited Cumberland during the time represented by one of the groups of coals, bituminous limestones and erect forests, we should have beheld vast swampy plains covered with dense forests, calamite brakes, and peaty bogs, intersected by sluggish streams and shallow lagoons. Had we visited it perhaps some centuries later, at the time when one of the barren groups of sandstone was being deposited, the eye would have ranged over a wide and shallow sea, filled with sandbanks, and with occasional low islets and spits, covered with sigillariæ and fringed with wide borders of calamites, struggling for existence among the shifting sands. Changes of this kind alternated again and again, while the whole area was constantly subsiding at a rate so slow, that mechanical deposition and animal and vegetable growth were able to a great extent to counteract and sometimes altogether to neutralize its influence. At length, however, in the upper coal-formation, aqueous conditions regained a decided preponderance. This then, be it borne in mind, was the process employed by the great Architect of the universe, in building up the coal-fields of Nova Scotia and of the world, and we are indebted to the clean and sharp section, effected by the tides of Chiegnecto Bay, for that fine exposure of its stony monuments which enables us to understand and explain in such detail its nature.

The beds that appear at the Joggins can be traced inland for many miles, and reappear with a very similar arrangement in the banks of the inland streams on their line of strike. They no doubt extend, with some modifications in the details, quite to the coast of Northumberland Strait. On this coast, however, the rocks are not so well exposed as on the shore of Chiegnecto Bay, and they have been disturbed by lines of fracture, extending from the great line of elevation of the Cobequid Mountains.

At Pugwash, we find large beds of limestone and gypsum, the former with lower carboniferous shells; among which are the *Producta Scotica* and a very similar but more finely striated species the *P. Lyelli.* There are also joints of *Encrinites*, a pretty little *Pecten* or scallop, and a smooth shell, *Terebratula Sufflata*, belonging to the same tribe with the Productæ, but more closely allied in form to the few species of that tribe which inhabit the existing seas. This limestone is of good quality, and has been extensively quarried. It dips to the S.W. On the shore in the vicinity a series of sandstones and brownish shales appears also with S.W. dips. Associated with them are some beds of gray and black shale with leaves of Ferns and Poacites. The limestone is again seen at Canfield's Creek, and there it is associated with gypsum. The dip is S.S.W. These Pugwash beds are evidently lower carboniferous, and if the same regularity that we have observed at the Joggins prevailed, would be associated with a series of coal-formation rocks regularly succeeding them. A portion of such a series does appear in ascending Pugwash River, but in proceeding to the eastward we find that the centre of the trough is broken up by a dislocation or anticlinal line, extending to Cape Malagash, which causes the coal-measure rocks to be ridged up, where otherwise they would have dipped gently toward the central line of the trough. Consequently on the east side of Pugwash Harbour, we find gray sandstones in very thick beds dipping to the north, and containing prostrate trunks of carbonized trees and calamites. The shore runs nearly in the direction of the beds, and the gray sandstones in consequence form a sort of sea-wall sloping toward the strait, and it is only in the coves and the sides of the points that we can see the underlying beds. In such places we observe beds of gray shale with leaves of Ferns and a small seam of coal. Underlying both these and the gray sandstones, are dark red, brown, and mottled sandstones and shales. These beds appear to belong to the Upper Coal-formation, and under and behind them there may be productive coal-measures. The beds above mentioned occupy the coast from Pugwash Harbour to Oak Island. On the shore of Wallace Harbour, there are gray sandstones and gray and brown shales with high dips to the north-east; they are far beneath the beds seen on the Gulf Shore, and probably belong to the middle coal-measures, possibly to their lower part. They contain at one place a thin seam of sulphurous coal, and chalybeate and sulphurous springs rise from them.

Sandstones and shales of the coal-formation prevail along the coast between Wallace and Cape Malagash; and there present some appearances worthy of notice, more especially the association of limestone, marine shells, and gypsum, with beds containing trunks of fossil coniferous trees, and the occurrence of coal-measure beds in a vertical position, or disturbed as far as possible from their original horizontality. At M'Kenzie's

Mill, not far from the eastern extremity of Wallace Harbour, the following curious succession occurs, in descending order:—

	Feet.
Gray limestone with shells of *Producta Lyelli* and *Terebratula*, the cavities of the shells filled with crystalline gypsum	2
White small-grained crystalline gypsum . .	10
Reddish shale and sandstone with layers of arenaceous and concretionary limestone . . .	40
Gray sandstone and shales with some reddish beds. One of the gray sandstones is filled with trunks and branches of fossil trees, fossilized by carbonate of lime, and showing under the microscope a very perfect structure of the Araucarian type	about 150

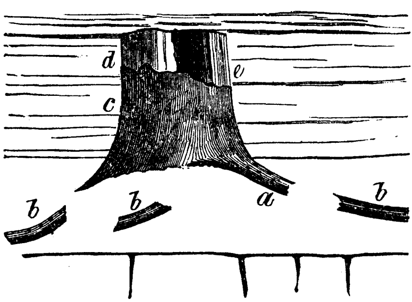
Here we have, on a small scale, some of the principal features of the lower carboniferous series, associated with vegetable remains similar to those found usually at a much higher level in the carboniferous system. The beds at this place dip S.S.W. 20°; but a little farther to the north there are sandstones and conglomerates, also of the carboniferous series, dipping to the N.E.

Proceeding along the coast to the north-east, we find the gray sandstones containing fossil trees and thrown quite on edge. As the strike of the beds corresponds nearly with that of the shore, large surfaces sometimes stand up along the face of the cliff like walls, and on these are distinct ripple-marks and worm-tracks, produced when the sandstones were beds of incoherent sand, but now, in consequence of the hardening and disturbance of the sandstone, forming sculptures on a vertical wall. A little farther on the same beds are seen dipping to the north at an angle of 45°, and containing abundance of fossil wood and some *Calamites.* A portion of the shore is then occupied by a salt marsh, and beyond this we have a considerable series of coal-measure beds at the extremity of Cape Malagash, dipping south at an angle of 40°. That the reader may have an opportunity of comparing these beds with those of the Joggins, at the other extremity of the same coal-field, and sixty miles distant, I shall give a section of them in descending order.

	Feet.
Brownish red sandstones and shales alternating with gray sandstones, one of them containing pebbles of white quartz . . .	about 600
Dark gray limestone	2
Gray and reddish sandstones	50
Dark gray limestone	3
Gray sandstones	50
Reddish sandstones and shales . .	not well seen.
Gray arenaceous shale, Fern leaves, and Poacites	6
Underclay with *Stigmaria*, and an erect stump with stigmaria roots, penetrating bed above .	3
Dark gray limestone	3
Alternations of gray and reddish sandstone and shale. In the lower part a bed of *coal* six inches thick, with stigmaria underclay	about 300
Gray sandstone	20
Alternations of reddish sandstones and shales and gray sandstone, with thin layers of clay ironstone and a layer of coaly shale . .	about 300

This is evidently very like some of the more barren parts of the Joggins shore, especially near the lower part of the coal-measures. I may remark, however, that if the section at Malagash was exposed in a cliff like that of the Joggins, I have no doubt that more beds with erect plants would appear. The erect tree mentioned in the section was described and figured by me in the Proceedings of the Geological Society in January 1846. Mr Binney had described a similar specimen found in Lancashire in June 1845; and before the close of 1846, Mr R. Brown of Sydney had described still finer instances of the same kind from the Sydney coal-field. These were the three first instances in which the stigmaria was ascertained to be the root of the sigillariæ of the coal-period; and even these were not altogether sufficient to dispel the doubts of some geologists. As the Malagash tree is thus an historical monument in the progress of geology, I give a sketch of it in Fig. 19.

Fig 19.—*Erect Fossil Tree at Cape Malagash.*



(*a b*) Stigmaria roots. (*c*) Bark marked with furrows.
(*d*) Woody surface with indistinct ribs. (*e*) Internal core.

On the south side of Malagash Cape and head of Tatamagouche Bay, the coal-formation rocks dip to the southward, but are not well exposed; and at Tatamagouche Harbour we find them dipping to the north, which they continue to do as far as the base of the Cobequid hills at New Annan. Cape Malagash thus forms an anticlinal ridge, which extends far to the westward into the interior of Cumberland; and if we consider the limestone at M'Kenzie's as the equivalent of the Pugwash and Napan limestones, then the trough between it and the New Annan hills corresponds to the Joggins trough, though narrower, and the northerly dipping beds of the Gulf Shore correspond to those north of the Joggins in New Brunswick. Perhaps, however, it is more probable that the great Cumberland trough is here, as already hinted, split into two by the intervention of the Malagash anticlinal. Unless the more important parts are concealed by the imperfection of the sections, the whole carboniferous series appears here to be less fully developed than on the western coast of the county.

The beds seen with northerly dip at Tatamagouche and thence to New Annan, have the aspect of those of the upper coal-formation.

At the mouth of the French river are gray sandstones and shales, containing a few endogenites, calamites, and pieces of lignite, impregnated with copper ores. Beneath these appears a series of brownish red sandstones and shales, with a few gray beds, occupying, in a regular descending series, about six miles of the river-section. They contain, in a few places, nodules of copper glance (gray sulphuret of copper), they are often rippled, and contain branching fucoidal marks. On one of the rippled slabs I found marks consisting of four footprints of an animal. They were three inches and a-half apart, and each exhibited three straight marks as if of claws. These were described in 1843; and in the following year I discovered at the same place another series of footsteps of different form. Neither of these were sufficiently well marked to give any definite information respecting the nature of the animal that produced them, but I am now convinced that they must have been the traces of reptilian animals. In my paper sent to the Geological Society in 1844, I find the following remarks:—

"When examining the red sandstones, near Tatamagouche, last summer, I found in one of the beds a few footmarks of an unknown animal, specimens of which were sent to this society. They were mere scratches made by the points of the toes or claws, and therefore could give few indications of the form of the feet which produced them. Their arrangement, however, appeared to indicate that the animal was a biped, and their form is quite analogous to that of the marks left by our common sandpiper, when *running* over a firm sandy shore. On a subsequent examination of the same place, I found a series of footmarks of another animal, and obtained a slab with casts of eight impressions, which I send with this paper. In this specimen the tracks are somewhat injured by the rain-marks which cover the slab, and the clay in which they were made was probably too soft to give good impressions; it has, however, preserved a furrow which must have been caused by the body or tail of the animal trailing over it. Many of the beds in the neighbourhood of that containing these footmarks are rippled, rain-marked, or covered with worm-tracks; and as such indications of a littoral origin are not infrequent in other parts of the newer coal-formation, it may be anticipated that many interesting relics of terrestrial animals will in future be discovered. At present, however, as no quarrying operations are carried on in the red beds, it is difficult to obtain access to the surfaces on which tracks might be expected to occur. The only vegetable remains found in the red sandstones of Tatamagouche are some of those irregular branching stains which have been considered as fucoidal marks; but in a bed of gray sandstone above the strata containing tracks, I found *Calamites*, *Endogenites*, *Stigmaria ficoides*, and fragments of carbonized wood. In a fragment from a dark calcareous bed near this place, I found a portion of a fossil plant covered with shells of a species of *Spirorbis*, and a few small scales of ganoid fishes."

It will be observed that *rain-marks* are mentioned as found with these footsteps, and I have now in my collection specimens from this place, I believe the first ever observed in the carboniferous system, though much finer specimens were found shortly afterwards by Mr Brown at Sydney, and described by him and by Sir C. Lyell.

In the French river-section, the northerly dips of the coal-measures increase in approaching the hills, the lowest beds dipping at an angle of 30°. Not far from the base of the hills, there is a small bed of coal with some gray shales and sandstones and a thin bed of limestone.

Useful Minerals of the Cumberland Coal-field.

Coal.—Only one deposit of this mineral is now worked in Cumberland—the Joggins main seam, consisting of two beds, three feet six inches and one foot six inches thick, with a clay parting between, varying from one foot to a few inches. It is a free-burning bituminous coal of fair quality. It is extracted by two shafts worked by horse-gins, and the coal is carried to the loading pier by a railway incline. The mine is drained by a level run out to the shore, and consequently is not worked below the level of high tide. The General Mining Association are the lessees of this mine as well as of all the other coal-mines of Nova Scotia and Cape Breton. The quantity of coal shipped in 1851 was only 2400 chaldrons. It was exported principally to St John, New Brunswick.

Taking into account the comparative thickness of the seams, and the facilities for extraction and shipment, there can be no doubt that the bed at present worked is the best in the section; which, as we have already seen, is remarkable for the great number and small thickness of its coal-seams. There can be no doubt, however, that some of the others, especially the principal beds in Groups XI. and XIII. of the section, might be mined with profit. The great disadvantage on the Joggins coast is the want of safe anchorage for shipping, which can be protected only by expensive piers and breakwaters.

About twenty miles south-east of the Joggins shore, at a place called Springhill, coal-measures appear with a dip to the north, indicating, with their position not many miles from the base of the Cobequid hills, that they belong to the southern side of the Cumberland trough. I have had no opportunity of examining the coal-seams of this place, but one of them is variously stated at eight and twelve feet in thickness, and the coal is of good quality. The Springhill bed is at too great distance from navigable water to permit it to be mined at present for exportation. It forms part of the reserve stores of coal, waiting for their full development till railways extend across the country, or till domestic manufactures demand supplies of mineral fuel within the province. The present inland demand might, however, permit it to be mined on a small scale; and the prospect of railway communication between Cumberland and Halifax on the one side, and New Brunswick on the other, is a sufficient warrant for the proposals now I believe being made to the provincial government to obtain a lease of it.

The following assays show the qualities of samples of Joggins and Springhill coal examined by me; but it must be observed that the specimen from Springhill was from the outcrop of the seam, and therefore probably injured by weathering.

Assay of Joggins Coal from the Main Seam.

The specimen is bright coal of uniform texture, with straight joints containing films of iron pyrites and calcareous matter.

Moisture	2·5
Volatile combustible matter	36·3
Fixed carbon	56·0
Reddish-gray ashes	5·2
	100·0

Assay of Springhill Coal.

The specimen is a compact coal, less bright than that of the Joggins and without films of pyrites, though it contains some sulphur intimately mixed with it.

Moisture	1·8
Volatile combustible matter .	28·4
Fixed carbon	56·6
Reddish ashes	13·2
	100·0

From the character given of the Springhill coal by persons who have used it, I should infer either that its quality has been overrated, or that my specimen is inferior to the average quality.

The above assays show that the Joggins coal much resembles that of Sydney, C. B., while the Springhill coal is more like that of Pictou. See assays of those coals farther on.

The structure of the Cumberland coal-field warrants the expectation that the Springhill seam may be traced toward the coast of Chiegnecto Bay, perhaps to the vicinity of Apple River, and also in the opposite direction. Attempts which have been made by a mining engineer in the service of the General Mining Association to effect the former of these results, have, however, been unsuccesful; and it would appear that the beds in the vicinity of Springhill are in a much more disturbed condition than those on the Joggins shore.

In like manner, it is a perfectly fair inference that the seams which appear in the coast-section of the Joggins, must extend along the northern side of the trough, far into the interior of the country; though whether they improve or deteriorate in their eastern extension is not at present known. It appears certain, however, that the coal-measures are less fully developed on the coast of Northumberland Strait than on the western coast, and the seams which have hitherto been found in them are very small.

It may, therefore, be inferred, that in the event of the interior of the Cumberland district being opened up by railway communication, the localities offering the greatest prospects of valuable discoveries are; 1st, The line of country extending E.S.E. from the Joggins toward the branch of River Philip called Black River; and, 2d, A line extending east and west, and passing through Springhill.

Clay Ironstone occurs in the Joggins section, in balls in the shales, and in irregular bands. None of these deposits appear to be of any economical importance.

Grindstone is one of the most important productions of the Cumberland coal-field. I have already referred to the mechanical qualities on which this rock depends for its value. The principal localities of the quarries are Seaman's Cove and Ragged Reef; the beds at the former being below the productive coal-measures, those at the latter above them. In smaller quantities grindstones are obtained from a number of other beds and reefs along the coast, and also from the continuation of these beds on the estuary of the Hebert River, and from the geological equivalents of the beds at Seaman's Cove, where they reappear in New Brunswick. Thirty-six thousand seven hundred and twelve tons of grindstones were exported from Cumberland in 1851. Grindstones are also quarried in the sandstones on the eastern coast of Cumberland, and at Wallace there are valuable beds of freestone, which have been quarried for exportation.

Limestone and *Gypsum* abound in the line of country extending from Minudie to Pugwash and Wallace. The former especially occurs in very thick beds at Napan River and at Pugwash; and these are also the principal localities of gypsum, which does not, however, appear to be so abundant in the lower carboniferous rocks of this county as in those of Hants and Colchester.

A singular variety of limestone occurs in a number of places on the Joggins shore. It is the black *bituminous* limestone, so often referred to in the section. This substance, though not in sufficiently thick beds to compete with the larger lower carboniferous limestones for ordinary purposes, is the most valuable limestone in the county for application as a manure, in consequence of the quantity of phosphate of lime contained in it, in the form of scales and bones of fish. In consequence of its containing this valuable ingredient, it is worth to the farmer more than three times the price of ordinary limestone, and I have no doubt that it will be extensively worked for agricultural purposes, when the use of mineral manures becomes more general among the farmers of Cumberland. It is possible that even at present the lime from the richest of these beds would be sufficiently appreciated on trial, to allow them to be profitably worked.

The Soils resting on the carboniferous rocks of Cumberland are very various in their quality, and run in lines across the county in correspondence with the strikes of the groups of beds from which the materials of the surface soils have been derived. Rich loamy and calcareous soils generally accompany the limestones, gypsums, and marly clays and sandstones of the lower carboniferous system. The soils of the coal-measures vary from light and sometimes stony sands to stiff clays. The upper coal-formation produces soils approaching somewhat to those of the lower carboniferous series. Hence along the north side of the Cobequid hills we have a broad band of good soil, and a similar one extending across the northern part of the county, while between these are alternate belts of poor and rich soils; almost the whole, however, being sufficiently deep and friable to be cultivable. The great fertility of the marsh-lands of the western coasts and rivers, and the almost exclusive attention of the population on many parts of the eastern shore to lumbering and shipbuilding, have caused the value of the upland soils of Cumberland to be much underrated; but they are now constantly rising in the estimation of the people of the county, and will do so more and more as improved methods of cultivation become more generally diffused and appreciated.

CHAPTER X.

THE CARBONIFEROUS SYSTEM—*Continued.*

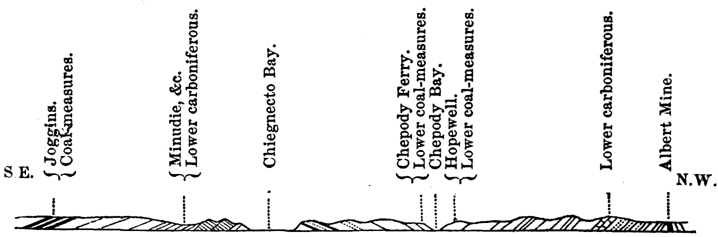
2. *Coal-field of New Brunswick.*

The coal-measures of the Joggins, dipping to the south-west, extend in the direction of their strike across Chiegnecto Bay to Cape Meranguin, but only the lower coal-measures appear there; and on tracing them a little to the northward, they become vertical and dip to the north, forming an anticlinal. This anticlinal appears to extend to the north-westward up the bay, for at Fort Cumberland the first rocks that we see on entering New Brunswick, are coarse gray sandstones dipping to the northward. This dip continues as far as the east side of the Petitcodiac River, where the highest beds are seen at the ferry below Dorchester. They are gray sandstones with *Calamites*, *Artisia*, and trunks of coniferous trees; and beneath them, extending along the coast to the southward, is a great series consisting principally of reddish beds. I have no doubt that the whole of these beds belong to the older part of the coal-formation. Nothing newer is seen in this neighbourhood; for at Dorchester, Fort Folly Point, and at Hopewell, on the opposite side of the ferry, the same gray sandstones reappear with southerly dips, and with fossils of the same species. The dip varies from S.S.E. to S.E. If we follow this series in descending order, to the northward up the Memramcook River, we soon come to conglomerate, limestone, and thin-bedded bituminous and calcareous shales, all belonging to the lower carboniferous series. On the west side of the Petitcodiac, we find a similar descending series toward the great metamorphic band ending in Shepody Mountain, and which consists of rocks older than the carboniferous system. The order of succession seen here is as follows, though there may be important omissions in the list, as the sections are not continuous:—

1. Gray sandstone, often coarse and pebbly, with shales and conglomerate, Hopewell Ferry, &c. These beds perhaps correspond to the great sandstone ledges of Seaman's Quarries, Joggins. They may be traced through Albert County to the south-west for a considerable distance.
2. Reddish sandstones and shales.
3. Limestone and gypsum.
4. Red sandstone and conglomerate.
5. Gray and dark-coloured conglomerate.
6. Calcareo-bituminous shales of the Albert Mine, Hillsborough. These beds appear here to lie at the very base of the lower carboniferous series. (See Section, Fig. 20.)

Thus far, in the New Brunswick coal-formation, we have met with the *lower* coal-measures and lower carboniferous series only. The middle and upper coal-formation seem to be wanting; and this I suspect is

Fig. 20.—*General Arrangement of the Strata between South Joggins and Albert Mine.*

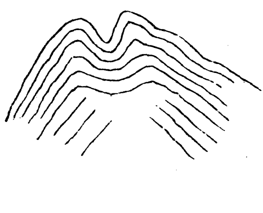


the character of the whole coal-area of New Brunswick; in which only very insignificant seams of coal have hitherto been discovered. The lower carboniferous series occupies a wide area beyond the Albert Mine, extending to and beyond the upper Petitcodiac, on which and at Butternut Ridge it contains much limestone and gypsum, with characteristic lower carboniferous fossils. Northward of this lower carboniferous tract, the gray sandstones and shales with fossil plants and thin seams of coal again appear, and extend northward as far as the Bay de Chaleur, and westward as far as Oromucto Lake, forming a great triangular district, the two longest sides of which are about 150 miles each in length and its shortest more than 100. I shall attempt no detailed description of this district, of which I have seen but a very small portion; but shall give a somewhat minute account of the lower carboniferous shales of Hillsborough, these being of much interest both geologically and in an economical point of view; and shall then very shortly notice the general features of the great coal-formation area to the northward.

Albert Mine, Hillsborough.—The beds at this place are thin-bedded shales, composed of extremely fine indurated clay with much bituminous matter. Some of them contain much lime, and when this is dissolved away by the weather or by an acid, the bituminous matter remains in the form of light porous flakes, resembling half-decayed bark. These shales contain great numbers of fossil fishes in a remarkably perfect state. They are flattened by pressure; but their forms are perfectly preserved, and the fins are as perfect as they were in life. These fishes belong to the same genera with those found in the Joggins coal-measures, but have been buried in such a manner that every scale is in its place, instead of being scattered about as at the Joggins and in the carboniferous rocks generally. The shales containing these fossils have been singularly disturbed and contorted, and they contain a bed or vein of a remarkably pure and beautiful bituminous substance, allied to pitch-coal, and of great value as a material for gas-making. This substance unfortunately became a subject of litigation; and as one point in dispute was whether it should be called coal or asphaltum, scientific gentlemen were summoned from the United States as witnesses, and the most discordant opinions were given, both as to the name of the mineral and its geological age. This was not wonderful in the circumstances, for the substance was really a new material, intermediate between the most bituminous coals and the asphalts, and the geologists examined had enjoyed very few opportunities of studying that very remarkable group of lower carboniferous rocks to which the deposit belongs. Consequently some in all sincerity called the mineral coal, others asphalt; and some maintained that it was in the true coal-formation, while others believed it to be in the old red sandstone. Only one of the geologists employed, Dr Percival of New Haven, assigned the deposit to its true geological position, as subsequently ascertained by Sir Charles Lyell and the writer, and stated above. To give an idea of this singular deposit, I quote the following details from a paper contributed by me to the Geological Society of London.

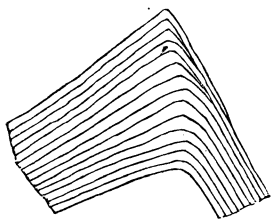
"The pit for the extraction of the mineral is situated on the south side of Frederick's Brook, a small stream running eastwardly into the Petitcodiac, and near the junction of two branches of the brook. In approaching the mine from the south, the shales are seen in nearly a horizontal position in a road-cutting. This may be a deceptive appearance. Dr Percival, however, considers it the true arrangement at this point. At the pit-mouth the beds dip to the south at angles of 50° and 60°, and consist of gray and dark-coloured thin-bedded bituminous shales; and these shales appear with similar dips on the south branch of the brook. The outcrop of the coal is not now seen, but in a line with it I observed a remarkable crumpling and arching of the beds in the bank of the brook, at the point where the southwardly dipping beds above noticed meet a similar or the same series dipping to the north-west; this is represented in Fig. 21. The outcrop of the coal in the bed of the brook was, as I was informed, very narrow, and the appearances now presented are as if the shales had arched over it. On the northern side of the arch above referred to, and in the north branch of the brook, are seen a thick series of bituminous and calcareous shales, with three

Fig. 21.—*Arched Strata near Albert Mine.*



beds of sandstone, the whole dipping to the north-west at a high angle. The strike of one of the most regular beds I found to be S. 18° W. magnetic. Many of the shales contain scales of fish, and one of them has a peculiar oolitic structure, consisting of a laminated basis of impure coaly matter or earthy bitumen, with crystalline calcareous grains, which are removed by weathering, and leave a light vesicular inflammable residuum of very singular aspect. The shales are in some places remarkably bent and contorted, as if by lateral pressure when in a soft state. A part of one of these flexures is accurately represented in Fig. 22, and illustrates some appearances in the mine to be subsequently noticed.

Fig. 22.—*Bent Strata, near Albert Mine.*



"The principal shaft has been sunk perpendicularly from the outcrop of the coal, and at its bottom is sixty-seven feet south of it. The gallery connecting the bottom of the shaft with the coal, shows thin-bedded bituminous shales with calcareous and ironstone bands and concretions, dipping at the end nearest the coal S.S.W., at an angle of 60°, though a dip to the S.E. is more prevalent along this side of the mine. The coal at this place is about ten feet in thickness, and its upper surface dips N.W. about 75°. On the S.E., or under side, it rests against the edges of the somewhat contorted beds, already noticed as dipping to the southward, and on the north-west side it is overlaid by similar beds dipping in the same direction with the coal, but so much contorted as to present on the small scale a most complicated and confused appearance. The coal itself, as seen in mass underground, presents a beautiful and singular appearance. It has a splendent resinous lustre and perfect conchoidal fracture; it is perfectly free from mineral charcoal and lines of impure coal or earthy matter. It is, however, divided into prismatic pieces by a great number of smooth divisional planes, proceeding from wall to wall, much in the manner of the cross structure seen in carbonized trees, and in the streaks of pitch-coal in the ordinary coals. At the N.W. side or roof, the coal joins the rock without change. On the S.E. side, on the contrary, there is a portion of coal a few inches thick, including angular fragments of the shale, some beds of which on this side are very tender and cleave readily into rhomboidal pieces. The coal enveloping these fragments must have been softened sufficiently to allow them to penetrate it, but it has more numerous and less regular divisional planes than in the central parts of the mass, and has probably been shifted or crushed somewhat, either when it received the included fragments or subsequently. Both at the roof and floor, the coal shows distinct evidence of a former pasty or fluid condition, in having injected a pure coaly substance into the most minute fissures of the containing rocks. On both roof and floor also, but especially the latter, there are abundant evidences of shifting and disturbance in the slickenside surfaces with which they abound. All these appearances I have endeavoured to represent in

Fig. 23.—*Relation of the "Albert Coal" to the containing beds, as seen near the shaft of the mine.*

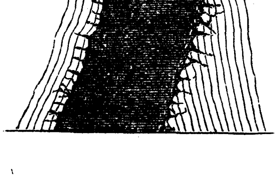


Fig. 23, which agrees in the essential points with a similar figure given by Professor Taylor, who does not, however, represent the contorted state of the beds and the crushing of the lower side of the coal.

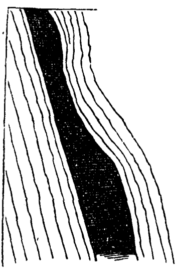
"The levels of the mine extend on both sides of the shaft along the course of the coal. On the south-west they extend about 170 feet, when the coal narrows to a thickness of one foot. In this direction, however, I had not time to examine them. In proceeding to the N.E., the coal has a general course of N. 50° E., bending gradually to N. 65° E., and everywhere presenting the appearances already noticed, though attaining, in one place, a width of thirteen feet. At the distance of about 200 feet from the shaft, a remarkable disturbance occurs. The main body of the coal bends suddenly to the northward, its course becoming N. 29° E.* for about twenty-five feet, when it returns to a course of N. 50° E. At the bend to the northward, a small part of the vein proceeds in its original course, and is stated by the persons connected with the mine to run out, leaving a large irregular promontory of rock between it and the main body of the coal. This disturbance has been variously represented as a fault, and as a cutting of the vein across the strata. Though I confess that the appearances are of a puzzling character, and are but imperfectly exposed in the mine, the impression left on my mind is, that it is, on a large scale, a flexure similar to that represented in Fig. 22, and accompanied by a partial tearing asunder of the beds. It seems evident

* These measurements were made with a pocket prismatic compass. They differ slightly from those of Dr Jackson, either from accidental circumstances, or from being taken in different levels of the mine.

that the beds must have been in a soft state at the time when this disturbance occurred, although there may have been subsequently some vertical shifting, especially on the west side of this "Jog."

"Beyond this flexure, the deposit contracts in width, and becomes more regular, and eventually its containing walls assume a conformable dip to the S. 5° E., at an angle of 69°. The appearance presented at the time of my visit in the extreme end of the most advanced level, is represented in Fig. 24, where it will be observed that the S.E. wall still shows indications of the prevailing contortions of the beds, and of the manner in which these cause the ends of strata to abut against the coal.

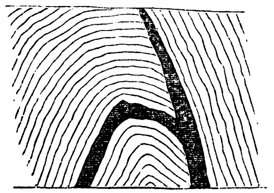
Fig. 24.—*Section of the beds at the East end of Albert Mine.*



"At this place, an exploratory level, driven to the S.E., shows a series of bituminous shales, with bands of ironstone, dipping regularly to the south-eastward. I could not, in any part of the mine, find beds corresponding to the Stigmaria underclay of ordinary coal-seams, though on the S.E. side some of the beds are of a more compact and purely argillaceous character than those on the N.W. side or roof of the seam. The ironstone bands and fish-bearing shales are, however, not very dissimilar from those in some coal-measures of the ordinary coal-formation. They present no indications of metamorphism or of the passage of heated vapours, and all their appearances show that their bituminous matter has resulted from the presence of organic substances at the time of their deposition.

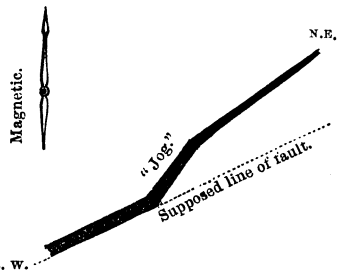
"It is evident that all the above phenomena can be explained on the supposition that this coaly mass occupies a fissure running along an anticlinal bend of the strata; and that, apart from the character of the mineral and the containing beds, this would be the most natural explanation. On the other hand, when we consider the contorted condition of the beds, indicating disturbance when in a soft state, and the slickenside joints, pointing to subsequent shifts, we cannot refuse to admit that a conformable bed of true coal, if subjected before and after its consolidation to such movements, might present all the appearances of complication and disturbance observed in this mass, more especially if originally of small extent, and thinning out toward the edges. On this view we should have to suppose,—1. Disturbance and contortion of the beds while soft, and, at the point in question, a regular and somewhat abrupt arching of the beds; 2. A fault throwing down the south side of the arch along a line, coinciding in part of its course with the highly inclined underside of the coal at the north side of the arch; and 3. Removal of the upper part of the north side of the arch by denudation. Fig. 25 represents the appearances which would thus be produced, and it will be seen that they very closely correspond with the present condition of the deposit, not excepting its thinning toward the surface. If this be the true explanation, it is probable that the sunken south side of the bed has not yet been reached in the excavations. It might, however, in approaching it from above, show a succession of

Fig. 25.—*Ideal representation of the cause of the appearances at Albert Mine.*



wedge-shaped included masses of rock or "horses," one of which I saw in the floor of the lowest level. On this view, also, the "Jog" or fault, above described, may be a lateral bend received by the bed in the original contortion of the strata; and at this point the straight fracture, producing the supposed downthrow, may have left the bed, and thus caused the appearance of the vein running in the former course of the bed along the line of fault, and also the greater regularity of the bed beyond the "Jog." This explanation is represented in Fig. 26."

Fig. 26.—*The "Jog" at Albert Mine, and its supposed relation to the line of fault.*



As many readers of this work may be interested in the controversies respecting this mineral, I may shortly mention its physical and chemical properties, and the results at which I have arrived respecting its nature and origin.

The substance has externally an appearance not dissimilar from the ordinary asphalt of commerce in its purest forms; but it is very much less fusible, and differs in chemical composition. Its fracture is conchoidal. Its lustre resinous and splendent or shining. Its colour and the powder and streak on porcelain, black; and it is perfectly opaque. It is very brittle and disposed to fly into fragments. Its hardness is 3, nearly, of Mohs' scale. Its specific gravity is 1·08 to 1·11 (according to Jackson and Hayes). It emits a bituminous odour, and when rubbed becomes electric. In the flame of a spiritlamp it intumesces and emits jets of gas, but does not melt like asphalt. In a close tube, however, it can be melted with some intumescence. In the above characters, with the exception of the colour of the powder, it agrees more nearly with the finer varieties of *Jet or Pitch Coal*, than with any other substance. For this reason I made comparative trials of its composition and that of specimens of jet from Whitby, with the following results :—

	Albert Mineral.	Whitby Jet.
Water	·4	1·5
Volatile combustible matter	57·2	57·1
Coke	42·4	41·4
	100·0	100·0
Ash in coke	·27	4·0

These results indicate a remarkable similarity in the proportion of volatile and fixed combustible matter ; an ultimate analysis might, however, establish important differences of detail.

If we compare the "*Albertite*," as it has been named by persons desirous of not committing themselves, with the substances most nearly allied to it, we can scarcely avoid arriving at the following conclusions. In its behaviour in the fire, chemical composition, and electrical properties, the substance is nearly allied to jet, from which, however, it differs in its extreme brittleness, its greater uniformity of texture, and more perfect lustre and fracture, and also in its black streak : a character which also separates it from ordinary bituminous coal and all the varieties of asphaltum. Its nearest analogue in this last particular is Lesmahagow cannel. Its lustre and fracture remarkably assimilate it to the finer varieties of asphalt, but its streak, mode of combustion, and chemical composition, effectually separate it from them. On the whole, the above considerations, in connexion with a number of experiments made by Jackson, Hayes, and others, and published in the reports on the mineral, place the substance at the head of the *Pitch Coals* or Jets, as the purest variety of that species of bituminous coal. It has, however, some claims to be viewed as a distinct mineral species, intermediate between coals and asphalts; and I suspect that its chemical composition may approach to that of *Asphaltene*, the coaly ingredient of the Asphalts.

Under the microscope, I have not been able to detect any organic structure, though I have found in some slices cells filled with yellow resinous matter, similar to those that occur in cannel-coal. Mr Bacon of Boston, however, states (in Jackson's Report), that he has found traces of cellular tissue; but Professor Quekett of London, after examining many specimens, considers it destitute of organic structure.

Some specimens of the mineral are laminated, and have brilliant discs about a line in diameter on the surfaces of the laminæ. Under the microscope, these discs exhibit very fine concentric and radiating lines, but they are merely concretionary, and in Pictou-coal such discs sometimes occur in an oblique position as regards the lamination. The Albertite has been declared to be free from sulphur; but minute concretions of ironstone and iron pyrites occur in it, and films of iron pyrites line some of the fissures of the containing beds. These appearances are, however, rare.

In inquiring into the origin and mode of formation of the deposit, the following alternatives present themselves. (1.) It may have been a bed or sheet of bituminous matter, thinning out at the edges, like that in Kent, U. C., described in the Report of the Canadian Survey for 1851–2,* and probably produced by the oxidation and hardening of the liquid produce of naphtha-springs. (2.) It may be bituminous matter melted by internal heat, and poured into an open fissure, as was perhaps the case with the *chapapote* of Cuba.† (3.) It may, like jet and other coals, have resulted from the bituminization of woody matter. With respect to these several hypotheses, I can merely state the probabilities which occur to me from the facts already known, and which may of course be greatly modified by the more perfect exploration of the deposit.

On the first of these hypotheses, though there is no great improbability in supposing the deposit to have been a conformable bed, it does not seem likely that so large and extremely pure a mass of bituminous matter could be a deposit from springs, or that, without alteration of the containing beds, it could have assumed an aspect and consistence so much akin to those of coal. It also seems difficult on this view to account for the disposition, in waters tenanted by fish, of the accompanying laminated bituminous shales.

The second view requires us to suppose that, after the crumpling and contortion of the beds, and the production of an open fissure, an underlying portion of the bituminous shales was exposed to heat and pressure, which caused its bituminous ingredient to be melted, forced upward, and consolidated in the upper and un-

* Page 90. † Taylor, Statistics of Coal.

altered portion of the beds. This would account for the occurrence and most of the appearances of the coaly deposit; but we must of course still suppose that the bituminous matter was originally produced during the deposition of the shales, probably from organic matter. To give any great degree of probability to this view, therefore, it would be necessary to have evidence of igneous alteration in some portion of these shales. Some countenance is perhaps given to it by the existence of petroleum-springs at present in the continuation of the same deposit, and by the presence of minute fissures filled with the mineral, which might, however, be explained on the supposition of pressure exerted on a soft or semifluid bed.

The hypothesis of formation from woody matter, after the manner of coal, is also accompanied with serious difficulties. The composition of jet and of recent bituminous coal found in peat-bogs, prove the possibility of this mode of formation; and this is certainly the most natural way of accounting for the production of the coaly and bituminous matter of the containing beds; but large and pure beds of coal are usually accompanied by evidences of growth *in situ*, and accumulations of drift-trunks are usually loaded with earthy matter, while none of these conditions exist in the deposit in question. The want of the first is, however, perfectly consistent with the long and perfect decomposition implied in this view, as well as in the homogeneity of the mass, and the abundance of bitumen in the containing shales; and in a deposit containing so little evidence of strong currents or violent changes, it may not be unreasonable to suppose that drift vegetable matter may have accumulated during long periods in clear water. In connexion with this it is worthy of remark, that the comparative absence of iron pyrites, in connexion with the presence of large quantities of carbonate of iron in the shales, *proves** that these beds were deposited in fresh and very pure water, if it be admitted that their bitumen resulted from the decomposition of organic matter. Neither is the great purity of the mineral an evidence against its accumulation in the manner of ordinary coal, since varieties of coal almost equally pure have long been known.† On this view, then, which is perhaps the most probable of the three, the Albert deposit is a fresh-water formation of a very peculiar character, belonging to the lower carboniferous period, and very singularly *distorted by mechanical disturbances.*

With the exception of the Albert bituminous shales, and their continuation on the Memramcook and towards the Petitcodiac, the lower carboniferous rocks of New Brunswick resemble perfectly those of Nova Scotia. The coal-formation rocks, however, which rest on these beds, and occupy a much greater area, appear to be developed to a much less extent than in Nova Scotia. In short, so far as I can learn from my own limited observations, and the reports of Mr Gesner and Dr Robb, they resemble the lowest parts of the Cumberland coal-measures, or those upper members which overlie the workable coals; as if these alone had been deposited, and the productive coal-measures left out. Consequently, although thin seams of coal and beds of "cannel-coal," which, however, appear to be in most cases bituminous shales analogous to those of Hillsborough, occur in a

* See paper by the writer on the "Colouring Matter of Red Sandstones," in Proceedings of Geological Society.

† See Assays in Taylor's Statistics of Coal.

great number of places, and in some localities are worked on a small scale, no really valuable bed of coal is known; and judging from the details given in the geological account of this coal-field contributed by Dr Robb to Professor Johnston's Agricultural Report, the prospects of any future discovery of this kind are by no means promising. The valuable character of the Albert coal, however, and the well-known fact that coal-measures often vary materially in their productiveness, as we trace them from one locality to another, give some ground to hope that a carboniferous area so extensive as that of New Brunswick may not ultimately be found to be so unproductive as it now appears to be.

The coal-formation of New Brunswick is little disturbed, and its beds are inclined at small angles—at least this is the character of the great tract fronting on the Gulf of St Lawrence; and in consequence of this, and the imperfect character of most of the coast and river sections, it is much less productive of facts interesting to the geologist than the rocks of the same age in Nova Scotia.

In the map, the distribution of the carboniferous rocks, and the localities of coal, &c., are copied, with a few alterations, from the map attached to Professor Johnston's Report on New Brunswick.

CHAPTER XI.

THE CARBONIFEROUS SYSTEM—*Continued.*

CARBONIFEROUS DISTRICT OF COLCHESTER AND HANTS—MUSQUODOBOIT VALLEY—USEFUL MINERALS.

3. *Carboniferous District of Colchester and Hants.*

In this district, which is as extensive as that of Cumberland, from which it is separated by the Cobequid chain of hills, we have a very great development of the limestones and gypsums corresponding to the Napan and Pugwash rocks of Cumberland, and the mountain or lower carboniferous limestone of England, and a very small development of the coal-measures. In other words, in the carboniferous period marine deposits were formed to a greater extent and perhaps for a longer time on the south than on the north side of the Cobequid chain, which, we shall presently see, was then a ridge probably not so high, but perhaps nearly as continuous as at present.

On consulting the map, it will be seen that this district is very irregular in its form; partly because the modern bay, with its fringes of marsh and new red sandstone, penetrates into it, and partly because it in like manner penetrates in long inlets, now river valleys, into the older metamorphic hills to the eastward. Viewing this district, then, as a portion of the dried-up bed of the carboniferous sea, its original shores can be observed both on the north and on the south. Thus on the flanks of the Cobequids, the lowest carboniferous beds consist of conglomerates; the stones and pebbles of which are identical with the rocks of the hills from which they have been derived, just as the materials of shingle beaches on modern coasts are derived from neighbouring cliffs. In like manner, at the base of the Horton and Ardoise hills, the lowest beds consist of white sandstones composed of the debris of granite, and shales made up of the mud produced by the slow wasting of slate; both of these materials being furnished by the rocks of the hills. One difference, however, of a marked character occurs on these opposite shores. The material of the lowest rocks on the south side of the district is fine and almost destitute of pebbles. That of the corresponding rocks on the north or Cobequid side is very coarse, being made up of large pebbles and even stones of considerable size. Similar differences occur in modern seas, and depend on the configuration and elevation of coasts, and their comparative exposure to the sea-swell and prevailing winds. The deposits in the more central part of the district are more uniform and persistent in their character.

In noticing this carboniferous area, I shall describe in the first place some of the localities and sections in which the arrangement and character of its rocks are most distinctly exposed; and these will afford us opportunities of studying the *lower* carboniferous series, almost as perfect as those which we enjoyed at the Joggins in the case of the coal-formation deposits.

At Wolfville and Lower Horton, in the south-western part of the district, we find the lower carboniferous beds to consist of gray sandstones and dark shales, resting on the edges of the slates of the Gaspereau River. In the road-cuttings in Lower Horton, the sandstones may be seen to contain fine specimens of *Lepidodendron*, a genus of which we have already seen examples at the Joggins. There appear to be two or three species of this genus in the beds of Horton Bluff, and one of them at least is distinct from any of those found in the true coal-measures. In some of the shales at the same locality, fish-scales are extremely abundant, and make up apparently the greater part of the mass of some thin beds. The whole of these rocks are, however, much better seen at Horton Bluff, a fine range of cliffs extending along the west side of the Avon estuary. At this place, however, the beds do not dip regularly in the same direction, but have been broken into great masses which dip in different ways, and have been fractured and displaced by *faults* or slips of one mass or another up or down, so as to break the continuity of the layers. Such disturbances are very frequent in all the sections of this district, and it will be easily understood that in the upheaval of large surfaces of rock, these would readily give way along the lines of greatest and least pressure, and be tilted in different directions and slipped up or down. The general dip of these beds, however, so far as it can be ascertained by putting together their disjointed portions, appears to be to the north-east or away from the older slaty rocks.

The Horton Bluff beds are the geological equivalents of the beds previously described as occurring at Hillsborough in New Brunswick; and like them they consist of dark calcareous shales abounding in remains of fish. At Horton, however, the bituminous matter, so abundant at Hillsborough, is almost entirely wanting, and the fish scales and teeth are scattered apart. There are also at Horton Bluff numerous bands of coarse limestone, and thick beds of the white granitic sandstone already referred to, as well as gray and red sandstones and marls in the lower part of the section. The most interesting and abundant fossils in this section are the remains of fish, which occur in incalculable numbers; every surface in some of the shales being thickly scattered over with their bright enamelled scales and sharp conical teeth. Some of them are smooth, others finely punctured, others marked with irregular ridges, and others with concentric lines; but all belong to the tribe of ganoids, which appears to have had exclusive possession of the carboniferous seas.* The appearances in these fish-beds, as in the bituminous limestones of the Joggins, indicate the long residence of these animals in the locality, and the gradual accumulation of their harder parts, as successive generations died or were devoured by their larger brethren, and as the waters in which they lived were gradually filled up by the deposition of fine mud. We have also evidence that trees grew on the neighbouring land, for trunks, branches, and leaves of *Lepidodendron* are very abundant, and *Stigmaria* is also found. In one bed, indeed, the trunks of Lepidodendron are found rooted in the erect position. They are very numerous

* Some of these fish have belonged to the genera *Palæoniscus* and *Holoptychius*, but they have not yet been examined by any competent ichthyologist.

but small, the largest being only eleven inches in diameter, and their height is only six inches. The bed immediately overlying them is filled with prostrate and flattened branches of trees of the same kind. This is the oldest fossil forest yet known in Nova Scotia, perhaps in the world. Small reptiles tenanted these forests, for Mr Logan found in 1841 a few footprints of a small creature of this class—the first ever found in rocks of so great age. *Coprolites*, or the fossil excrements of fishes, a shell allied to cypris, and trails resembling those made by worms on muddy shores, are also very abundant at Horton Bluff. No coal has been found in these rocks.

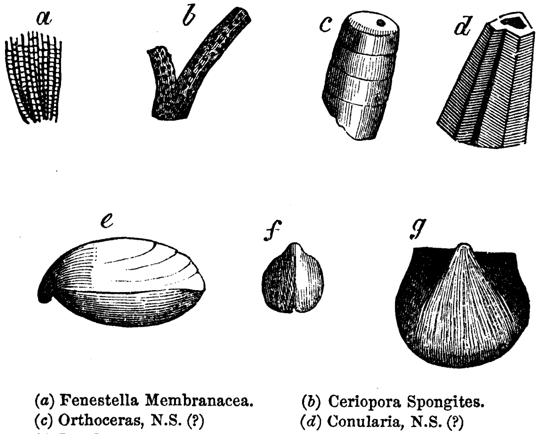
It is evident that in the beds above described, we have the occurrence, in the very lowest part of the carboniferous system, of beds very similar to the middle coal-formation as it occurs in Cumberland, though sufficiently distinct in their mineral characters and association of fossils to prevent us from confounding the two; an error which has, however, been committed by some of the earlier writers on the geology of the country, and has led to much additional confusion. Beds of similar character and age occur at Halfway river, near Windsor, on the St Croix river, at Upper Rawdon, and at the Gore. In all these localities they skirt the base of the slate hills. On the north shore of Hants, they have been thrown up to the surface by an anticlinal bend of the strata, and are seen at Five Mile river, Noel, Teny Cape, and Walton. In all these places they appear to underlie the great lower carboniferous marine limestones. We have observed a similar fact at Hillsborough, and it also occurs in some parts of the eastern coal-districts. We may therefore conclude that in the very dawn of the carboniferous era, before or coeval with the formation of the great limestone and gypsum beds, conditions somewhat similar to those afterwards so extensively exemplified in the true coal-measures, prevailed very widely in Nova Scotia. This is not in any way unaccountable, for we have no reason to doubt that marine deposits were forming somewhere when alluvial flats existed at the Joggins, or that there were shores, dry land, swamps, estuaries, and lagoons, contemporary with the seas in which the Hants and Cumberland limestones were formed. At the same time, it is true that in the older carboniferous period marine deposits were formed in the greatest quantity, while in the later portion of the period there was much more of swamp and estuary deposition.

We may now direct our attention to the strictly marine deposits which rest upon the Horton Bluff beds, and which may be seen along both sides of the estuary of the Avon, not directly in contact with the shales, &c., which intervene between them and the metamorphic hills, but in such positions as to leave no doubt as to their relative age. One of the best exposures of these rocks in this vicinity, is on the right bank of the Avon immediately above the Windsor bridge, and I shall describe this section in detail, that the reader may at the outset be familiarized with the principal members of that great gypsiferous series which occupies the greater part of the district now under consideration.

The first rock seen south of the bridge is a thick bed of red marly sandstone, a soft rock coloured red by peroxide of iron and cemented by carbonate of lime. Below this is a bed of greenish marl similar to that above in composition, but wanting its colouring matter. Then there is a thick gray limestone, containing enough of fragments of shells to lead us to infer that it may have been made up of such materials, but so decomposed and agglutinated together that it appears now a compact almost non-fossiliferous rock. Below this we find again red and greenish marly sandstones. The whole of these beds dip to the north at an angle of 50°. At this point, however, there is a fault, marked by a little gully, cut in consequence of the surface water finding a more ready passage at this place. The next beds seen are again red marls, but dipping to the south at an angle of 55°. On this rests a yellowish limestone, above which are more red and greenish marls. Next we have another limestone of flaggy or laminated structure, with a number of fossil shells scattered over some of the surfaces, as if they had lived on these surfaces or been scattered over them after death. These shells, like those of the Cumberland lower carboniferous limestones, belong to the genera *Productus*, *Spirifer*, and *Terebratula*, all shells of the same family, one of the most singular of the tribes of bivalve shell-fish, and, in so far as we can judge from the habits of its living representatives, intended to inhabit the depths of ocean. The presence of fossil shells of this tribe is therefore considered by all geologists as conclusive evidence that the deposits in which they occur were formed in the bottom of the open sea. Above this limestone, in the order of succession, we have alternations of marls and limestones, and next a bed of white crystalline gypsum, contrasting strongly in its purity and whiteness with the other beds of more mechanical origin. Here the shore becomes low and no rock is seen, but a little to the eastward we find the great gypsum quarries of Windsor, excavated in the outcrop of a very thick bed, the strike of which would bring it out to the shore just where our section fails, and where the gypsum has been removed partly by the river and partly by the quarrymen who earliest dug this rock for exportation. A little farther to the southward, at the next bluff point, there is a very thick bed of limestone, filled with, or rather made up of, fossil shells of various species and genera, affording a remarkably perfect display of the shelly coverings of the creatures that inhabited the carboniferous seas. A few of the more

Fig. 27.

Fossils from the Lower Carboniferous Limestone of Nova Scotia.



(*a*) Fenestella Membranacea. (*b*) Ceriopora Spongites.
(*c*) Orthoceras, N.S. (?) (*d*) Conularia, N.S. (?)
(*e*) Terebratula Elongata. (*f*) Spirifer, N.S. (?)
(*g*) Productus Lyelli.

abundant species are represented in Fig. 27, and I shall shortly notice some of them here, to avoid the necessity of referring to them in other localities in which they occur.

At the head of these ancient Molluscs is a *Nautilus*, to a cursory observer not unlike the ordinary Nautili of the Indian Ocean; nor are these ancient Nautili inferior in dimensions to their modern relatives, for at Windsor they may sometimes be seen as much as six inches in diameter. With the Nautilus, we may occasionally find an *Orthoceras* (Fig. 27, *c*), a shell of the same family, but straight instead of being whorled. It is usually about one-fourth of an inch in diameter, and four or five inches in length; but I have seen specimens nearly an inch in diameter. The Orthoceras as well as the Nautilus was a chambered or partitioned shell, intended to serve as a float as well as a protection to the animal, which could thus sport on the surface of the sea as well as creep upon its bottom. The inner chambers of these shells are now empty or incrusted with crystals of calc-spar; but the outer chambers are filled with hard limestone, often containing numbers of smaller shells. A species of *Conularia* (Fig. 27, *d*) is also found in this limestone, though less abundant here than in some other places to be hereafter noticed. This shell is believed to have belonged to an animal of the class Pteropoda, the next to that (the Cephalopoda) which contains the Nautilus and Orthoceras. This last is the highest class of the Mollusca, now represented on the coast of Nova Scotia only by the squid (*Loligo Bartrami?*); the shell-bearing families of this class are now mostly confined to the seas of warm latitudes.

The bivalve shells are very numerous, especially four or five species of *Terebratula*, three species of *Spirifer*, and three of *Productus*. These shells belong to a tribe differing in some important particulars from the ordinary bivalve shell-fish, and remarkable as having been very numerous in ancient periods of the earth's history and comparatively few now. One of the most abundant species of each of these genera is represented in Fig. 27, *e*, *f*, *g*. The Terebratula is not unlike some of the modern representatives of the family; for example, the Parrot-bill terebratula, now found, though rarely, on the coasts of Nova Scotia. The Productus is remarkable for the great convexity and comparative magnitude of one of its valves, which, as has been conjectured by an eminent zoologist, may have been the lower valve, and have formed a sort of cup containing the animal, and closed by the smaller valve, which in some allied genera of similar form is very much thinner as well as smaller than the other. The *Spirifer* is distinguished by the presence within the shell of two spiral stony threads, twisted like cork-screws, and perhaps connected in the living animal with the opening of the shell, or the protrusion of the long spiral arms with which all these creatures were provided. These screws are often finely preserved in the Windsor limestone. I may mention here, that in all the carboniferous limestones of Nova Scotia, the shells of this family are usually found with the valves closed and the interior often hollow. This shows that they were not dashed about by violent waves, nor exposed to be filled with fine mud. Yet it does not prove that the death of the animals was sudden or violent, for the hinge of our modern Terebratula is so constructed that it does not gape when dead, like other bivalve shells. The appearances are those which should occur in a bed of shells gradually accumulated in deep and clear water. In addition to these bivalves of more antique forms, the limestone of Windsor contains species of *Pecten* or Scallop, its relative *Avicula*, and *Modiola*.

Descending a little lower in the animal scale, we have fragments of a species of *Encrinite*, which was a complicated kind of starfish, mounted on a stalk. A pretty little coral, *Ceriopora Spongites*, is also very abundant, and with shells, which are entangled in great numbers among its branches, makes up whole layers of the limestone (Fig. 27, *b*). There is also a diminutive sea-fan, *Fenestella Membranacea* (Fig. 27, *a*), which spreads out into leaves several inches in length.

The only shell in this limestone that is identical with any of the creatures whose remains are entombed in the coal-measures of the Joggins, is the little *Spirorbis*, which has attached itself to the inside of the outer chamber of some of the larger Nautili, after the death of their owners. The reason of the difference in the fossils of these different members of the same geological system is, that one is of marine or deep-sea origin, while the other represents the tenants of the shallow creeks, lagoons, and estuaries of the same period. A similar difference subsists in all modern seas. While, however, distinct species and genera of fossils occur in the littoral and oceanic deposits of the same era, still more decided differences distinguish the formations of one period from those of another; for instance, the lower carboniferous limestones from those of the older Devonian and Silurian periods. Hence, if the student once familiarizes himself with the shells of the Windsor limestones, or even with the few species represented in Fig. 27, he has the means of recognising the limestones of the same age in all parts of the province, and of distinguishing them from those of every other formation.

The sandstones and marls of this Windsor section differ little from the similar beds in the coal-measures, except that they are less laminated, and less sorted into sand and clay, and contain no vegetable remains—all indications that they were deposited in deep water at a distance from land, and where changes of tides and currents had little influence. The limestone is evidently the result of the growth of shells and corals in the sea-bottom, forming in the course of ages thick and wide-spread masses, like the coral reefs of the Pacific, with beds of fine calcareous mud and comminuted shells and corals washed from these banks or reefs by the sea. The coral and shell bank itself forms a rich fossiliferous limestone. The material produced around it by the wasting action of the sea, becomes a compact earthy limestone with few fossils, except minute fragments of shells, often only to be detected by the microscope.

The only apparent anomaly in the deposit is the gypsum, which must have been formed by chemical action, or deposited from solution in water. Various explanations may be given of the origin of the veins and masses of gypsum which occur in different geological formations, from the silurian to the tertiary, and which, so far as I am aware, are peculiar to the lower carboniferous series in no country except Nova Scotia. Different explanations may no doubt apply to different countries and modes of occurrence. For the gypsum of Nova Scotia, occurring as it does in thick and extensive beds, interstratified with marl and limestone, there appears to me to be but one satisfactory theory—that of the conversion of beds of calcareous matter into sulphate of lime by free sulphuric acid, poured into the sea by springs or streams issuing from volcanic rocks. Modern volcanoes frequently give forth waters containing sulphurous and sulphuric acid. In the volcanic region of Java, for instance, there is a lake of sulphuric acid from which flows a stream in which no animal can live. The water of this stream being probably more dense than sea-water, will naturally flow for some distance along the bottom of the sea, and if it meets with beds of calcareous matter will convert them into gypsum. One of the volcanoes of the Andes gives origin to a similar stream; and the volcanic mountain of Maypo, in the same range, is surrounded by great masses of gypsum, probably produced by the action of sulphurous waters or vapours on the limestone of the region. We know that in the carboniferous sea of Nova Scotia there were great beds of shells and corals. We also know that the volcanic action which upheaved the metamorphic hills which formed the land of the period, was not quite extinct when these shell-beds were growing. The production of gypsum was a natural consequence of the action of sulphuric acid, evolved from such volcanic regions, on the calcareous beds and reefs. In accordance with this view, the gypsum is found only in association with the marine limestones, though, as might have been anticipated, these last sometimes occur without any gypsum. In all other respects, except this conversion of part of the limestone into gypsum, and some changes probably of similar origin in the associated marls, the lower carboniferous series of Nova Scotia and New Brunswick resembles the corresponding formation in Great Britain and the United States, to the fossils of which its shells and corals have also a very marked resemblance, and several of the species are identical.

The rocks we have examined at Windsor may serve as a specimen of those that occupy nearly the whole low country of Hants, the greater part of the carboniferous area of Colchester, and the long belt extending up the Musquodoboit river. The limestones and gypsums which form the most important members of the series, appear at a great number of places, and are extensively quarried. The principal localities are the St Croix river, Newport, Kennetcook river, Walton, Noel, White's or Big Plaster Rock and other places on the Shubenacadie, Brookfield, Onslow, Stewiacke, and Upper and Middle Musquodoboit. One of the finest natural exposures of gypsum in the province is on the St Croix river, a few miles from Windsor. Here the gypsum forms a long range of cliffs of snowy whiteness. This cliff consists principally of the variety of gypsum named "hard plaster," or "sharkstone," by the quarrymen; the latter name referring to the rough shagreen-like texture of its weathered surfaces. It is *Anhydrite*, or gypsum destitute of the combined water, which gives to the ordinary variety its softness and its usefulness as a material for modelling and plastering. Anhydrite occurs in connexion with most of the beds of gypsum, generally forming separate beds, but sometimes mixed in large masses or nodules, or minute transparent crystals, with the common plaster. It is not at present applied to any useful purpose, being too hard to be profitably ground for agricultural uses. It may, however, be used as a substitute for marble, for the internal decoration of buildings, and some of the varieties in the cliffs of the St Croix are well adapted to this use, and could be procured in any quantity.

Having thus described the lower carboniferous rocks as they occur at Horton and Windsor, I shall now attempt to give a general view of their arrangement in the area now under consideration, as well as their rela-

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tions to certain limited tracts of coal-measures which rest upon them, especially in the northern part of the district. To effect this, I shall take advantage of the sections afforded by the Folly and De Bert rivers, and the Shubenacadie; and shall describe these as they would appear to an observer descending the southern slope of the Cobequids, following the course of the Folly river, crossing Cobequid bay, and ascending the Shubenacadie to the Grand Lake.

On the Folly river, about eight miles from its mouth, we leave the ancient metamorphic slates of the hills and enter the carboniferous system, which we find resting on the edges of the slates, and dipping to the south. The first rock seen is conglomerate, in enormously thick beds, and made up of fragments of all the rocks of the hills. Passing this ancient beach of the old carboniferous sea, we find, without the intervention of any marine limestones, coal-measure rocks, consisting of gray sandstones and dark shales, with a few thin seams of coal, and abundance of leaves of Poacites, and a few Calamites and Stigmariæ. Succeeding these beds is a great thickness of red and gray sandstones and shales, with a general dip to the southward, though broken by so many faults that it is not easy to form an estimate of their aggregate vertical thickness. Finally, we observe, as we descend the river, these same sandstones and shales dipping at high angles to the northward. They are then overlaid by the new red sandstone, and we see no more of the carboniferous rocks till we approach the mouth of the Folly and De Bert, where we find the lower carboniferous limestone, gypsum, and conglomerate, mentioned in our description of the new red, and dipping to the north-east. The fossils of this limestone are the same species found at Windsor and elsewhere in beds of the same age. We have here a broken and disturbed coal-measure trough, constructed in the same manner with that of Cumberland, but on a much smaller scale, and probably including only the lower members of the coal-formation. The absence of the lower carboniferous limestone near the hills, corresponds with what we observed in Cumberland, and is accounted for by the circumstance that the Cobequids formed the shore of this ancient sea, while the limestones could be formed only in deep water at some distance from the turbid water and the pebbly beach—an arrangement corresponding exactly with what is observed in the modern coral-reefs of the Pacific.

We can trace the coal-measure band, of which the Folly river gives us a cross section, all the way from Advocate Harbour, near Cape Chiegnecto, to the upper part of the Salmon river, where it adjoins the carboniferous district of Pictou. It is everywhere much broken and disturbed; and though it widens considerably toward its eastern extremity, it nowhere attains a great development, either in horizontal extent, or in the magnitude of its coal-seams. From Advocate Harbour to Partridge Island this belt consists principally of greatly contorted and somewhat altered shales and sandstones, containing a few fossil plants, some scales of fishes, and in places abundance of shells of Modiola. In a bed near Partridge Island, Dr Harding of Windsor found, several years since, a fine series of footprints, probably of a small reptilian animal. Eastward of Partridge Island, in Clarke's Head, we find the lower carboniferous limestones somewhat altered, with beds of common gypsum, and a beautiful purple variety of Anhydrite. At Moose river and Harrington river, the black shales and gray sandstones again appear. In Economy, we have these and the lower carboniferous limestone with its characteristic fossils, and on the banks of the Portapique and Great Village rivers, the whole series is well exposed, with appearances similar to those observed in the Folly. Eastward of the latter river, the coal-formation band widens rapidly. On the Chiganois and North rivers, it contains bituminous limestones, with *Cypris* and fish-scales; thick beds of shale, with clay-ironstone; several small coals, the largest, I believe, about eighteen inches in thickness; and in the beds associated with these coals are fossil plants of several of the species described in connexion with the Joggins section. On the North river also we find the lower limestone underlying the coal-measures at the base of the mountains, and re-appearing, in greatly increased thickness and associated with beds of gypsum, on the south side of the trough. Still farther eastward, on the Salmon river, there is a bed of good coal nearly two feet in thickness, and associated with shales, containing fine specimens of *Ulodendron*, *Ferns* and other coal-formation fossils.

Applying to this narrow coal-formation trough the information we have obtained from the Joggins section, we may conclude that along the base of the Cobequid mountains on their southern side, a band of swamps and shallow and land-locked waters existed contemporaneously with the wider tract of the same description on the northern side of the mountains; and it is quite possible that the northern edge of the lower carboniferous limestones may have formed a barrier-reef, separating this narrow littoral band from the more open sea without. In its present condition, this coal-formation belt of the south side of the Cobequids, presents many difficulties to the geologist. The various movements which have taken place along the south side of the mountains, and which have probably continued up to the close of the new red period, have shattered these rocks in lines parallel to and at right angles with the hills, and have also bent and contorted them in a remarkable manner. In this respect, the carboniferous rocks on the Cumberland side of the hills differ very much from those of the Colchester side; the former being very little disturbed in comparison.

Crossing Cobequid bay from the mouth of the Folly to that of the Shubenacadie, we find the first rock that appears at the mouth of the latter to be a black laminated crystalline limestone without fossils, and supporting a great thickness of marls and gypsum similar to those of Windsor. The limestone and marls resting on it dip to the south-west. It thus appears that the lower carboniferous beds on the opposite sides of the bay dip inland, so that the bay forms, in so far as these rocks are concerned, an *anticlinal valley;* a somewhat rare occurrence, as the beds of sedimentary rocks usually dip away from hills rather than from depressions. The rocks in the banks of the Shubenacadie are, however, much broken by faults, though the general dip in the lower part of the river appears to be to the southward. The rocks succeeding the "Black Rock" limestone, for about three miles up the estuary of the Shubenacadie, consist principally of soft marly sandstones filled with veins of reddish fibrous gypsum, which run in every direction, and form a complete network, so complicated that it is difficult to understand how the rocks could have been supported in such a manner as to leave open the fissures which the gypsum fills. It is possible, however, that these cracks were not all open at once, but were produced by different movements to which the mass has been subjected; and there is another way of accounting for this appearance, to be stated shortly. There are also a few wide veins filled with the peroxide of iron and sulphate of barytes. The former is in part in the red ochrey state, and in part in the state of red and brown hematite, often in beautiful coralloidal forms with an internal fibrous structure. The barytes is in small tabular crystals. These veins also contain oxide of manganese and calc-spar. Their contents were probably introduced by water, rising from rocks beneath which afforded these materials.*

The reader will observe that the veins of gypsum contained in these rocks are very distinct from the large beds of the same mineral. The latter were formed as horizontal layers at the same time with the containing beds. The former have filled up cracks opened after the beds were consolidated. The fibrous texture which the gypsum veins nearly always display, arises from the circumstance that little slender prisms of the mineral have sprouted forth from the sides of the fissures until they filled them. Hence they always stand at right angles to the sides of the vein. Similar appearances are observed in the greater number of minerals lining or filling veins or fissures. I am inclined to believe, however, that the fibrous gypsum in the gypseous marls has been produced in a different manner from the "combs" of quartz and other minerals found in the fissures of slate, trap, &c. The gypsum veins show no signs of

* For the manner in which these minerals may have been formed, see descriptions of mineral veins at Five Islands and Acadia Mine.

having met in the middle, though they often appear to have been added to at each side; and we may infer that the prisms of gypsum grew by additions to each end, furnished by water permeating the rock, and *pressed the sides of the fissure apart* as they grew in length. Veins of fibrous ice are formed in this way in banks of clay, exerting an enormous expansive force sufficient to break down the strongest retaining walls; and when circumstances are favourable, these clusters of icy prisms may be seen to raise objects lying on the surface of water-soaked clays to the height of several inches. Wherever segregation and crystallization are going on in the fissures of rocks, similar effects may be produced; and it is quite possible that they play an important part in geological dynamics. It is at least not unlikely that some of the remarkable contortions and dislocations observed in the gypsiferous rocks of Nova Scotia may have been produced in this way.

These marly rocks contain a bed of anhydrite and common gypsum, in addition to the gypsum veins above mentioned.

Proceeding to the southward, along the eastern bank of the river, we reach a high cliff of brownish-red and gray sandstones, dipping S. 30° W., and containing a few fossil plants. These beds probably overlie those previously noticed, and much resemble the sandstones that in the Joggins section intervene between the lower limestones and the coal-measures. To the southward of this cliff, which is called the Eagle's Nest, the shore for some distance shows no section. On the west side, however, where the rocks corresponding to the Eagle's Nest form a high cliff, they are separated by a fault from an immense mass of gypsum named White's or the Big

Plaster Rock, and one of the principal localities of the extensive gypsum-trade of this river. The Big Rock at one time presented to the river a snowy front of gypsum, nearly 100 feet in height; but it has been greatly reduced by the operations of the quarrymen, who bring down enormous quantities by blasting. It is a massive bed, arranged in thick layers, and the whole bent into an arched or almost cylindrical form. In its lower part there is much anhydrite, and also dark laminated limestone, having on its surfaces of deposition immense numbers of flattened shells of *Conularia*. A compact limestone, containing *Terebratulæ*, also appears near the bottom of the mass. Faults, denudation, and disturbance render it quite impossible to discover in the river section the relations of this mass of gypsum to the neighbouring beds. Its nearest neighbour to the south is a series of dark shales and gray sandstones, with a few fossil plants of coal-formation genera. These beds are very much contorted, but have a prevalent dip to the south. They may be either members of the coal-formation or equivalents of the Horton lower carboniferous shales. A sheet of paper could hardly have been crumpled into more fantastic curves than these beds, no doubt once flat and horizontal. This is an effect of lateral pressure acting upon them while in a soft state, and it testifies to the enormous forces of this description which have been applied before these beds attained their present hard and brittle condition. These beds appear on both sides of the Five Mile river, a stream running into the Shubenacadie at right angles, and they extend along the course of this stream and that of the Kennetcook, which is continuous with it though flowing in the opposite direction, far into the interior of Hants.

On the Kennetcook, they contain a small seam of coal, and have more the aspect of true coal-measures than any other beds I have seen in this county.

Hitherto we have found few fossils in this section; but at the next point above the contorted coal-measures of Five Mile river, we have a grand example of a fossiliferous limestone, forming the cliff named Anthony's Nose. This limestone, which is a mass of corals and shells similar to those noticed at Windsor, is about 40 feet thick, and stands quite on edge projecting like a huge wall into the river. Soft marls rest against each side and include a bed of gypsum, and, at a little distance, a thick bed of this mineral appears with an arched stratification. On the opposite side of the river there are other limestones and gypsums, also very much disturbed; and, immediately adjoining them on the south, there is a cliff of reddish standstone, like that of Eagle's Nest, and nearly in a horizontal position.

Beyond this place, the river-section is not continuous, but gypsum and limestone, full of marine shells, appear in several places, and the marls and red sandstones occasionally peep forth from beneath thick beds of boulder-clay. Finally, at Gay's river, Key's on the Shubenacadie, the lower end of Grand Lake, and Nine Mile river, the gypsum and limestone are seen almost in contact with the ancient metamorphic slate and quartzite, which bound this carboniferous district on the south.

At one of these places, Key's, on the old Halifax road, one of the beds of gypsum contains white and bleached-looking quartzose pebbles and sand. In this case, it is probable that the acid which produced the gypsum acted on a mass of calcareous matter, mixed with sand and gravel, which became entangled in the gypseous mass produced. Such instances of the enclosure of foreign bodies in gypsum are rare. I have, however, seen layers of sand and earthy matter, and fragments of limestone, and in a few instances vegetable remains have appeared in the earthy layers. Some beds of gypsum are also blackened by bituminous matter, derived no doubt from animal or vegetable substances.

Over nearly all the beds of gypsum in this region, the whole surface is riddled by funnel-shaped cavities, named "plaster-pits," by the aid of which the gypsum may be traced in localities where it does not itself reach the surface. These pits are well exposed in the face of the "Big Rock" formerly described. They are produced by the solvent action of the surface-water penetrating through the fissures of the gypsum, in a manner which we shall have better opportunities of studying when we arrive at the gypsiferous districts of Cape Breton.

The section formed by the long narrow tideway of the Shubenacadie, and continued less perfectly along its fresh-water portion, enables us to form an idea of the structure of the southern part of the Hants and Colchester area, across its whole breadth. It is evident that the regular succession of the beds has been much disturbed by faults or fractures, most of which have a direction approaching to east and west. They have shifted the masses of beds, so that we cannot now, without extensive investigations of all the minor sections afforded by tributary streams, put them together into a continuous series. The following is the nearest approximation to such a restoration of the original arrangement that I can offer. 1st, From the mouth of the Shubenacadie westward to Walton and Cheverie, the shales which lie at the base of the carboniferous system appear in several places, and immediately resting on them are red sandstones and marls, with limestone and gypsum; and the lowest bed of limestone is a laminated dark-coloured crystalline bed without fossils. 2dly, The red sandstones and marls with gypsum and limestone, form a wide band extending through Hants to the Avon estuary, south of these lowest members of the series; and in places there appear, in and over these beds, gray and brown sandstones with fossil plants. 3dly, Along the course of Five Mile and Kennetcook rivers, extend rocks having the aspect of the lower part of the coal-formation, and these appear to be the newest carboniferous beds in this district. 4thly, Immediately to the south of these, we again find the red marls, gypsum, and limestone, forming a second broad belt, extending from Rose's Point and Admiral's Rock, on the Shubenacadie, through Newport to Windsor. This is the re-appearance of the same part of the formation seen below White's Plaster Rock, and it is worthy of note, that it is here much more fossiliferous than in the lower part of the river. Lastly, From the point of the Gore mountain, along the base of the Douglas and Rawdon hills, we can trace the lower carboniferous shales all the way to Horton. That trough-shaped arrangement, so characteristic of the carboniferous rocks in this part of Nova Scotia, can therefore be traced even in the fractured section of the Shubenacadie.

Eastward of the Shubenacadie this general arrangement soon disappears, for the carboniferous district of Colchester here splits into three branches, entering between the hilly ridges of the metamorphic country to the eastward. The most northern of these passes along the valley of the Salmon river, and is connected with the Pictou district. The second passes up the valley of the Stewiacke river. The third forms a narrow band extending from the Grand Lake nearly to the sources of the Musquodoboit river. In the northern branch both the lower carboniferous and coal-formation series appear, as we have already noticed; but in the two others the lower carboniferous rocks prevail almost or altogether to the exclusion of the coal-formation. In one place only on the Lower Stewiacke, do rocks having the aspect of those at Five Mile river appear. In the Stewiacke branch, which in the period in question must have been a sheltered bay or channel, the corals and shells of the limestones attain a magnitude and perfection not, so far as I know, equalled in any other part of the province. Gypsum also abounds in this branch, and in one place there is a large deposit of sulphate of barytes. In the southern or Musquodoboit branch there is much gypsum and also limestone; but the latter does not appear to be rich in fossils. I have found in it only a few Encrinites.

As the district just described presents the most important development in the province of the Lower Carboniferous series, I have employed it to introduce the reader to that part of this great system of rocks, just as the Cumberland district served a similar purpose in relation to the coal-measures; and I may now conclude by a review of the condition of Southern Hants and Colchester at the time when the marine limestones and gypsums were produced. At this period then, all the space between the Cobequids and the Rawdon Hills was an open arm of the sea, communicating with the ocean both on the east and west. Along the margin of this sea there were in some places stony beaches, in others low alluvial flats covered with the vegetation characteristic of the Carboniferous period. In other places there were creeks and lagoons swarming with fish. In the bottom, at a moderate distance from the shore, began wide banks of shells and corals, and in the central or deeper parts of the area there were beds of calcareous mud with comparatively few of these living creatures. In the hills around, volcanoes of far greater antiquity than those whose products we considered in a former chapter, were altering and calcining the slaty and quartzose rocks; and from their sides every land-flood poured down streams of red sand and mud, while in many places rills and springs, strongly impregnated with sulphuric acid, were flowing or rising; and, entering the sea, decomposed vast quantities of the carbonate of lime accumulated by shells and corals, and converted it into snowy gypsum. Of the creatures that may have crept or walked on the land, we know nothing except the hint afforded by the few footprints found by Mr Logan and Dr Harding in the shales of Horton and Parrsboro', and which testify that reptilian life in some of its lower forms had already begun to exist. The sea had already attained almost its maximum of productiveness in fishes and creeping things, but we have no reason to believe that the land had yet received from its Creator any of those higher creatures which were destined to be introduced in a subsequent "day of the Creator."

Useful Minerals of the Hants and Colchester District.

Gypsum is at present the principal product of this district. It is largely quarried at Windsor, Newport, Walton, Shubenacadie, and a number of other places; and, in 1851, 78,903 tons* were quarried, amounting to the value of over £10,000 at the ports of shipment. The greater part of this large annual produce of gypsum is exported to the United States for agricultural purposes. The quantity of gypsum in this district is enormous, and probably cannot be exhausted by any demand ever likely to occur. It is now quarried only in the places most accessible to shipping, and its small value per ton indicates the facility with which it can be obtained, in a country in which the price of labour is by no means low.

Limestone is also extremely abundant in this district, and might be quarried and exported as readily as the gypsum. Limestone being abundant in New Brunswick and in the United States, is not however in demand for exportation, and the wants of the country are at present small; especially in a district in which the land is in most places well supplied with calcareous matter. So soon, however, as a railway or canal connects this district with Halifax, it may be anticipated that a demand will arise for lime to supply the wants of the shore-districts, which are almost entirely destitute of this mineral.

Iron Ore occurs in veins traversing the lower carboniferous limestones and sandstones near the mouth of the Shubenacadie. The ores are red ochre, red hematite, and brown hematite. The quantity does not appear sufficient to form a basis for mining or smelting operations.

Gray Oxide of Manganese occurs in the iron veins of

* 76,743 in Hants and 2160 in Colchester.

the Shubenacadie, and in irregular veins and nodules in limestone at Walton and Cheverie, from which places small quantities have been exported. It also occurs on the Musquodoboit river. I have no doubt that if the limestones of Walton and Cheverie can be profitably quarried on a large scale, the manganese might be separated and form a considerable additional source of revenue; but it seems doubtful whether mining operations for the manganese alone can be carried on without loss.

Galena, or sulphuret of lead, is found in disseminated crystals and small veins in limestone at Gay's river and some other places. Some specimens which I have examined contain a considerable proportion of silver; but I cannot learn that this ore appears at any of these localities in sufficient quantity to pay for its extraction. The occurrence of valuable ores of lead in the lower carboniferous limestones in England and other countries, gives some reason to hope that more important indications of this metal may yet be discovered.

Sandstone suitable for building purposes occurs at Horton, Halfway river, Windsor, the Shubenacadie, and probably many other places; but not in such quantity nor of such excellent quality as in the coal-formation of Cumberland and Pictou. For this reason it may not, for some time at least, be worthy of attention as an article of export, but it can be abundantly obtained for domestic use.

Clays suitable for bricks and common pottery can also be procured in large quantity on the Shubenacadie. Yet in the last census Hants made no return of bricks, while the quantity made in Colchester was stated at 420,000.

Coal in small seams occurs at Salmon river, North river, Chiganois river, De Bert river, Folly river, and

Great Village river, in the coal-measure belt extending along the south base of the Cobequids, and these small seams appear at intervals as far west as Cape Chiegnecto. I have seen the outcrops of these coals in several places, and according to my own observations and the best information I can obtain from others, none of them exceed eighteen inches of clean coal. Better seams may possibly be found, but the measures are exposed by so many river-sections that it seems unlikely that they should have so long escaped observation. Indications of coal have also been observed in the coal-measure band extending from Lower Stewiacke toward and along the Kennetcook river. These measures are not well exposed, and I believe that nothing definite is known as to their real value. The occurrence of coal in this central district would, however, be of so great importance to the province, and to the success of its main line of railway, that the subject well merits a thorough investigation.

Sulphate of Barytes, which is manufactured into a pigment employed as a substitute for or adulteration of white lead, has been quarried on the banks of the Stewiacke. The deposit, which at first appeared to be large, is stated to be now exhausted, at least in so far as it can be reached by the ordinary operations of the quarryman.

CHAPTER XII.

THE CARBONIFEROUS SYSTEM—*Continued.*

CARBONIFEROUS DISTRICTS OF PICTOU, SYDNEY, AND GUYSBOROUGH—ISOLATED PATCHES AT MARGARET'S BAY AND CHESTER BASIN.

4. *Carboniferous District of Pictou.*

In noticing this and the following districts, I shall avail myself of the details into which we have entered, to enable me to condense my descriptions, and to dwell only on those features that may be peculiar, or very dissimilar from those already described. In entering the Pictou coal-district from Colchester, we pass over disturbed and somewhat altered lower carboniferous sandstones and conglomerates, with intrusive and metamorphic rocks on either side, forming outlying masses of the Eastern Cobequids. The first characteristic and distinctly marked beds that we find, are the limestones on the upper part of the West river. At the Salt Springs these limestones, with their accompanying sandstones, are seen in a vertical position, and with their fissures filled with micaceous iron-ore, a very decided proof of igneous action. There appears to be in this part of the Pictou district a considerable area of altered carboniferous rocks, showing that in this vicinity active volcanic agencies have subsisted after the deposition of the lower carboniferous series. A little farther down the West river, at M'Kay's Lime Rock, we find the limestone unaltered, and containing *Encrinites*, *Terebratulæ*, *Fenestella*, *Corals*, and other fossils, similar to those of the limestones of Hants and Colchester. Having thus reached a known member of the carboniferous series, we may take a general glance over the district with the aid of the map, and mark the distribution of its principal rock-formations.

From the West river we can trace the limestones and other members of the lower carboniferous series to the East river, along the valley of which they enter, in the form of a narrow bay, into the metamorphic district to the southward. Beyond the promontory of these latter rocks bounding this inlet on its eastern side, the lower carboniferous rocks continue to skirt the older hills as far as the coast of the Gulf of St Lawrence near Arisaig, where they rest unconformably on slates belonging to an older formation. The lowest carboniferous rocks seen here are conglomerates interstratified with beds of amygdaloidal trap, which have flowed over their surfaces as lava currents, just as the trap of the Bay of Fundy has flowed over the red sandstone. Several of these ancient lava streams alternate with beds of conglomerate; and while their lower parts have by their heat slightly altered the underlying bed, their upper parts, cooled and acted on by the waves, have contributed fragments to the overlying conglomerate. Over these conglomerates is a great series of reddish and gray sandstones and shales, similar to those we have observed elsewhere. They contain no gypsum, but there is a thick limestone with a number of the fossil shells already noticed in similar beds of this age. Along the whole southern edge of the Pictou district, therefore, we observe the lower carboniferous series, distinguished by its characteristic fossils, and containing beds of limestone and gypsum, though the latter, as well as the associated marly beds, is less important than in Hants county. To the northward of these older members of the system, we find in some localities, and especially in the East river, a large development of the productive or middle coal-measures ; and the remaining part of the district, stretching along the coast of Northumberland Strait, and connected with the eastern part of Cumberland, presents precisely the same characters which we have observed in the last mentioned district, of which it is strictly a continuation.

The most remarkable feature in the Pictou district is the enormous thickness of coal-measures on the East river, forming the Albion Mines coal-field; and these deserve a detailed notice, not only from their economical importance but their geological interest, as presenting a vastly greater development of coal-seams and their accompaniments than we have observed elsewhere. I shall therefore describe the general arrangement of the rocks on the East river with the aid of the general section, (Fig. 28.)

The oldest carboniferous bed that I have observed on the East river, is a limestone which rests directly on the edges of a hard metamorphic slate, which must have formed the sea-bottom on which the former rock was deposited. Angular fragments of the slate are included

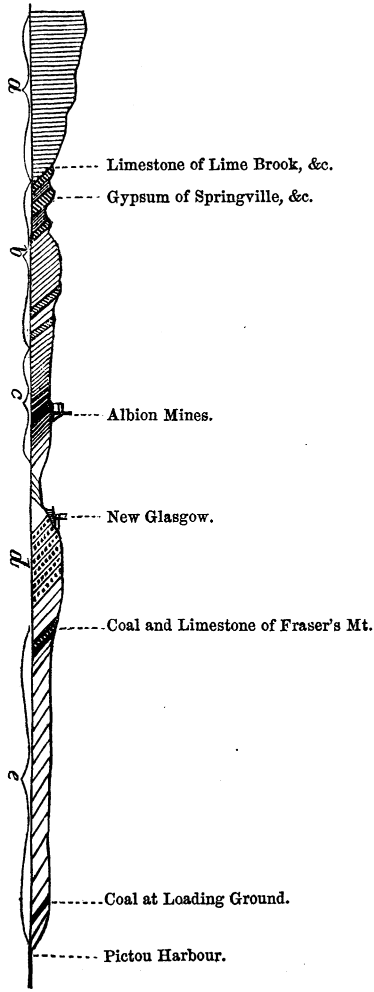


Fig. 28.

General Section of the Carboniferous Rocks of the East River of Pictou.

(*a*) Devonian Slates. (*b*) Lower Carboniferous Series. (*c*) Coal-measures. (*d*) Great Conglomerate. (*e*) Upper Coal-formation.

in the lower part of the limestone. This limestone which appears at Lime Brook on the east branch of the East river, contains in its upper part fossil corals of the genus *Cyathophyllum*, the branches of which are sometimes half an inch in diameter. On this limestone rest marls with gypsum veins, and at least one large bed of gypsum and anhydrite, the outcrop of which appears distinctly at Forbes Lake and Creelman's Farm on the East Branch, and less conspicuously at Springville. Above these gypseous rocks, which being soft have been eroded into a valley, is another limestone rich in fossil shells, including many of those already noticed and some others. Succeeding this in ascending order is a great series of hard brownish sandstones and shales, like those of Eagle's Nest on the Shubenacadie, and probably corresponding to the lower members of Mr Logan's Joggins section. These occupy the East Branch and main river for some distance. They contain a few fossil plants, in one instance impregnated with carbonate and sulphuret of copper; and at least two beds of limestone, not rich in fossils, but affording the characteristic species *Terebratula Elongata* and *Productus Scoticus*. One of these limestones, seen near the forks of the river, is remarkable for showing, when slices are examined under the microscope, that it is made up of small fragments of shells with entire specimens of very minute species. The rocks in this part of the section are much fractured; but a comparison with the continuation of the same beds in M'Lellan's Brook, shows that the order is ascending, and that the lower coal-measures rest on the rocks last described.

The coal-measures of the Albion Mines consist of the same materials, and contain many of the same fossil remains with those of the Joggins; but they differ in the arrangement of these materials and fossils. Instead of a great number of thin beds of coal and bituminous shale, we have here a few beds of enormous thickness, as if the coal-forming processes, so often interrupted at the Joggins, had here been allowed to go on for very long periods without interference. It is almost a necessary consequence of this that erect plants are not found in the Albion measures, and that well-preserved vegetable fossils are comparatively rare, while vast quantities of vegetable matter have been accumulated in the state of coal. The sections at the Albion mines are not perfect. They show, however, five or six seams of coal, and an immense thickness, perhaps 800 feet, of black shales with cypris and remains of ferns and other leaves. There are also underclays and ironstones abounding in stigmaria.

The parts of these measures best known are those exposed by the operations of the mine, and the following section observed by H. Poole, Esq., late superintendent of the mine, in sinking the "Success Engine Pit" at the New or Dalhousie workings, will enable the reader to understand the gigantic development of the coal-seams at this place.

	ft.	in.	ft.	in.
Surface clay			8	2
Shale and bands of ironstone alternate			64	10
Main coal seam—	ft.	in.		
Coarse coal . .	0	2		
Good coal . .	5	0		
Ironstone . .	0	6		
Carry forward,	5	8	73	0

	ft.	in.	ft.	in.
Brought forward,	5	8	73	0
Good coal . .	14	4		
Ironstone . .	0	4		
Coarse coal . .	7	7		
Ironstone . .	0	4		
Coarse coal . .	3	1		
Ironstone . .	0	4		
Coarse coal . .	2	11		
Ironstone . .	0	5		
Coarse coal . .	4	11		
	39	11	39	11
Shale and bands of ironstone alternate			157	7
Deep seam—				
Bad coal . .	0	2		
Good coal . .	3	10		
Ironstone . .	1	2½		
Coal . . .	3	7¾		
Slaty coal . .	0	9¼		
Good coal . .	4	2		
Coarse coal . .	1	0½		
Good coal, "worked by Carr"	3	8		
Inferior coal . .	6	3		
	24	9	24	9
Total .			295	3

These measurements were taken on the side of a vertical shaft, and the beds dip to the north-east at an angle of twenty degrees. The vertical thickness of the two large seams of coal, the main and deep seams, which are the largest yet known in Nova Scotia, is therefore $37\frac{1}{2}$ feet and $22\frac{1}{4}$ feet respectively. The main seam has been very extensively worked, and its outcrop has been traced for several miles; but it is remarkable that it preserves its character as a seam of good coal only for a limited distance. Both in the north-west and south-east extension of the workings, it becomes very impure and intermixed with shale, indicating that though great in thickness, it is very limited in horizontal extent. The measures are also cut off to the northward by a line of disturbance running along the south side of an enormous bed of conglomerate which succeeds these coal-rocks in ascending order, or apparently so. (See section.)

This conglomerate is a very remarkable bed, quite dissimilar from any thing occurring elsewhere in the coal-formation of Nova Scotia. It consists of large rounded stones firmly cemented together by calcareous matter, and with occasional small irregular layers of red sandstone. It dips at a high angle to the north, though much of this dip seems to be due to false stratification, or deposition on originally inclined surfaces. Owing to its hardness it forms a prominent ridge, extending nearly east and west from Fraser's mountain, east of the East river, to the Middle river, and thence through the Greenhill to the West river, beyond which it reappears in Roger's Hill and Mount Dalhousie, at the base of the eastern end of the Cobequid range. On the East river it is succeeded by a series of coal-measure sandstones and shales, with one small seam of coal and a bed of limestone, the whole dipping at moderate angles to the northward. This bed might be supposed to be a re-appearance of the lower carboniferous conglomerate, thrown up by a great fault; but it contains within it fragments of older lower carboniferous grits found higher up the river, and is not succeeded by any equivalent of the middle coal-measures. It must therefore either be a bed formed after the Albion coal-measures and resting on them, or a contemporaneous gravel-beach extending across the Pictou coal-area, and separating these coal-measures from the more open space in which the less productive coal-formation rocks to the northward were formed. This would account for all the anomalies of the Albion coal-measures, as it would imply that they were guarded against the disturbing causes which in other localities prevented the continuous accumulation of coal. For this reason and a variety of others which are fully stated in my paper on these coal-measures in the Journal of the Geological Society, I prefer this last view. The following quotation from that paper presents a summary of the argument.

" 1. The outcrop of the conglomerate extends from a point opposite the promontory of metamorphic rock east of the East river to the high lands of Mount Dalhousie, in the eastern extremity of the Cobequid range of hills, crossing the mouth of an indentation in the metamorphic district, which in the older part of the carboniferous period must have been a bay or arm of the sea, exposed to an open expanse of water lying to the northward. 2. The conglomerate cannot be traced to the margin of the metamorphic country, except at its extremities; so that in all probability it never extended over the low carboniferous district included within its line of outcrop. This is the more remarkable, inasmuch as the conglomerate has evidently resisted denudation better than any of the associated beds. 3. The conglomerate is full of false stratification and wedge-shaped beds of reddish sandstone, in the manner of ordinary gravel-ridges, and it even presents the appearance of passing into sandstone toward the dip, as if the coarse conglomerate were limited to the vicinity of the outcrop. 4. In the sandstone overlying the Albion measures, as well as in portions of the coal-formation manifestly overlying the great conglomerate, there are small seams of coal corresponding in their characters with those of the Joggins and Sydney, where no similar conglomerate occurs. 5. The supposition that the Albion coal was formed in a depressed space, separated by a shingle-bar from the more exposed flats without, accounts for the great thickness of the deposits of coal and carbonaceous shale, the absence of sandstones, and the peculiar texture and qualities of the coal, as well as the association with it of remains of fish and *Cypris;* since modern analogies show that such an enclosed space might be alternately a swamp and lagoon without any marked change in the nature of the mechanical deposits. 6. Movements of depression causing the rupture of the barrier, or enabling the sea to overflow it, and perhaps also admitting currents of oceanic water through the valleys of the metamorphic district to the southward, would sufficiently account for the overlying sandstones, as well as for the denudation of the coal-measures supposed to have preceded the accumulation of these sandstones.* 7. The dislocation extending along the outcrop of the conglomerate is easily explained by the supposition that, in later elevatory movements, this hard and stony bed determined the direction of fracture of the deposits."

To these reasons I may add, that if in the carboniferous as in the modern period, westerly winds prevailed in this latitude, it would be very natural that a beach

* These sandstones overlie the coal-measures as they approach the conglomerate, but with dip to the N.

should be thrown out from the eastern end of the Cobequid range, across the bay to the eastward, in which the Albion measures are situated.

If these views are correct, we have a right to expect that the tract of coal-formation country to the northward of the great conglomerate, and extending from it to the eastern extremity of the Cumberland district, should present characters similar to those of that district. Accordingly the section on the tideway of the East river, and the corresponding sections on the Middle river, and on the coast toward Merigomish, show a series of coal-formation rocks not very dissimilar from some parts of the Joggins section. Their dips are to the northward, and in their lower part there is a bed of concretionary and laminated limestone, the only fossil in which appears to be the little *Spirorbis* already so frequently mentioned. Almost immediately above this limestone is a small bed of impure coal, probably two feet thick. These beds are accompanied by some black shales, and succeeding them in ascending order is a series of sandstones and shales abounding in leaves of ferns, calamites, &c. The highest beds seen on the south side of Pictou harbour and at Merigomish are thick bedded gray sandstones, which afford grindstone and building stone, and abound in petrified coniferous wood; and with these are associated some shales and underclays with a thin seam of coal, which in Merigomish island is eleven inches thick. Perhaps it is the same seam which has been found at the loading ground at South Pictou, and near the mouth of the Middle river.

Northward and westward of Pictou harbour is a series of rocks, nearly resembling those just described, and generally dipping to the south-east at angles of 15° to

25°. In Roger's hill, six miles westward of Pictou, are thick beds of coarse conglomerate, considerably disturbed, associated with greenstone and hard claystone, and showing in one part a vein of crystalline sulphate of barytes. This conglomerate I believe to be geologically identical with that of New Glasgow. It is succeeded by a great series of deposits, chiefly consisting of reddish sandstones and shales; but including several thick beds of gray sandstone, affording quarries of valuable grindstone and freestone, and accompanied by gray shales, conglomerates, thin beds of coarse limestone, and thin beds of coal. As there are no very good natural sections in this part of the country, it would be difficult to ascertain the aggregate thickness of these deposits; it must, however, be great, since they occupy, with general south-east dips, the whole country from the hills last named to the entrance of Pictou harbour. The principal fossils found near Pictou, are *Calamites*, *Lepidodendron*, *Endogenites*, coniferous wood, ferns, *Artisia*,* and carbonized fragments of wood impregnated with iron pyrites and with sulphuret and carbonate of copper. In this series also, and near the town of Pictou, is a bed of sandstone containing erect calamites, evidently rooted *in situ*, and described in a paper by the writer in the proceedings of the Geological Society for 1849. The appearances at this place are so similar to those observed at the Joggins, that they need not be noticed here; but these and the occurrence of *Stigmaria in situ* in some of the shales and sandstones of the same neighbourhood, serve to indicate the analogy that obtains between the coal-rocks of Cumberland and this part of Pictou. Some

* Transversely wrinkled stems, believed to be casts of the pith of plants, some of them of rush-like forms.

of the shales near the town of Pictou are loaded with ferns and *Poacites;* and shells of a *Unio* or some nearly allied genus also occur though rarely. Small seams of coal are believed to occur in this neighbourhood, but their outcrops cannot at present be seen.

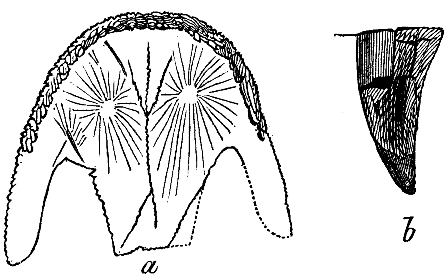
The coast-section, westward of the entrance of Pictou harbour, is for some distance very imperfect. Much red sandstone, however, appears; and a bed of limestone from two to three feet thick, and a small bed of coal, have been discovered. Some gray sandstones also appear: in one of which there are numerous fragments of carbonized wood, containing sulphuret and carbonate of copper. This deposit and others of a similar nature, found in this series at various places, have given rise to hopes, probably delusive, that valuable deposits of copper may be found in this part of the coal-formation. These ores of copper are always associated with remains of fossil plants, and they have no doubt been produced by the deoxidizing effects of this vegetable matter on water impregnated with sulphate of copper, and probably rising in the form of springs from some of the older subjacent rocks.

The rocks in the coast-section west of Pictou harbour, dip to the south-eastward as far as the mouth of Carribou river, beyond which the same beds are repeated, but better exposed, and dipping to the north. One of the cupriferous beds above referred to, a coarse gray sandstone, appears in Carribou river, and was at one time worked for the copper it contains, but is now abandoned. At the mouth of the river are gray sandstones, red sandstones, and red and gray shales, and associated with these is a bed of coal five inches in thickness, with the usual underclay with stigmaria rootlets. Beyond this place, as far as the second brook beyond Toney river, there is a great series of beds having precisely the aspect of the upper coal-formation of Cumberland, and containing one thin bed of non-fossiliferous limestone, and a great thickness of reddish shales, some of them finely ripple-marked and worm-tracked, and with leaves of ferns. The beds then become horizontal, and are repeated with southerly dips (S.S.E.), at first at a small angle, but toward the extremity of Cape John the dip increases, and the rocks at length become vertical. The lowest beds seen at the extremity of the cape are gray coarse sandstones, with *Calamites* and carbonized trunks of trees. Associated with these are reddish sandstones and shales, and in front of the cape, but under water, is the outcrop of a small bed of gypsum. The northerly dipping beds in the above section extend to the westward across River John, and are continuous with those described (*vide* Cumberland District) as occurring on the French river of Tatamagouche. The southerly dipping beds towards Cape John probably extend under Tatamagouche Bay, and are continuous with the rocks on the south side of Cape Malagash.

A coal-district so singular in its structure, and probably also in the mode of formation of its beds, as that of the Albion mines, might be anticipated to afford interesting and peculiar fossils. Unfortunately, however, these beds are not exposed in good natural sections, and the operations of the miner are a very imperfect substitute for these. One bed, however, included in the Albion main coal, has afforded some interesting facts. It is a seam of coaly ironstone varying in thickness from four inches to a foot, and in some portions of the mine is extracted with the coal and thrown aside as rubbish, so that large quantities of it can be examined at the surface. It contains abundance of *Spirorbis*, attached to much-decayed plants. Large scales of ganoid fishes are also found in it, as well as fragments of the large bony spines with which these fish were armed. Some of the latter are half an inch in diameter. A still more interesting fossil was found by the writer in this bed in 1850. It is the upper part of a skull, seven inches in breadth and five inches in length, and armed with strong conical teeth, somewhat curved, and finely striated longitudinally. (Fig. 29.) This fossil was sent

Fig. 29.

Outline of Skull of Baphetes Planiceps; and Tooth, natural size.



(*a*) Anterior part of Skull, viewed from beneath.
(*b*) One of the largest Teeth, natural size.

to London, and examined by Professor Owen, by whom it was described, and figured in the Proceedings of the Geological Society (1853) under the name of *Baphetes Planiceps*, alluding to its supposed amphibious habits, and the flatness of its skull. Professor Owen believes the creature to which it belonged to have been one of those gigantic batrachian or frog-like reptiles whose remains have been found in the triassic sandstones of Germany, but not previously in rocks so old as the coal-measures. When this opinion was given, the head only, without the teeth, had been received in London, and a more definite and detailed decision may be anticipated when the latter have been examined. In the mean time, however, we may consider it probable that this skull belonged to a large frog-like reptile, which preyed on the fishes whose remains are found with it in the "holing stone," as the bed is called by the miners. This band, with its peculiar fossils, shows that, at Pictou as at the Joggins, the coal-forming area was occasionally submerged under brackish water, perhaps by the partial rupture of the great conglomerate bank to which we have already referred.

Useful Minerals of the Pictou District.

Coal is the most important of these; and Pictou has long been the principal producer of this valuable mineral in British America. 59,574 chaldrons were raised in 1851, and the quantity has I believe been still greater in subsequent years. The greater part is shipped to the United States, and is used in iron-foundries and gas-works, and for the production of steam. The mines are worked by the General Mining Association, and a population of about 2000 souls is clustered around the pits and supported by their produce. The coals are carried by a railway, worked by locomotives, to the loading ground at South Pictou, six miles distant from the mines.

The coal hitherto exported has been obtained almost exclusively from the upper part of the main seam; from twelve to nine feet of which are worked on the post and stall method. The pits originally worked were on the low ground immediately west of the East river, where an engine-pit was sunk to the depth of about 400 feet. In the progress of these works, however, it was found that the coal deteriorated very much in quality in its extension to the eastward; and this circumstance, in connexion with a serious "crush" in the mine, determined the proprietors to make new openings to the westward, named the Dalhousie Pits. After these were sunk, however, and connected with the railway by an expensive incline, it was found that in this direction also the good coal gradually diminished; and after two years' experience the new pits were found to be insufficient to meet the increasing demand for coal. The present manager, Mr Scott, has therefore reopened the old pits, and is now working a new floor of this great seam, below that previously worked out in this part of the mine; and in this way the whole area of the mine will be worked over, and after this is exhausted there will still remain the underlying or "deep seam." Both seams can also be worked to a much greater extent by sinking deeper pits farther toward the dip, or by working below the present engine-pit on the "under-dip" method. Although, therefore, as previously explained, the thick seams of the Albion mines are not spread over a very extensive area, there is no immediate prospect of their exhaustion; and it is to be hoped that long before this can occur other seams will be discovered within the district.

The following detailed section, taken from a continuous specimen of the whole seam, extracted for the New York Industrial Exhibition by Mr Poole, the late manager, will enable the reader to understand the available amount of good coal which the main seam contains.

			ft.	in.
	1.	Roof-shale: vegetable fragments and attached *Spirorbis* (in specimen) .	0	3
	2.	*Coal*, with shaly bands	0	6½
	3.	*Coal*, laminated; layers of mineral charcoal and bright coal; band of ironstone balls in bottom	2	0
Worked in old mine.	4.	*Coal*, fine, cubical, and laminated; much mineral charcoal	3	2
Worked in old mine.	5.	Carbonaceous shale and ironstone, with layer of coarse coal ("holing-stone"). Remains of large fishes and coprolites. This bed varies much in thickness.	0	4½
Worked in old mine.	6.	*Coal*, laminated and cubical, coarser towards bottom	9	3
	7.	Ironstone and carbonaceous shale, with coaly layers and trunks of *Lepidodendron*, *Ulodendron*, *Sigillaria*, *Stigmaria*, &c., all prostrate . . .	0	8
	8.	*Coal*, laminated as in No. 6, a line of ironstone balls in bottom . . .	1	2
Worked in 2d floor.	9.	*Coal*, laminated and cubical, a few small ironstone balls. Many minute spines in this and underlying coal . .	6	7
Worked in 2d floor.	10.	Ironstone and pyrites	0	3
Worked in 2d floor.	11.	*Coal*, laminated and cubical, as above	10	3
	12.	*Coal*, coarse, layers of bituminous shale and pyrites	1	0
		Carry forward,	35	6

		ft.	in.
	Brought forward,	35	6
13.	*Coal*, laminated, with a fossil trunk in pyrites	2	1
14.	*Coal*, laminated and cubical, with layers of shale, passing downward into black slicken-sided under-clay with coaly bands	2	3
15.	Under-clay (to bottom of specimen) .	0	10
	Thickness perpendicular to horizon	40	8
	Vertical thickness	38	6

From this seam at least 24 feet in vertical thickness of good coal can be extracted. A cubic foot of Pictou coal weighs about 82 lbs., rather less than 28 feet being equal to a ton of coal; hence a square mile of this seam would yield in round numbers 23,000,000 tons of coal—an enormous quantity as compared with the present annual produce, but less than two-thirds of the annual consumption of Great Britain. The other seams in the Albion measures may be safely estimated at half the value of the main seam.

The Albion coal has a laminated texture, and much mineral charcoal on its surfaces, and is a highly bituminous caking coal. Its specific gravity, according to the trials of Professor W. R. Johnston,* is 1·318 to 1·325. The result of twelve trials made by the writer of samples from different parts of the mine was, that the specific gravity varies from 1·288, which is that of the best coal extracted, to 1·447, which is that of the coarsest coal that has been worked. The mean specific gravity of six samples taken from the top, middle, and bottom of the seam, in the central part of the mine,

* Report to the United States Government on American Coals.

was 1·325, or exactly the same with one of Professor Johnston's results. According to Professor Johnston's trials, 1 pound of this coal is capable of converting 7·45 to 7·48 pounds of water into steam, or from the temperature of 212°, 8·41 to 8·48 pounds. This gives it a high place among bituminous coals as a steam-producer. The worst defect of Pictou coal is, that it contains a considerable quantity of light bulky ashes; and this causes it to be much less esteemed for domestic use than on other grounds it deserves. It is very free from sulphur, burns long, with a great production of heat, and remains a-light when the fire becomes low much longer than most other coals.

The following assays show the composition of the coal from the upper floor in different parts of the mine, and illustrate its gradual deterioration at either extremity of the workings.

		S.E. side: old workings. (About 1 mile E. of Dalhousie Pits.)	N.W. side: old workings.	W. side: Dalhousie Pits.
Fall Coal.	Moisture	1·750	1·550	Thinned out
	Volatile combustible	25·875	27·988	
	Fixed carbon . .	61·950	60·837	
	Ashes	10·425	9·625	
		100·000	100·000	
Top Bench.	Moisture	1·500	1·500	2·2
	Volatile combustible	24·800	28·613	22·7
	Fixed carbon . .	51·428	61·087	62·–
	Ashes	22·272	8·800	13·1
		100·000	100·000	100·0
Bottom Bench	Moisture	2·250	1·800	2·5
	Volatile combustible	22·375	27·075	22·7
	Fixed carbon . .	52·475	59·950	58·8
	Ashes	22·900	11·175	16·0
		100·000	100·000	100·0

It will be observed that in all parts of the mine the lower coal is inferior to that of the middle of the seam, and still more so to that of the upper part above the "holing stone," or the "fall coal," as it is termed by the miners. It will also be observed that all the coals in the first column are inferior to those in the second, and that those in the third are also inferior, while in this part of the mine the upper three feet of fall-coal have disappeared, or been reduced to an insignificant thickness by thinning out or being replaced by shaly matter.

The following table gives the composition of all the varieties of coal in the whole thickness of the seam, as ascertained by an elaborate series of assays made by the writer in 1854.

Assays of Samples of Albion Coal, taken at distances of one foot in thickness, in the main seam.

No.		Volatile matter by rapid coking.	Volatile matter by slow coking.	Carbon fixed.	Ashes.
1. Coal	...	26·	19·9	63·8	16·3
2. Do.	...	27·8	24·1	63·8	12·1
3. Do.	...	27·4	25·7	60·	14·3
4. Do.	...	27·2	25·	65·5	9·5
5. Do.	...	25·8	25·1	64·8	10·1
6. Do.	...	25·2	24·9	62·5	12·6
7. Do.	...	27·4	22·0	68·5	9·5
8. Do.	...	26·8	22·9	66·7	10·4
9. Do.	...	27·0	23·9	61·3	14·8
10. Carbonaceous shale		16·4	15·9	26·3	58·8
11. Coal	...	28·8	25·8	59·7	14·5
12. Do.	...	27·2	25·4	62·5	12·1
13. Do.	...	27·6	24·7	65·5	9·8
14. Do.	...	26·6	23·9	61·0	15·1

No.		Volatile matter by rapid coking.	Volatile matter by slow coking.	Carbon fixed.	Ashes.
15. Coal	...	26·8	23·1	65·1	11·8
16. Do.	...	28·8	24·9	62·3	12·8
17. Do.	...	30·4	26·0	65·0	9·0
18. Do.	...	26·0	26·1	63·0	10·9
19. Do.	...	26·0	25·0	66·3	8·7
20. Do.	...	26·8	22·7	63·6	13·7
21. Coarse Coal		25·8	23·3	58·3	18·4
22. Do.	...	27·2	22·5	60·3	17·2
23. Coal	...	29·4	23·6	64·3	12·1
24. Coarse Coal		25·8	22·4	57·6	20·0
25. Do.	...	25·8	23·1	60·2	16·7
26. Do.	...	27·8	21·9	54·8	23·3
27. Coal	...	27·0	24·3	65·5	10·2
28. Do.	...	25·6	22·4	65·0	12·6
29. Do.	...	25·8	22·7	62·7	14·6
30. Do.	...	27·2	23·1	67·4	9·5
31. Do.	...	32·6	22·4	66·5	11·1
32. Coarse Coal		22·2	21·5	50·4	28·1

These coals being taken from the western part of the workings, do not show the fall coal of the old pits, this part of the seam having there, as already explained, thinned out. All these coals afford a fine vesicular coke, and their ashes are light gray and powdery, with the exception of those of the coals marked "coarse," which are heavy and shaly.

The *Deep Seam*, situated at the vertical depth of 150 feet below the main seam, and consequently cropping out to the surface about 150 yards to the south-west of the outcrop of the latter, contains about twelve feet of good coal, divided by intervening layers of shaly and impure coal into three bands. The best coal of this seam is superior to that of the main seam, but owing to the division above mentioned, it cannot be worked so economically as the main seam, and is therefore likely to be left until the latter is exhausted, at least in its more accessible portions. The comparative purity of some portions of this seam, however, would entitle them to demand a higher price in the market than the ordinary produce of the Pictou mines. Its best portions contain only from 5·3 to 11 per cent. of ashes, and afford much illuminating gas, and a fine vesicular coke, similar to that of the main seam coal. The ashes of some of the deep seam layers are of a reddish colour, whereas those of the coal from the main seam are invariably white or light-gray. There can be no doubt, that nothing but its association with a bed of so much greater magnitude prevents this seam from being immediately worked.

Several other coal-seams exist in the Albion measures. One of these is six feet in thickness, and affords coal similar to that of the main seam, but with a larger proportion of ashes. Another, which occurs about 450 feet below the main seam, is a coarse-looking coal of shaly aspect. On trial, however, I have found a specimen of it to yield no less than 56·6 per cent. of gas of high illuminating power, and a good vesicular coke, the ashes of which amount to only 8 per cent. of the whole. Such a coal would be as valuable as the best Scottish cannel for the production of gas, if it occurs in sufficient quantity without too great an admixture of sulphuret of iron. I have no definite information on these points, but I am informed that it is only fourteen inches thick.

As Pictou coal is now largely used in the manufacture of illuminating gas, the following comparative trials of the volume of gas which it affords, made by the writer in the spring of 1854, may be interesting. They were made on a small scale, by means of an iron retort and graduated glass-vessels; but their accuracy was afterwards confirmed by trials of some of the coals on the large scale in the Pictou gas-work.

	Cubic feet for Ton.
Coal from upper nine feet of the main seam, from the Dalhousie pits, ...	3902
Coal from middle of main seam, the portion now mined in the lower floor, ...	5080
Coal from upper three feet of best coal of deep seam, ...	6668
Coal from lower three feet of best coal of deep seam, ...	8504

The average yield of the first of these samples in the Pictou gas-work is about 4000 cubic feet. As the lower coals now beginning to be opened are more productive of gas, it may be anticipated that the reputation of Pictou coal in the gas-works will increase. I may mention here that the value of Pictou coal for this purpose, as well as for family and steam uses, depends in part on the good quality of its coke, and in part on its comparative freedom from sulphur. These excellent qualities, in connexion with its great heating power, more than compensate for its large per-centage of ash as compared with some other coals.

The small coal-seams already mentioned as occurring near New Glasgow, at Merigomish, Middle river, South

Pictou, Carribou, &c., are all too small to be profitably worked in the present state of the country, and no large or valuable seams are at present known within the county of Pictou, except those of the Albion measures. The coast and river sections are, however, too imperfect to warrant the assertion that no such beds remain to be discovered; but it is probable, for reasons already stated, that the coal-seams north of the New Glasgow conglomerate will all be found to be thin, like those of the Joggins and Wallace sections, which in other respects the coal-measures in that part of the county so much resemble. Still there is no part of the country surrounding Pictou harbour of such a character that it may not contain seams of coal of workable dimensions, though such beds as those of the Albion mines cannot reasonably be expected. It is also probable that workable seams occur in the eastern prolongation of the Albion measures, toward Merigomish. In this part of the district, a small seam associated with shales containing *Modiolæ* like those of the Joggins, is known in M'Lellan's brook. It dips to the north-west, showing that it is broken off from the Albion measures by a fault or faults; and it appears to belong to the lowest part of the coal-formation, as the lower carboniferous sandstones and limestone almost immediately underlie it. Another seam appears to the south-east of New Glasgow, near the new road to Pine-tree gut. It is of larger dimensions than that in M'Lellan's brook, and good coal has been taken from its outcrop for domestic use. Other seams no doubt exist along this tract, which is marked by a valley or depression extending to the eastward, between the ridge caused by the New Glasgow conglomerate and the lower carboniferous and Devonian hills toward M'Lellan's mountain. It is by no means improbable that a very valuable prolongation of the Albion measures may be found in this direction.

Clay Ironstone occurs in the Albion coal-measures, apparently of good quality, and in sufficient abundance to be extracted profitably, if in a country in which smelting-furnaces are in operation. At present, however, no attention is paid to it. From the abundance of boulders of *Brown Hematite* scattered over the surface of the lower carboniferous rocks on the East river, it would appear that veins of that rich ore of iron exist in these rocks, in the same manner as at the Shubenacadie. The outcrop of these veins has not yet been observed, and, as the country is much covered by drift materials, it may prove somewhat difficult to discover them. The presence of these ores, in connexion with a large bed of peroxide of iron in the older slates to be hereafter described, leaves little doubt that were other circumstances favourable, iron-works might be established on the East river without any fear of deficiency in the raw material.

Gray Freestone, for architectural purposes, is found in a great number of places in the Pictou coal-formation, and is quarried both for domestic use and for exportation to the United States and neighbouring colonies. Many buildings have been constructed of Pictou freestone in the large cities of the American Union; and its cheapness, durability, and fine colour, are likely to secure an extended demand. The principal quarries are on Saw Mill brook, at the head of Pictou harbour, where stone of excellent quality and colour, and both in blocks and flags, is found in great abundance. These quarries have been very extensively opened, and a railway and loading pier three-fourths of a mile in length have been constructed. The greatest quantity shipped in any year has been 3000 tons; but with the present facilities from 10,000 to 12,000 tons can be annually shipped from the "Acadia Quarry," which is the principal opening.

Gypsum, in workable quantity, occurs only on the East river, and is at too great a distance from a port of shipment to be quarried at present, except for domestic use.

Limestone is quarried for use in the country at the East and West rivers, and small quantities are occasionally taken from the beds at Merigomish and Cape John.

Manganese ore, *Sulphate of Barytes*, *Umber and Ochres*, are found in small quantities. *Brick* and coarse *Pottery* are made to a small extent. Some of the sandstones are quarried for *grindstones*, and the bed of limestone mentioned as occurring near New Glasgow and at Little Harbour, affords a curiously waved *gray marble*, which has not, however, been yet brought into the market.

The *Copper Ores* found in the coal-formation have been already mentioned. The principal localities are Carribou river the West river a little below Durham, and the East river a few miles above the Albion mines. Similar appearances also occur on French and Waugh's river, in the band of coal-formation rocks connecting the Cumberland and Pictou districts. In all these places the principal ore is the gray sulphuret of the metal, with films and coatings of the green carbonate. These ores are associated with fossil plants, to which, as already explained, their accumulation is to be attributed. The ores are rich and valuable, and the only reason which prevents them from being worked, is the conviction that the deposits are too limited to be of economical importance. This has been found to be the case in two instances in which trials have been made by the agents of the Mining Association. The following is the composition of a sample from Carribou analyzed by the writer:—

Copper . .	40·00
Iron . .	11·06
Cobalt . .	2·10
Manganese .	·50
Sulphur . .	25·42
Carbonate of lime	·92
	80·00

5. *Carboniferous District of Sydney County.*

The Pictou district is bounded on the south by an irregular tract of slaty and syenitic rocks, forming the hills of Merigomish and those extending toward Cape St George. In the coast-section, the last and lowest rocks of the Pictou carboniferous district are seen near M'Cara's brook to rest unconformably on slates to be subsequently described, and which are of Devonian age. Passing these, towards Malignant cove, the lower carboniferous conglomerates and sandstones are again seen, but very much disturbed and altered by heat. It is a very instructive study to compare the soft conglomerates and their interstratified trap at M'Cara's brook, with the continuation of the same beds eastward of Arisaig pier, where they appear fused into hard quartzose rocks, in some of which the original texture is entirely obliterated.

The conglomerate and sandstone seen at Malignant cove conduct us through a gap in the metamorphic hills, or round by Cape St George, to the gypsiferous rocks of the neighbourhood of Antigonish. These run along the south side of the metamorphic hills with general southerly dips, from Cape St George to the western extremity of this district, and exhibit a very large development of the gypsums and limestones, the latter containing some of the fossils already noticed in other localities.

At Cape St George the lower carboniferous conglomerates appear to be largely developed. Between this place and Morristown there are red sandstones, conglomerate, and gray sandstone, the latter containing *Calamites*, *Artisia*, and other coal-formation fossils. Near Morristown these beds dip to the N. E., and have been disturbed by a spur of trappean or altered rock, containing kernels of epidote, and associated with contorted dark shales, probably the equivalents of the Horton Bluff beds. Beyond this interruption, the coast shows soft reddish sandstones and shales with some beds of gray sandstone and conglomerate, dipping to the S. S. E. at an angle of 50°, and on these rests a bed of limestone nearly 100 feet thick; in its lower portion laminated, the laminæ being occasionally broken up so as to give it a fragmentary or brecciated appearance; in its upper part, compact and penetrated by small gypsum veins. On this limestone rests a rock consisting of alternate layers of limestone and gypsum, above which is a great thickness of pure flesh-coloured crystalline gypsum, and on this again, white laminated fine-grained gypsum, with minute grains of carbonate of lime. The whole thickness of the gypsum is about 200 feet, and it forms a beautiful cliff fronting the sea. (Fig. 30.)

Fig. 30.

Cliff of Crystalline Gypsum, near Ogden's Lake, Sydney County.

This gypsum and limestone can be traced with scarcely any interruption to the village of Antigonish, about five miles distant, where the same beds are seen in the banks of Right's river. Near the mouth of this river, at the head of Antigonish harbour, is a thick bed of white gypsum, dipping to the south-west. Succeeding this, in descending order, after a small interval (which appears to have been occupied by sandstones, now nearly removed by denudation), is a bed of dark-coloured limestone, in which, at different points where it appears, I found *Productus Martini* with other shells also occurring on the East river; and *Productus Lyelli*, a shell not yet met with in the East river limestones, but very characteristic of the gypsiferous formation in other parts of the province. Below this limestone there is another break also showing traces of sandstones and a bed of gypsum, and then a thick bed of dark limestone, partly laminated and partly brecciated, without fossils, and containing in its fissures thin plates of copper-ore. Beneath this limestone is a great thickness of reddish conglomerate, composed of pebbles of igneous and metamorphic rocks, and varying in texture from a very coarse conglomerate to a coarse-grained sandstone. In one place it contains a few beds of dark sandstones and shales. These are succeeded by red, gray, and dark sandstone and dark shales, in a disturbed condition, but probably underlying the conglomerate. They contain a few fossil plants, especially a kind of *Lepidodendron*, which appears to be identical with a species found in a similar geological position at Horton and Noel. The limestones with their characteristic fossils may be seen still farther west on the West river of Antigonish.

On the west side of the Ohio river, about fifteen miles from Antigonish, this carboniferous district terminates against the metamorphic hills, which here occupy a wide surface, and send off a long branch to Cape Porcupine in the Strait of Canseau. This branch consists in great part of slates older than the carboniferous system, but it also appears to contain altered carboniferous rocks. It bounds this district on the south. Along its northern side, the lower carboniferous limestones and gypsum appear at the north end of Lochaber lake, at the South river, and at the northern end of the Strait of Canseau. They are probably continuous or nearly so between these points. In the coast between the place last mentioned and Antigonish, carboniferous rocks, principally sandstones, appear in several places; and towards Pomket and Tracadie, in the central part of the district, the coal-formation, probably its lower portion, is seen; and small seams of coal have been found in it. I have had no opportunity of examining them, but have no doubt that they form the southern edge of the coal-field underlying St George's bay, and the eastern side of which appears at Port Hood in Cape Breton.

The Sydney area thus appears to be of triangular form, with the lower carboniferous beds extending along its western and south-eastern sides, and the coal-formation occupying a limited patch on the northern side. It does not appear probable that any valuable deposits of coal occur in it; but it is rich in limestone and gypsum, and has that fertile calcareous soil which so generally prevails over the rocks of the gypsiferous series.

6. *Carboniferous District of Guysborough.*

This district is separated from that last described by a narrow belt of metamorphic country forming a range of low elevations. Part of these altered rocks may belong to the lower carboniferous series itself, but the greater part of them are of higher antiquity. On the south side of this ridge, we find a belt of carboniferous rocks, extending from the Strait of Canseau along the north side of Chedabucto bay. Westward of the head of this bay, the carboniferous rocks extend in a narrow band, separating the inland metamorphic hills from those of the Atlantic coast, almost as far as the sources of the west branch of the St Mary's river, fifty miles west of Chedabucto bay.

North of the town of Guysboro', and not very far from the metamorphic rocks, is a bed of blackish laminated limestone. I could find no fossils in it, but it has the characters of the lowest carboniferous limestones as seen elsewhere. It has some of its fissures filled with micaceous specular iron, and is associated with conglomerate and sandstone somewhat altered. This limestone dips N. 60° W. at a high angle. Limestone re-appears with a high easterly dip on the opposite side of the harbour, and near it are altered shales nearly in a vertical position. Southward of the town of Guysboro', limestone again appears in thick beds, and between it and the town are reddish sandstones and conglomerates dipping S. 60° E. Some of these beds are evidently made up of the debris of the granite-hills to the southward, proving that these older hills were land undergoing waste in the carboniferous period.

The whole of the beds near Guysboro' harbour are much disturbed and in part altered; and, immediately to the westward of the town, a spur of porphyritic and trappean rock extends from the hills to the northward, nearly across the carboniferous valley: the eruption of these igneous rocks has probably occurred in the carboniferous period, and effected much of the baking and other alteration which the rocks of that period have experienced.

Beyond this ridge of igneous rock, the long valley extending to the westward is occupied by gray and reddish sandstones and conglomerate, with gray shales in a few places, the whole forming a narrow trough. On the southern margin of this trough, the conglomerate contains pebbles of gray quartzite, micaceous flag, and blue slate, precisely similar to the metamorphic rocks immediately to the southward, and in these conglomerates and the sandstones resting on them, I found a few fragments of *Calamites* and *Lepidodendron*. Fossils appear, however, to be rare in this district, and I have not observed in it any coal; nor do the limestones appear, so far as I am aware, west of Guysboro'.

With the exception of limestone and freestone for building, I am not aware that this district affords any useful minerals. *Galena*, or sulphuret of lead, is said to have been found in small quantities near Guysboro', and small veins of *Specular Iron* traverse many of the altered rocks in that vicinity. The soils of this valley, however, especially on the St Mary's river, are causing it to rise rapidly in importance as an agricultural district, and its scenery is in many places varied and beautiful.

Before passing to the coal-fields of Cape Breton, I may shortly notice two limited patches of carboniferous rocks occurring on the margin of the metamorphic rocks on the south coast of Nova Scotia, at Margaret's bay and Chester basin.

At Margaret's bay, red and gray sandstones and a bed of limestone appear, though much buried under masses of granitic drift. In limestone from this place, I have found the *Terebratula Elongata*, a characteristic lower carboniferous shell. At Chester basin, the lower carboniferous rocks appear still more distinctly, and contain thick beds of limestone of various qualities. One of the beds is said to be a good hydraulic cement, and another in weathering leaves an *umber* of a rich brown colour, which is manufactured and sold under the name of Chester mineral paint. The limestone at this place contains several of the shells already mentioned as characteristic of the carboniferous system. A small seam of coal is also stated to occur near Chester; but I have not seen it.

These isolated patches are interesting, as they are evidently portions of the margin of a carboniferous district either sunk beneath the Atlantic or removed by the action of its waves.

CHAPTER XIII.

THE CARBONIFEROUS SYSTEM—*Continued.*

CARBONIFEROUS DISTRICT OF RICHMOND AND SOUTHERN INVERNESS—USEFUL MINERALS—DISTRICT OF NORTHERN INVERNESS AND VICTORIA—USEFUL MINERALS—DISTRICT OF CAPE BRETON COUNTY—USEFUL MINERALS.

7. *Carboniferous District of Richmond and Southern Inverness.*

THIS district is separated from those of Sydney and Guysboro' only by the Strait of Canseau, a narrow transverse valley excavated by the currents of the drift period. The lower carboniferous conglomerates and limestones are seen on both sides of the strait, and the lowest members of the system are seen at Plaister Cove and its vicinity, and are succeeded to the southward and eastward by the coal-formation. As this district presents some curious and interesting features, I shall notice some parts of it rather in detail.

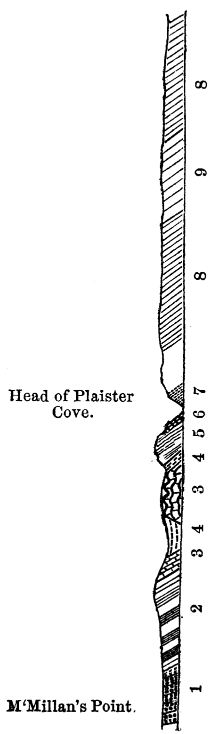
The coast-section in the vicinity of Plaister Cove is remarkable for the highly perfect manner in which it displays the gypsiferous rocks, and the information which it consequently affords as to their structure and origin.

The following summary of the beds seen in this section, is from a paper contributed by the writer to the Geological Society in 1849. (See Fig. 31.)

"(1.) At M'Millan's Point, about three quarters of a mile north of the cove, are thick beds of gray conglom-

Fig. 31.

Coast Section at Plaister Cove.



1. Hard gray conglomerate. 2. Alternations of hard sandstone and gray shale. 3. Limestone. 4. Marl. 5. Gypsum. 6. Gypseous limestone. 7. Marl. 8. Dark shales with calcareous bands. 9. Brown and gray sandstone and shale.

erate, in a vertical position. These beds form the base of the carboniferons system in this district; and, at a short distance inland, they have been invaded by trap and other igneous rocks, belonging to a great line of igneous disturbance extending to the north-eastward. The conglomerates near M'Millan's Point have been thrown up along an anticlinal line connecting the igneous range last mentioned with that of Cape Porcupine, on whose flanks the same conglomerates appear. The valley now occupied by the strait is in great part due to the want of continuity of the igneous masses at this point, though the distribution of the surface detritus shows that it has been subsequently deepened by diluvial waves or currents from the northward.

"(2.) Between M'Millan's Point and Plaister Cove, the shore is occupied by black and gray shales and very hard sandstones in frequent alternations. The sandstones have been much altered by heat, and are traversed by veins of white carbonate of lime, sometimes mixed with sulphate of barytes. At the point immediately north of Plaister Cove, these beds dip at a high angle to the south-eastward.

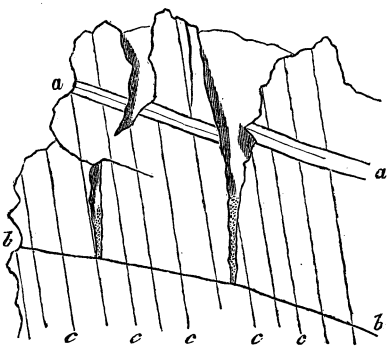
"(3.) Overlying these beds is a bed of limestone about thirty feet in thickness; it is of a dark colour, laminated and subcrystalline; its laminæ are in some parts corrugated and slightly attached to each other, and in other places flat and firmly coherent; it is traversed by numerous strings of white calcareous spar, containing a little carbonate of iron and small crystals of blue fluor spar, a mineral rare in Nova Scotia, and which I have found only in the lower carboniferous limestones. The limestone supports a few layers of greenish marl and gypsum, which appear in a small depression on the north side of the cove; but beyond this depression the limestone re-appears with a northerly dip. It is then bent into several small folds, and ultimately resumes its high dip to the south-east. I found no fossils in this limestone, except at its junction with the overlying marl, where there is a thin bed of black compact limestone containing a few indistinct specimens of a small species of Terebratula. In appearance and structure this limestone is very similar to the laminated limestones which underlie the gypsiferous deposits of Antigonish and the Shubenacadie.

"(4.) This bed is succeeded by greenish marl, traversed by veins of red foliated and white fibrous gypsum, and containing a few layers of the same mineral in a granular form; it also contains a few veins of crystalline carbonate of lime. In its lower part it has a brecciated structure, as if the layers had been partially consolidated and afterwards broken up. Near its junction with the limestone, it contains rounded masses of a peculiar cellular limestone, coloured black by coaly matter; and higher in the bed there are nodules of yellow ferruginous limestone, with a few fragments of shells. The greenish colour of the marl seems to be caused by the presence of a minute quantity of sulphuret of iron. Where a portion of the marl is heated, the sulphuret is decomposed, and the colour is changed to a bright red.

"(5.) On this marl rests a bed of gypsum, whose thickness I estimated at fifty yards. Where the marl succeeds to the limestone, the shore at once recedes, and the gypsum occurs at the head of the cove. The gypsum is well exposed in a cliff about eighty feet in height; but, like most other large masses of this rock, it is broken by weathering into forms so irregular, that its true dip and direction are not at first sight very obvious. On tracing its layers, however, it is found to have the same dip with the subjacent limestone and marl. About two-thirds of the thickness of the bed consist of crystalline anhydrite, and the remaining third of very fine-grained common gypsum. The anhydrite prevails in the lower part of the bed, and common gypsum in the upper; but the greater part of the bed consists of an intimate mixture of both substances, the common gypsum forming a base in which minute crystals of anhydrite are scattered; and bands in which anhydrite prevails, alternating with others in which common gypsum predominates. It is traversed by veins of compact gypsum, but I saw no red or fibrous veins like those of the marl. In some parts of the bed, small rounded fragments of gray limestone are sparingly scattered along layers of the gypsum.

"The exposed part of the mass is riddled by those singular funnel-shaped holes named "Plaster pits," sections of which are exposed in the cliff; they penetrate both the anhydrite and common gypsum, though they are contracted where they pass through harder portions of the rock, and especially the veins of compact gypsum, some of which are only slightly inclined, and look at first sight like layers of deposition. The pits of which I saw sections have evidently resulted from the percolation of water through the more open parts of vertical joints, and they were cut off where they were intersected by another slightly inclined set of open fissures, which afforded a passage to the water. The accompanying sketch (Fig. 32) shows one of these pits, and its relations to the joints and stratification of the gypsum.

Fig. 32.—*Plaster Pits.*



(*a*) Gypsum vein. (*b*) Open joint. (*c*) Bedding of the gypsum.

"(6.) Above the gypsum are a few layers of limestone, portions of which appear near the base of the cliff; one of them is studded with tarnished crystals of iron pyrites; another is a singular mixture of gray limestone and reddish granular gypsum. The portions of limestone contained in this rock do not appear to be fragments or pebbles, and they are penetrated by plates of selenitic gypsum. They may be parts of a bed of limestone broken up and mixed with gypsum when in a soft state, or the limestone and gypsum may have been deposited simultaneously and separated by molecular attraction. A rock of this kind is not rare as an accompaniment of gypsum, and it may be merely a result of the mixture of the soft surface of the gypsum with the mechanical detritus first deposited on it.

"(7.) On the opposite side of the creek, which makes a small break in the section, is a thick bed of marl, whose dip appears to be the same with that of the gypsum. In general character it resembles the marl underlying the gypsum. In some parts it is greenish and homogeneous in texture; in other parts it is brecciated, and some layers have a brownish colour and shaly texture. In some parts it is highly gypseous and contains layers of granular gypsum, one of which is black, its colour being due to a small proportion of coaly or bituminous matter.

"(8.) Beyond the marl the shore is occupied for a short space by boulder clay. Beyond this it shows a great thickness of dark shales with calcareous bands, containing a few small shells; they dip to the E.S.E. at a high angle, and overlie the gypsum. They are succeeded by a thick band of very hard gray and brownish sandstones and shales, containing a few fragments of plants stained by carbonate of copper. These are again overlaid by dark shales, and these by an enormous thickness of gray and brown sandstone and shale. Some of the shales in this part of the section have assumed a kind of slaty or rather prismatic structure."

I beg the reader to observe, in the above section, the contrast between the hardened sandstones and shales and the soft marls and gypsum, a contrast equally marked in other parts of the carboniferous districts, and often producing, by the removal of the softer beds, that isolated position of the gypsum masses which is frequently so perplexing. It is also important to observe, that this great mass of gypsum is a regular bed, interstratified with the others, and belonging to the series of processes by which the whole were formed. I have already, in noticing the gypsum of Windsor, referred to its probable origin, and may now apply the same method of explanation to that of Plaister Cove. On this view then the history of this deposit will be as follows:—

First, The accumulation of a vast number of very thin layers of limestone, either so rapidly or at so great a depth that organic remains were not included in any except the latest layers. *Secondly*, The introduction of sulphuric acid, either in aqueous solution or in the form of vapour; the acid being a product of the volcanic action whose evidences remain in the neighbouring hills. At first the quantity of acid was too small, or the breadth of sea through which it was diffused too great, to prevent the deposition of much carbonate of lime along with the gypsum produced; and its introduction was accompanied by the accumulation on the sea-bottom of a greater quantity of mechanical detritus than formerly: hence the first consequence of the change was the deposition of gypseous marl. At this stage organic matter was present, either in the sea or the detritus deposited, in sufficient quantity to decompose part of the sulphate of lime, and produce sulphuret of iron; and also to afford the colouring matter of the nodules of black limestone found in the marl. *Thirdly*, The prevalence for a considerable period of acid waters, combining with nearly all the calcareous matter presented to them, and without interruption from mechanical detritus. The anhydrite must have been deposited with the common gypsum; but, under the circumstances, it seems difficult to account for its production, unless it may have been formed by acid vapours, and subsequently scattered over the bed of the sea. *Fourthly*, A return to the deposition of marl, under circumstances very similar to those which previously prevailed; and, *lastly*, The restoration of the ordinary arenaceous and argillaceous depositions of the carboniferous seas.

Of the gypsum veins found in the marls, those which are white and fibrous may have been nearly contemporaneous in their origin with the marl itself; those which are red and lamellar have been subsequently introduced. The granular gypsum is in all cases a part of the original deposit. The comparatively small quantity of red oxide of iron in these marls and other associated beds is the most important feature of difference between the deposit of Plaister Cove and those of most other parts of this province. There is, however, a large quantity of reddish and brown sandstone in the beds overlying the gypsum, though on the whole these colours are less prevalent than in the carboniferous system of Nova Scotia Proper.

The rocks seen at Plaister cove and its vicinity appear to be overlaid in ascending order by a great thickness of black shales, which near Ship harbour contain shells of *Modiolæ*. These shales are succeeded by true coal-measures, which, at a place called Little river and at Carribou Cove, contain seams of coal and a variety of characteristic fossil plants. One remarkable peculiarity of these coal-measures is, that they have been folded up by lateral pressure, so that they are often vertical, and that the limestones with marine shells and the gypsum, are often brought into immediate contact with masses of these disturbed coal-measures. Coal-measure beds in a less disturbed condition extend up the river of Inhabitants nearly to its sources, and occupy the country between that river and the southern part of the Bras d'Or lake. The lower carboniferous limestone appears on the north-west arm of River Inhabitants, at West

Bay, at Lennox Passage, on Isle Madame, and at St Peter's. At Lennox Passage it is associated with a great bed of excellent gypsum, and contains an abundance of fossil-shells. At St Peter's it is non-fossiliferous, and rests against syenite and metamorphic slates, forming the western margin of a large tract of metamorphic country, along the edge of which it extends, with some conglomerate and sandstone, in a very narrow belt, skirting the whole eastern side of the Bras d'Or lake, and connecting this district with that of the county of Cape Breton.

Useful Minerals of the District of Richmond, &c.

Coal appears at various places, but is not yet worked in any part of this district.

The bed at Carribou Cove has attracted some attention, owing to its appearance in the coast-section in a very accessible situation. It is a seam of mixed coal and bituminous shale eleven feet eight inches in thickness, in a vertical position, or rather thrown over on its face; its dip being W. 57° S., at an angle of 80°, and the bed which was originally its underclay being its roof. The coal from the outcrop of this bed is of a soft and crumbling quality, and filled with layers of shale.

A specimen of the best coal, selected from different parts of the bed, gave, on analysis—

Volatile matter	25·2
Fixed carbon	44·7
Ash	30·1
	100·

The shale associated with the coal contains a sufficient quantity of bituminous and coaly matter to render it combustible, but it differs from coal in leaving a stony residue instead of a pulverulent ash.

It appears from the above analysis that the best coal of this bed is very impure, its percentage of ash being double that of Pictou coal; and when this is taken in connexion with its intimate intermixture with shale, it must be evident that the produce of this seam could not be exported with profit. It might possibly be worked to supply fuel of an inferior description for use in the neighbouring country. In the deeper parts of the bed, the coal is probably harder and of much better appearance than at the outcrop, but in its mixture with shale and high percentage of ash no material improvement can be expected. It will also be found to contain a large proportion of the bi-sulpuret of iron, much of which has been removed from the outcrop by weathering.

The other strata seen in the vicinity of the coal are gray shales and hard sandstones, with a small seam of bituminous shale. No other bed of coal appears in the vicinity, though, as the coast-section for about half a mile on either side shows little except boulder-clay, it cannot be affirmed that others are not present. If other beds occur, they can be found only by expensive works of discovery, unless accidentally uncovered by excavations made for other purposes.

Coal also appears at Little river, a small stream emptying a little to the eastward of Carribou Cove. At the mouth of this stream there is a bed of gypsum. The coal occurs 2½ miles inland. Here, as at Carribou Cove, the measures are vertical, the strike or direction of the beds being N. 40° W. Two beds are seen at this place, one four feet in thickness, the other ten inches thick. They are separated by five feet of shale. Above the place where they cross the river I observed in the bed of the stream fragments of coal and bituminous shale, which have probably been washed from the outcrop of a third bed.

The coal of the principal bed is hard, and very little injured by exposure. Its fracture is uneven and crystalline, with glistening surfaces; and its texture is very uniform, the lamination or "reed" being rather indistinct, and almost free from dull coal or mineral charcoal. Its specific gravity is 1·38. When burned in a stove or grate, it ignites readily, fuses, swells, and cakes, giving a strong flame and a lasting fire. It leaves a rather large quantity of brownish ash. In a smith's forge it works well, its behaviour being similar to that of Pictou coal. On analysis, it is found to contain—

Volatile matter	30·25
Fixed carbon	56·40
Ash	13·35
	100·

Compared with the coals of Pictou and Sydney, the Little river coal is more bituminous than either, or contains more volatile matter and less fixed carbon. It contains about the same quantity of earthy matter with Pictou coal; but in quality and colour the ash resembles that of Sydney. Practically it will be found to be a serviceable coal for domestic fires, well adapted for smiths' use, and, from the large quantity and high illuminating power of its gaseous matter, probably a good gas-coal. There should be little waste in its extraction, and it will suffer little by being "banked" or kept in the open air. It contains more sulphur than the Pictou coal.

The coal of the small bed (No. 2) is somewhat similar to that of No. 1; but it is more impure, and contains much bi-sulphuret of iron. The fragments found in the river, and supposed to be derived from a third bed, are very similar to the coal of No. 2.

The point at which the coal appears on Little river is distant in a direct line from the main road to Ship harbour about one mile and a half, and from Ship harbour four miles; from the shore at Carribou Cove two miles and a half; and from the navigable part of River Inhabitants two miles and a quarter. There is at present no road in any of these directions, but good lines could easily be obtained. In the direction of the Strait of Canseau, the coal-measures appear to be cut off at the distance of about half a mile from the river, by one of the fractures which abound in the district. In the opposite direction, it is possible that they may extend to the estuary of the River Inhabitants.

In the direction of the beds of coal, the ground in the vicinity of the river is low, rising to about thirty feet only above the stream. Only a very small depth of coal could therefore be drained by a level from the river-bed, or without the aid of machinery. The vertical position of the beds will also require a method of mining different from that employed in the other coal-fields of the province, where the seams are only slightly inclined. These circumstances, in addition to the comparatively small dimensions of the beds, as they tend to increase the expense of extracting coal, must operate as objections to the opening of this deposit. On the other hand, the seam No. 1 is sufficiently large to be conveniently worked, its coal would command a fair price in the market, and it is near harbours from which its produce could be shipped at any season. There is also a probability that the beds might be traced to localities more favourable for the extraction of the coal; and that, by works of discovery carried on in the adjacent measures, other workable seams might be found. A company has recently applied for a lease of this coal-field.

Coal also appears at the basin of Inhabitants, and in two places on the river of the same name; but I am not aware that it is of any practical importance.

The only other useful minerals found in the district are limestone and gypsum. The most accessible deposit of the former is that of Plaister Cove, which is large and of fair quality. Large beds of good limestone also occur at Little river and the north-west arm of River Inhabitants. The bed of gypsum from which Plaister Cove derives its name is of enormous thickness, and contains some good gypsum, though about two-thirds of its thickness consist of anhydrous gypsum or "hard plaster." The bed which occurs near Carribou Cove is of good quality; but where it appears on the shore it is deeply covered by boulder-clay. A little farther inland, however, it is nearer the surface. The marls associated with these beds, as they contain large quantities of carbonate and sulphate of lime in a finely divided state, might be usefully applied as a dressing to land.

Gypsum has been exported from the bed already mentioned at Little river, and to a considerable extent from Lennox passage, where, as well as at Arichat and St Peter's, there is good limestone.

8. *Carboniferous District of Northern Inverness and Victoria.*

In following the coast-sections to the northward and westward of Plaister Cove, we find the carboniferous rocks reduced to a narrow belt, by the projection of a mass of igneous and altered rocks toward the coast. The conglomerate appears in several places, and also the lower carboniferous limestone, which has been altered by heat into a variegated marble, capable of being applied to ornamental purposes. At Long Point the metamorphic hills begin to recede from the coast, and from Port Hood the carboniferous rocks extend quite across the island to St Ann's harbour, and northward to Margarie, beyond which place a narrow belt continues to line the coast as far as Cheticamp.

At Port Hood the coal-measures appear with characters very similar to those of the Joggins section. Their dip is W. 20°, in some places varying to W. by N. 25°; so that their strike nearly coincides with that of the shore, and only a small thickness of beds can be seen in the coast-section. The beds seen consist of gray sandstones and gray and brown shales, with black and calcareous shales, and thin seams of coal. Calamites, Artisia, Stigmaria, and coniferous wood abound; and, in a bed of sandstone a little to the northward of the village, magnificent examples of Sigillaria stumps, with their roots and rootlets attached, are seen *in situ*. The beds dipping seaward at a small angle, and undergoing rapid waste, expose these stumps on a horizontal surface, and not in a vertical cliff as at the Joggins; and this affords great facilities for studying the arrangement of their singular roots. Some of the stumps are two feet and a half in diameter, and may be seen to give off their pitted stigmaria roots in four main divisions, exactly at right angles to each other, each main root subdividing regularly into two, four, and so on. They are in the state of casts in hard calcareous sandstone, and they have grown on a soil consisting of loose sand, now sandstone, and stiff clay, now represented by beds of shale. Some of the layers of sandstone immediately under the roots are distinctly ripple-marked, and must, when the trees grew on them, have been either very recently elevated from the sea-bed, or must have been layers of blown sand. If it were not for the general uniform bedding of the coal-formation sandstones embedding these plants, an observer would be strongly inclined to refer them to the latter cause; and I think it by no means impossible that some of them may have had such an origin, and may have been afterwards smoothed and levelled by water, before the overlying beds were deposited on them.

More than one generation of these trees have grown on this spot, for I observed one of the stony trees to be penetrated by a cast of a Stigmaria with rootlets attached, which passed quite through it. This had manifestly belonged to a new generation of trees, growing above the remains of others already in the state of casts in sand, but not consolidated into stone.

One of the beds of shale in the vicinity of a small coal-seam at this place, contains abundance of *Modiolæ*, *Cypris*, fish-scales and teeth, and *Coprolites*, or the fossil excrement of fishes.

Four miles to the north-east of Port Hood, the lower carboniferous limestone and gypsum appear; and this part of the system continues to Mabou river, where it is very extensively developed. The limestone near this river has shells of *Productus Martini*, and abundance of fragments of *Encrinites;* and one of the beds has an *Oolitic* structure, that is, it is made up of small round grains, precisely like small shot cemented together, or the roe of a fish. This peculiar structure is supposed to have been produced by the calcareous matter collecting itself around minute grains of sand or other bodies, and thus taking the form of little balls, which were rolled about by the waves until cemented into rock. It was at one time supposed to be confined to a particular part of the geological series, still named in England the Oolitic formation, but it has been found in rocks of very different ages. Examples of it occur in the limestones of Windsor and Pictou; but this of Mabou is much more perfect. Its little rounded grains are nearly quite uniform in size, smooth and black, and cemented together by gray calcareous matter.

Near the mouth of Mabou river, there is an enormous bed of gypsum, which was being quarried when I last visited it, for the purpose of making road-embankments, this rock being the only available material at hand. Enormous plaster-pits have been excavated in the outcrop of this great gypseous mass. One of them forms a circular grassy amphitheatre, capable of containing hundreds of persons, and I was informed that there is a spring of water in its centre.

Immediately to the northward of Mabou river, the lower conglomerates crop out from under the limestones and gypsum, and rise on the flanks of Cape Mabou, a lofty headland, the nucleus of which is syenite, of greater antiquity than the carboniferous system, and which is connected with an isolated chain of igneous and metamorphic hills extending for some distance to the northward.

At Margarie, the coal-formation again appears, with its characteristic fossil plants; but it occupies only a very limited area, and the whole of the remainder of this district seems to consist of beds of the lower carboniferous series. The coal-formation rocks of Port Hood and Margarie are evidently only the margin of a coal-field extending under the sea, and perhaps as far as its appearance above the sea-level is concerned, in great part swept away by the waves. This coast is now rapidly wasting, in consequence of its exposure to the prevailing westerly winds blowing across the whole width of the Gulf of St Lawrence; and its rivers and harbours are from this cause choked with shifting sands. Owing to this waste of the coast, a sand-beach which connected Port Hood Island with the mainland has been swept away, and a safe harbour has thus been converted into an open roadstead, exposed to the northerly winds and encumbered with shoals. This will prove a serious drawback to any attempt to work the coal-beds of this locality.

The lower carboniferous limestone and gypsum appear at Cheticamp, in a number of places on Margarie river, and at Ainslie lake, which is a fine sheet of water, more than ten miles in length, and the largest lake, properly so called, in Cape Breton. To the eastward of this lake, a spur from the metamorphic country to the northward separates this part of the district from the lower carboniferous country of the county of Victoria. At the extremity of this spur, on the border of Whykokomagh basin, the lower carboniferous conglomerate with syenitic pebbles forms a hill named the Salt Mountain. On this conglomerate rest thick beds of laminated limestone, from which rise unusually copious springs, some of them of pure water, others said to be salt or brackish. At Middle river, we again find the lower carboniferous limestone with several of its characteristic fossil shells; and from this place, as far as St Ann's harbour and the Big Bras d'Or, the whole of the low country consists of sandstone, shale, and conglomerate, with limestone and gypsum appearing in several places. A lofty ridge of syenitic rocks separates St Ann's from the Bras d'Or, and at its extremity, Cape Dauphin, there is a patch of carboniferous rocks which have been described in detail by Mr Brown in the proceedings of the Geological Society. Mr Brown gives the following section, which is interesting as illustrating the arrangement of the several members of the series in this part of Cape Breton. The order is descending, and the beds dip S. 80° E. at an angle of 58°.

Lower coal-measures, seen about half a mile from Cape Dauphin—a few fossil plants—thickness not stated.	
Fine grained and pebbly sandstones (millstone-grit)—fossil plants	200 ft.
Finely laminated gray shales with thin bands of limestone	110
Slaty sandstones with traces of plants .	10
Blue and gray shales with thin beds of nodular limestone	120
Strong sparry limestone	6
Soft crumbling marls	90
Strong limestone	18
Carry forward,	354 ft.

Brought forward,	354 ft.
Brown sandstone	12
Red shales	33
Blue shales	8
Strong limestone—lower beds laminated—fossil shells.—*Productus Lyelli*, *Encrinus* .	17
Mottled red and green marls	24
Intermingled sandstones and limestone .	22
Blue shale	6
Red shale	8
Strong limestone	5
Mixed gray and brown shales . . .	12
Concretionary limestone	4
Soft blue clay	3
Slaty limestone in layers one to two inches thick	47
Soft blue marl, with gypsum near the bottom	32
Gypsum	8
Soft green marl	3
Marl, with layers of limestone . . .	28
Coarse limestone and shales . . .	44
Crumbling porous limestone . . .	50
Calcareous breccia, containing partially worn fragments of red syenite	24
Limestone showing no lines of bedding—*Terebratula Elongata*, *T. Sufflata*, *Productus Lyelli*, fragment of *Avicula* . . .	60
Compact slaty limestone	6
Soft brown shale	6
Brown and purple marls	40
	1056 ft.

In this section the lower carboniferous rocks are of much less aggregate thickness than usual; yet they display the several dissimilar members of the series pretty fully. The "millstone grit" corresponds with the deposit of the same name overlying the carboniferous limestone of England. It also corresponds with the thick succession of sandstones between Plaister Cove and Ship harbour, with those overlying the gypsiferous rocks in Pictou county, with the sandstones of the Eagle's Nest, on the Shubenacadie, and with the lower groups of Mr Logan's Joggins section. The limestone, marls, and gypsum are well developed, except that the latter is of smaller thickness than is usual. The lower conglomerate is wanting; but this is always an irregular deposit, and it appears in its proper place in most other sections in this part of Cape Breton, as for instance at St Ann's harbour, where the gypsum also is very largely developed. This section, as described by Mr Brown, did good service in confirming the new and more accurate views of the structure of the carboniferous rocks in this province, promulgated by Sir C. Lyell in 1842.

Useful Minerals of N. Inverness and Victoria.

Gypsum and *limestone* are very abundant in this district. The former may be obtained in any quantity at Mabou, Margarie river, St Ann's, Big Harbour on the Great Bras d'Or, &c. The latter abounds in the same localities, as well as in several others where the gypsum is absent. The altered limestone at Craignish and Long Point would afford several pretty and unusual varieties of coloured *marble*.

Coal occurs at Port Hood, and the outcrops of the beds have been opened on a small scale for domestic use. I saw only a bed of one foot in thickness, the outcrops of the others being completely covered with surface rubbish; but I believe all the beds that have been found are small. The coal is, however, said to be of good quality, and I have no doubt will eventually be worked for domestic use, if not for exportation. As but a very limited thickness of beds can be seen in the coast-section, it may be anticipated that a judicious survey of the district would discover other seams of coal in addition to those at present known; and if any means could be devised to restore to Port Hood a safe harbour, it is probable that, should the present demand for coal continue, these measures would soon attract the attention of adventurers.

Freestone for building is obtained, of good quality, at Port Hood Island and Margarie, and also at Whykokomagh; but it is not yet worked on a large scale.

The soils of this district being based principally on the calcareous rocks of the lower carboniferous series, are in general of excellent quality.

9. *Carboniferous District of Cape Breton County.*

This, though the last, is one of the principal carboniferous districts of the province, as it includes the important and productive coal-field of Sydney, which is second only to Pictou in its export of coal, and scarcely yields to the Joggins in its excellent exposures of the coal-formation rocks and fossils. As we owe nearly all that is known of this district to the labours of R. Brown, Esq. of Sydney, I shall avail myself, in describing it, of the information contained in his papers;* adding occa-

* See List in Chapter I.

sionally any other items of information that I have collected in short visits to this interesting district.

The island of Boulardarie, the whole of which I include in this district, though politically a part of it belongs to Victoria county, consists in its western part of the lower carboniferous limestone, and overlying hard sandstones, having apparently an undulating arrangement, as represented by Mr Brown in his section of the island. The limestone, as I have observed it on the north side of Boulardarie, is hard and compact, and contains the *Productus Martini*. At the eastern end of the island, the limestone and millstone-grit dip to the N.E. and underlie the coal-measures which appear near Point Aconi. The coal-measures, extending from Point Aconi to the outcrop of the millstone-grit, are stated by Mr Brown at 5400 feet in vertical thickness.

Crossing the Little Bras d'Or, the coal-measures continue with north-easterly dip across the peninsula separating this strait from Sydney harbour, and thence with various faults and disturbances to Miré bay. As the general dip is seaward, Mr Brown remarks, "this great area of coal-measures is probably the segment only of an immense basin, extending toward the coast of Newfoundland; a supposition which is confirmed by the existence of coal-measures at Neil's harbour, 30 miles north of Cape Dauphin." Inland of this broad band of coal-measures, the whole country northward of a line drawn west from Miré bay to the east arm of the Bras d'Or lake, is occupied by the older members of the series, with the exception of a tract of syenitic, porphyritic, and altered rocks, which appears at and near George's river on the south-east side of Little Bras d'Or. These igneous rocks have altered the lower carboniferous limestone, as well as perhaps some underlying beds of the same system, showing that igneous action had not terminated in these ancient metamorphic districts at the commencement of the carboniferous period; and this appears to have been the case along the boundary of the metamorphic and igneous rocks in many parts of Cape Breton.

This extensive carboniferous district is connected with that of Richmond county on the south, by a very narrow stripe of limestone, red conglomerate, and sandstone, skirting the base of the hills of porphyry, syenite, and slate, which rise steeply from the side of the Bras d'Or lake, which here is a broad and beautiful inland sea, presenting fine scenery in almost every direction. The limestone and conglomerate may be seen in several places to rest on the edges of the older slates and in some places, especially at Irish Cove, the former rock is filled with well-preserved fossil shells, including immense quantities of the *Conularia*, which in most other localities is rather rare; as well as *Productus Lyelli*, *Terebratula Elongata*, *Spirifer Glaber*, and a species of *Euomphalus*. The limestone is sufficiently soft to allow fine specimens of these shells to be detached by weathering.

The coal-measures are by far the most interesting part of this area, and are well exposed on the north side of Sydney harbour, and on the south end of Boulardarie. Mr Brown has published an elaborate section and description of them as they occur at the former place, from which the following facts are gleaned.

" The productive coal-measures cover an area of 250 square miles; but, owing to several extensive dislocations, it is impossible to ascertain their total thickness with any degree of accuracy; from the best information in my possession, I conclude that it exceeds 10,000 feet. We have one continuous section on the north shore of Boulardarie island, 5400 feet in thickness, and in the middle portion of the field several detached sections, varying from 1000 to 2000 feet in thickness, whose exact relative positions have not yet been determined; although it is quite clear that they are higher up in the formation than the highest beds of the Boulardarie section."

Mr Brown then proceeds to describe the section on the north-west side of Sydney harbour, from Stubbard's Point to Cranberry Head, a distance of 5000 yards, and exhibiting a vertical thickness of 1860 feet of beds. The dip is N. 60° E. 7°. Of these beds he gives a detailed section, including 34 seams of coal, and 41 underclays with Stigmaria or fossil soils. The whole of the beds composing the section are summed up as follows:—

Arenaceous and argillaceous shales	1127 ft.	3 in.
Underclays	99	6
Sandstones	562	0
Coal	37	0
Bituminous shales . . .	26	5
Carbonaceous shales . . .	3	3
Limestones	3	11
Conglomerate	0	8
	1860 ft.	0 in.

Erect trees and calamites occur at eighteen distinct levels. The greater number are Sigillariæ, many of them with distinct Stigmaria roots, and a few are Lepidodendra. They occur in circumstances very similar to those of the erect trees at the Joggins already described. Mr Brown's various papers on these fossils gave to the geological world the first really satisfactory information* respecting the true nature and mode of growth of Stigmaria; and to these I may refer the reader, more especially to that in volume fifth of the Geological Journal, page 355, from which I quote the following account of a fine specimen of *Sigillaria Alternans* with Stigmaria roots, regularly ramifying, and having attached to them conical tap roots, which penetrated directly downwards into a thin bed of shale overlying the main coal. This seam, like the main seam at the Joggins, has, when it was a bed of soft peat, supported a forest of Sigillariæ and Lepidodendra, many of which still remain erect in the overlying shale, with all their roots and long spreading rootlets attached.

"Immediately over the coal there is a bed of hard shale, six inches in depth, in which no fossils are found; this is overlaid by a *softer* shale abounding in coal-plants; all the upright trees that I have examined are rooted in the six-inch shale; the crown of the base of that which I am now describing is just four inches above the coal; its roots dip gradually downwards until they come in contact with the coal, at about eighteen inches from the centre of the tree, and then spread out over its surface. When this fossil was brought out of the mine the under side was covered up with hard shale to which about one inch of coal adhered; in cutting away this layer of coal, I met with the termination of a perpendic-

* Mr Binney can claim priority in date of publication; but his specimens were much less perfect in details of structure, and therefore less satisfactory than those described by Mr Brown.

ular root immediately in contact with the coal, which I carefully developed; proceeding in this manner, my patience was amply rewarded by the discovery of a complete set of conical tap roots. The horizontal roots branch off in a remarkably regular manner, the base being first divided into four equal parts by deep channels running from near the centre; an inch or two farther on, each of these quarters is divided into two roots, which, as they recede from the centre, bifurcate twice within a distance of eighteen inches from the centre of the stump."

"There are four large tap roots in each quarter of the stump, and, about five inches beyond these, a set of smaller tap roots, striking perpendicularly downwards from the horizontal roots, making forty-eight in all: namely, sixteen in the inner, and thirty-two in the outer set; and what is a still more remarkable feature in this singular fossil, there are exactly thirty-two double rows of leaf-scars on the circumference of the trunk. This curious correspondence in the numbers of the roots and vertical rows of leaf-scars, surely cannot be accidental. I am not aware that any similar correspondence has ever been observed either in recent or fossil plants. The inner set of tap roots vary from two to two and a half inches in length; the diameter at their junction with the base of the trunk being about two inches. The outer set are much smaller, being about one inch in diameter at their junction with the horizontal roots, and from one to one and a half inch in length. Very few of either set are strictly conical, although they probably were originally of that shape; some are squeezed into an elliptical, others into a triangular form; all have been wrinkled horizontally by the shrinkage due to vertical compression. A thick tuft of broad flattened rootlets radiates from the terminations of the tap roots, and a few indistinct areolæ are visible on their sides; the length of these rootlets does not appear to exceed three or four inches, their width being one-fourth of an inch; a raised black line runs down the middle of each, similar to that observed in the rootlets of Stigmariæ. These short thick tap roots were evidently adapted only to a soft wet soil, such as we may easily conceive was the nature of the first layer of mud deposited upon a bed of peat, which had settled down slightly below the level of the water."

"We may infer also, from the existence of a layer of shale without fossil plants, immediately over the coal, that the prostrate stems and leaves which occur in such large quantities in the next superincumbent bed, fell from trees growing upon the spot, and were entombed in layers of mud held in suspension in water, which at short intervals inundated the low marshy ground on which they grew; for had the plants been drifted from a distance, we should find them in the first layer of shale as well as in those higher up."

"Although the main coal is generally overlaid by shale, yet occasionally the shale thins out, and the thick sandstone, which is the next stratum in the ascending order, forms the roof of the coal. In such cases the surface of the peat-bog could not have been level when the shale was deposited upon it, some small patches having been still above water; and as no upright trees are found in the sandstone roof, it may reasonably be inferred that plants would not vegetate upon the bog itself, a layer of soft mud being necessary in the first instance for germinating the seeds; but when a plant had once taken root in this mud its rootlets penetrated downwards into the peat, and furnished an abundant supply of nutriment for the rapid growth of the tree, from the rich mass of decaying vegetable matter beneath."

The Sydney coal-measures contain not only erect trees, but also numerous beds with *Modiola*, *Cypris*, *Spirorbis*, *Fish-scales*, &c.; though these do not so frequently overlie coal-seams as at the Joggins. The shales at Sydney are also much more rich than those at the Joggins in the leaves and other more delicate parts

Fig. 33.

Foliage from the Coal-formation.

a b c d e f g.

(*a*) Pecopteris Heterophylla (?) (fern)—Moose River. (*b*) Sphenophyllum Schlotheimii—Pictou. (*c*) Lepidodendron Binerve—Sydney. (*d*) Asterophyllites Foliosa (?)—Sydney. (*e*) Poacites—Joggins. (*f*) Neuropteris Rarinervis (fern)—Sydney. (*g*) Odontopteris Subcuneata (fern)—Sydney.

of plants; and on this account I give here sketches of a few examples of the foliage of the coal-formation period, as displayed in the rocks of Nova Scotia and Cape Breton. (Fig. 33.) On the mode of occurrence of such leaves, Mr Brown remarks:—

"The shales are the most prolific in plants, especially those which form the roofs of the coal-seams. It is singular that not even a trace of a fossil plant nor any organic substance has been found in any of the red shales, although they have been carefully examined for that purpose.* Wherever erect trees occur, ferns, asterophyllites, sphenophylla, and other delicate leaves are found in the greatest abundance; from which I infer that they fell from growing trees and shrubs, having been covered up by successive layers of fine mud, deposited at frequent intervals over a low marshy district. in these localities, single fronds of ferns are sometimes found covering a slab of shale two feet square, as sharp and distinct in their outline as if they had been gathered only yesterday from a recent fern, and spread out with the greatest possible care, not a single leaflet being wanting or even doubled up. Some beds also seem to contain one species of plant only, all others being excluded; of this we have a striking example in the argillaceous shale (No. 60): in the top of this bed, through a thickness of three inches, we find Asterophyllites Foliosa, piled up layer above layer, from the base of the cliff to the crop of the bed, a distance of 200 feet, clearly proving that these plants grew on the spot." This description may give the reader some idea of the abundance and perfection of the fossil vegetation preserved

* This does not apply to the coal-formation of Pictou, where ferns, poacites, and sphenophyllum are found in red shales, though rarely.

in the Sydney coal-measures. As already stated also, a bed of shale in the Sydney section has afforded the finest example yet known of carboniferous rain-marks. These occur in a bed at the top of one of those bands in which the sandstones are rippled and fossils rare. At some distance below it there are modiola shales, and ten feet above a stigmaria underclay and coal. These marks then were preserved in beds formed during the transition from aquatic to terrestrial conditions, by the silting up of the modiola lagoon or creek, and most probably on a bed daily left dry at low tide.

Useful Minerals of the Carboniferous District of Cape Breton County.

Coal ranks at the head of these; about 80,000 tons being raised annually from the Sydney main seam, which is worked by the General Mining Association, on the north side of Sydney harbour, and is shipped at the bar at North Sydney, to which place a railway has been laid. The coal from this seam is used principally for domestic fires, for which it is admirably suited. About 30,000 tons are annually consumed in Nova Scotia, the remainder being exported to the United States.

Of the thirty-four seams included in Mr Brown's section, only four are of workable thickness; they are,

	ft.	in.
1. The Indian cove seam, about 450 feet of vertical thickness below the main seam . . .	4	8
2. The main seam	6	9
3. The Lloyd's cove seam, about 730 feet of vertical thickness above the main seam	5	0
4. The Cranberry head top seam, about 280 feet above Lloyd's cove seam	3	8

Of these only the main seam is worked at present. It yields a bright, free-burning coal, giving out its heat very rapidly, and leaving a very small quantity of heavy reddish ashes. According to Professor Johnston it yields—

Volatile matter . . .	26·93
Fixed Carbon . . .	67·57
Ashes	5·50
	100·000

Its steam-producing power is rather less than that of Pictou coal, being, according to the same authority, 7·01 to 1 lb., or from the temperature of 212°, 7·99 to 1 lb. It also yields less illuminating gas; and, from the presence of a little bisulphuret of iron, is more destructive to furnace bars than Pictou coal. For domestic use, however, its comparative freedom from dusty ashes more than compensates for these defects.

The quantity of coal annually raised in the county of Cape Breton, and almost entirely at Sydney, is stated in the census of 1851 at 53,000 chaldrons.

The coal-seams on Boulardarie island are not now worked, though trials of some of them have been made by the Mining Association; and small quantities are occasionally extracted from their outcrops by the country people. Proposals have, I am informed, been recently made to the government to lease the beds at Point Aconi.

Valuable coal-seams also appear at Lingan or Bridgport, and one of them, which is about nine feet in thickness, affords a fine caking coal, having a very small percentage of ash, and yielding 35·16 per cent. of volatile combustible matter; so that it is rather superior to the produce of the Pictou mines as a gas-coal. The mines at this place, after having been abandoned for some time, have recently been re-opened by the Mining Association.

Clay Ironstone, in nodules, occurs in several of the shales of the Sydney section, but I have no information respecting its probable industrial value.

Limestone and *Gypsum*, as already mentioned, abound in a number of places, but are not extensively worked. An altered limestone, which extends from the neighbourhood of Long Island, on the Little Bras d'Or, toward the East Arm, has recently afforded some samples of gray and white *marble*, and may possibly prove valuable. *Freestone* and *grindstone* are also quarried, though in small quantity.

CHAPTER XIV.

DEVONIAN AND UPPER SILURIAN SYSTEMS.

DEVONIAN AND UPPER SILURIAN ROCKS—IGNEOUS MASSES ASSOCIATED WITH THEM—DISTRIBUTION AND CHARACTERS IN EASTERN NOVA SCOTIA—IN WESTERN NOVA SCOTIA—IN CAPE BRETON—IN NEW BRUNSWICK—PROBABLE DATE OF DISLOCATIONS AND METAMORPHISM—USEFUL MINERALS.

JUST as in studying the New Red Sandstone, we observed that its slightly inclined beds rested on the edges of more disturbed carboniferous rocks, so in our description of the carboniferous system, we have found its lowest beds to rest unconformably on a still older formation, usually hardened and altered by heat; and we have found that in many instances there are evidences that these more ancient rocks actually formed the shores of the sea in which the lower carboniferous series was deposited. These older rocks resolve themselves into two distinct groups, differing in nature and probably in age, and that which we have now to consider is the more recent of the two. It includes rocks in three very different states.

First, Some portions of it consist of shaly, sandy, and calcareous deposits, considerably hardened and much disturbed, yet retaining abundance of fossil shells and other evidences of a marine origin.

Secondly, Other portions, originally no doubt similar to those now less altered, are highly metamorphosed by heat, and are not only hardened and in some cases half-fused, but have assumed a fissile structure, causing them to split into thin plates in directions not usually corresponding with the original bedding. This is termed *slaty* structure, and the reader may observe that it is this structure, induced by intense heat and electrical influence, that distinguishes slates, properly so called, from ordinary shales.

Thirdly, Associated with these rocks are great masses and dikes or thick veins of igneous or volcanic rocks, some of them poured forth before the commencement of the carboniferous period, others subsequently. These igneous rocks, though of similar origin with the trap of the New Red Sandstone, differ somewhat in composition and appearance. They are mostly coarser grained or more crystalline, indicating that they are less superficial, and hence have cooled more slowly. Hornblende usually replaces the Augite of the trap. Felspar, which is the pure white or flesh-coloured part of ordinary granite, exists in greater abundance than in trap. Quartz or uncombined silica is also often present in considerable quantity. Rocks of this class are very variable in their composition and appearance, hence it is difficult to give them accurately distinctive names. For this reason I give below an explanation of the terms which I shall employ in naming these rocks, as they occur in this geological district in Nova Scotia.

Greenstone consists of hornblende and felspar, sometimes in large distinct crystals of black or green hornblende and white felspar, and in every gradation of crystalline texture between this and a gray or greenish rock in which the separate crystals are scarcely distinguishable. When there are large distinct felspar crystals embedded in the mass, it is named *Porphyritic* greenstone.

Syenite consists of distinct crystals of reddish, gray, or white felspar, with a smaller quantity of dark-coloured hornblende and some quartz—the whole forming a material somewhat similar to granite, with which it is often confounded.

Granite, composed of distinct crystals of quartz, felspar, and mica. Granite is a rare rock in this district, though found in great masses in the other metamorphic district.

Compact Felspar is a rock consisting of the materials of felspar with some quartz, but not distinctly crystalline. It is sometimes fine-grained and flinty in aspect, and in other cases dull and rough in its fracture, approaching to the rocks called *Trachyte* and *Claystone.* Its colours are usually dull-gray, reddish-brown, and greenish. It often contains scattered distinct crystals of lighter coloured felspar, and is then *Felspar Porphyry.*

These igneous rocks have without doubt been the agents which altered the bedded rocks with which they occur; and their protrusion from beneath has also been the cause of elevating and fracturing these sedimentary deposits.

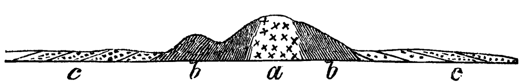
On consulting the map, it will be observed that this district occupies some irregular patches in Cape Breton, a very irregular hilly tract in eastern Nova Scotia, commencing at Cape Porcupine and Cape St George, and extending toward the Stewiacke river; the long narrow band of the Cobequid mountains; and a belt of variable width skirting the northern side of the other metamorphic district in the western counties. In New Brunswick several promontories of these rocks appear in the vicinity of the Bay of Fundy, and are the eastern extremity of a large tract of similar character spreading through the New England states. Both in Nova Scotia and Southern New Brunswick, this group of rocks includes the highest hills, and in the former province it forms all the principal watersheds.

Owing to the alteration and disturbance to which its rocks have been subject, the structure of this district is much more complicated and at the same time less interesting than that of those which have been described above, and its interior position causes it to present few good sections to the geologist. For these reasons less attention has been devoted to it than to the carboniferous districts, and the details of its structure are comparatively unknown. In describing it, however, I shall endeavour to follow the method previously pursued, by attending somewhat minutely to some of the best and most instructive exposures in coast and river sections, and applying the information obtained from these to the elucidation of the true relations and structure of the remaining portions. I shall then describe the important deposits of useful minerals which occur in this group of rocks. In this order of proceeding, it will be convenient to study first the development of the formation in Eastern Nova Scotia, and to proceed westward, returning afterward to the island of Cape Breton.

At *Cape Porcupine* the igneous and metamorphic rocks come boldly out upon the Strait of Canseau, in a precipice 500 feet in height, and afford a good opportunity of studying these rocks and their relations to the carboniferous system. The central part of Cape Porcupine is a mass of reddish syenite, consisting principally of red felspar and hornblende. This once molten mass passes by gradual changes into hard flinty slates, which in shattered and contorted layers lean against its sides, and on these again rest beds of conglomerate, forming the base of the carboniferous series, and made up of pebbles of syenite and flinty slate like those of the cape itself. Here we can plainly read the following history. *First*, Beds of mud deposited in the sea, probably in the silurian period. *Secondly*, These beds upheaved and metamorphosed by the injection of the molten syenite. *Thirdly*, Large portions of the altered and igneous rock ground up into pebbles by water, and scattered over the sea-bottom to form the lowest layer of a new geological formation, the same that we have studied in preceding chapters. The structure of Cape Porcupine is represented in Fig. 34.

Fig. 34.

Arrangement of Syenite, Slate, and Conglomerate at Cape Porcupine.



(*a*) Syenite. (*b*) Slate. (*c*) Conglomerate and Sandstone.

At Cape Porcupine the altered rocks of the group now under consideration, occupy less than three miles of the coast-section, and are separated by carboniferous rocks and by Chedabucto bay from the eastern extremity of the granitic metamorphic district of the Atlantic coast, distant about twenty-four miles. As Cape Porcupine affords no fossils, and can therefore tell nothing of the condition of the earth and its inhabitants at the time when these slates were deposited, we may proceed to trace the continuation of its rocks into the interior.

From Cape Porcupine the southern margin of the metamorphic rocks extends along the northern side of the carboniferous district of Guysboro' for about sixty miles, when it meets and apparently unites with the granitic group. In several places along this line, igneous action appears to have continued or to have recurred as late at least as the coal-formation period. This is testified by the condition of the lower carboniferous rocks in many places near Guysboro', westward of which place a considerable promontory of altered and igneous rocks extends to the southward, nearly across the carboniferous district.

The northern margin of the band commencing at Cape Porcupine, may be traced to the westward about forty miles, when it unites with a broader but very irregular promontory of similar rocks extending toward Cape St George. Between these two bands is included the carboniferous district of Sydney county. The tract formed by their union is the widest extension of these rocks in the province (see map and general section prefixed to Chapter II.)

The metamorphic promontory extending to Cape St George, and including the Antigonish and Merigomish hills, attains a greater elevation than the band connected with Cape Porcupine. At its extremity, however, it becomes divided into a number of detached hills and ridges, separated by lower carboniferous beds, to which in some cases the metamorphic action has extended itself. The Antigonish and Merigomish hills contain large masses of syenite, porphyry, compact felspar, and greenstone, associated with slates and quartzite.* On their western side near Arisaig, there is a patch of shale, slate, and thin-bedded limestone, with fossil shells, and but very little altered.

The northern boundary of the broad band of metamorphic and hypogene rocks, formed by the union of the two promontories already noticed, extends in a westerly direction along the south side of the Pictou carboniferous district, until it reaches the east side of the East river of Pictou, when it suddenly bends to the south, allowing the carboniferous strata to extend far up the valley of that river. Here, as at Arisaig, its margin includes fossiliferous slates, among which is a thick bed of iron-ore including fossil shells. A few of the fossils of these beds are stated by Sir C. Lyell to agree specifically with those of the Hamilton group of the United States geologists. Professor Hall of Albany, to whom I have sent a small collection of these fossils, chiefly from Arisaig, where most of the species are the same with those of the East river, is of opinion that they belong to the age of the Hamilton and Chemung groups. In other words, they belong to groups of the same age with the Devonian rocks of England and the Old Red Sandstone of Scotland. With respect to these fossils, I may remark that they are all marine, that they belong to numerous genera and species, and that none of them are identical with the fossils of the carboniferous lime-

* Quartzite is a flinty rock produced by the hardening and alteration of sandstone.

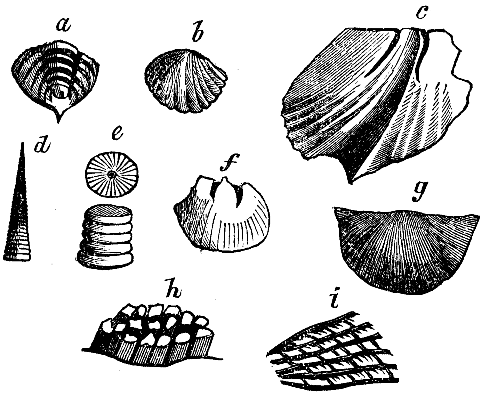
stones. Both at Arisaig and the East river, excellent opportunities are afforded for studying this difference. The collector may, in the shales of Arisaig or the slates of the East river hills, collect a great number of marine species, some of them in a fine state of preservation, others distorted and partly defaced by the partial alteration of the containing rocks. At both places he can observe that the rocks containing these fossils have been tilted up and hardened, before the lowest beds of the carboniferous system were deposited. At both places he can find in these overlying carboniferous rocks abundance of fossils, also marine, *but entirely distinct from those of the older group.* He thus finds that in passing from one of these formations to the other, he has passed from one great period of the earth's history to a succeeding one, in which no trace remained of the animal population of the former. He has entered in short on a new stage of the creative work.

Though I have sent considerable collections of the Devonian fossils of Arisaig and the East river to naturalists in London, and to Professor Hall, the palæontologist of the New York survey, I have been unable to get them fully determined and compared with their contemporaries in England and the United States. As a specimem of them, I give a few species in Fig. 35, and an imperfect list will be found in the table of fossils near the close of this volume.

Immediately on the east of the East river, the metamorphic band is about fifteen miles in breadth, and includes masses and dikes of syenite and greenstone, and beds of quartzite and slate, the latter of very various colour and texture. Beyond the East river, the metamorphic band again widens; and between the upper

Fig. 35.

Fossils from the Devonian and Upper Silurian (?) Rocks of Nova Scotia.



(*a*) Tail of Trilobite (Phacops)—Arisaig. (*b*) Atrypa—Arisaig. (*c*) Spirifer (cast)—Moose River, &c. (*d*) Tentaculites—Bear River. (*e*) Crinoidal joints—East River. (*f*) Orthis (cast)—East River. (*g*) Chonetes—Arisaig. (*h*) Coral (Favosites) (cast)—Nictau. (*i*) Coral (Dictyonema)—New Canaan.

part of the Middle river of Pictou and that of the west branch of the St Mary's river (the point to which we have already traced its southern boundary) it forms a broad and irregular tract of metamorphic country. Westward of this tract it is again subdivided; one branch extending near the margin of the granitic group, on the south side of the Stewiacke river, as far as the Shubenacadie; another extending for a short distance between the Stewiacke and Salmon rivers; and a third, or rather a group of detached masses, extending through Mount Thom, to the eastern extremity of the Cobequid range of hills. In the hilly country connected with Mount Thom, and in the vicinity of the upper parts of the Salmon, West, and Middle rivers, considerable breadths of lower carboniferous strata have been partially metamorphosed, and invaded by greenstone and other igneous rocks. A mass of granite, containing dark gray felspar, abundance of black mica, and very little quartz, occurs on the east side of Mount Thom. This is the only instance, so far as I am aware, of the occurrence of true granite in this group of rocks in eastern Nova Scotia.

The Cobequid hills, extending nearly in an east and west direction for about ninety miles, in that part of Nova Scotia lying north of the southern arm of the Bay of Fundy, must be referred to the metamorphic group now under consideration. Both their stratified and igneous rocks are similar to those of the parts of this group already described. Fossils are absent or very rare in those parts of it which I have explored, with the exception of Earlton, in the eastern extremity of the range, where there are slates containing fossils similar to those already noticed. I shall make no attempt to describe the numerous and singular varieties of altered and igneous rocks found in the Cobequid mountains, but shall content myself with a description of its structure in its central portion, which is illustrated by the section in Fig. 1, Chap. II.

On the northern side of the hills, near the post road from Truro to Amherst, and also on Wallace river, the lowest rocks of the carboniferous system, consisting of reddish-brown conglomerates, are seen at the base of the hills. Their dip is to the northward at a high angle. On ascending the hills, masses of red, flesh-coloured, and gray syenite are seen, and rise rapidly to the height of several hundred feet; the northern side of the range being steeper and more lofty than the southern. The syenite of this part of the hills has often been described as a granite; but wherever I have observed it, it is a true syenite, containing reddish or white felspar, black hornblende, and nearly colourless quartz. Some of the red varieties are large grained and very beautiful. The gray varieties are often fine grained, and appear to pass into greenstone.

It is remarkable that the syenite and greenstone of this part of the mountain are traversed by numerous small veins of true granite. Whether these have been produced by segregation, or are parts of a later outburst of granitic rock, I cannot determine with certainty, but think the latter more probable. I am not aware that any masses of true granite occur here. It is, however, quite possible that after or during the cooling of the syenite, veins may have been injected into it from granitic masses below which have not reached the surface.

Penetrating further into the range, we find thick dikes of greenstone associated with slate and quartzite. The greenstone is of various degrees of coarseness, and at some points is penetrated by a network of syenitic or felspathic veins. The general course of the greenstone dikes coincides with that of the range of hills. Toward the southern side of the hills, gray quartzite, and gray, olive, and black slate prevail, almost to the exclusion of igneous rocks. The strike of these beds is nearly S. W. and N. E., with high dips to the southward. On the south they are bounded and overlaid unconformably by carboniferous conglomerate and sandstone.

The structure observed in this part of the chain appears to prevail throughout; the syenitic rocks forming a broad band on the northern side, and slates and quartz rock with dikes of igneous rock, probably of later date than those on the north side, occurring on the southern ridges. The only exception to this that I am aware of is at the extreme eastern end, where the igneous rocks are less massive and the syenite disappears.

The Cobequid range presents a succession of finely wooded and usually fertile ridges; and the chain is very continuous, though broken by some narrow transverse ravines. Many of the streams flowing from these hills plunge downward in fine cascades at the junction of the hard rocks with the softer carboniferous beds. The most remarkable of these waterfalls on the south side is that of the Economy river, on the north side that of the principal branch of Waugh's river.

Passing from the Cobequid mountains to the *Slate hills of the south side of the Bay*, we find slates not very dissimilar from those of the Cobequids, in the promontory northward of the Gaspereaux river. Here the direction both of the bedding and of the slaty structure is N. E. and S. W.; but the planes of cleavage dip to the S. E., while the bedding, as indicated by lines of different colour, dips to the N. W. These slates, with beds of quartzite and coarse limestone, are continued in the hills of New Canaan, where they contain crinoidal joints, fossil shells, corals, and in some beds of fawn-coloured slate beautiful fan-like expansions of the pretty *Dictyonema* represented in Fig. 35, (*i.*) Very fine specimens of this fossil have recently been found by Dr Webster of Kentville. It was the habitation of thousands of minute polypes, similar to those which construct the corals and sea fans. The general strike of the rocks in New Canaan is N. E. and S. W.

At the falls of the Nictau river, the fossiliferous slates contain a bed of peroxide of iron, probably accumulated as iron-sand in the sea-bottom. It is six feet in thick-

FALL OF THE ECONOMY RIVER.
(Cobequid Hills)

ness, and abounds in fossil shells, especially of species of *Spirifer*, found also at the East river of Pictou. Westward of Nictau river, the metamorphic slates are interrupted by great masses of granite, which form the hills along the south side of the Annapolis river, from a place called Paradise to Bridgetown, and with some interruptions nearly as far as the town of Annapolis. This granite is hardly distinguishable in its character from that of the south coast of the province, except that it is perhaps more felspathic, and less largely and perfectly crystalline. I possess no facts which can determine whether its age is that of the coast granites, or whether it here replaces the greenstone, porphyry, and syenite which usually occur in the group now under consideration. Near Paradise it is traversed by veins of reddish compact felspar, with crystals of schorl and transparent smoky quartz. The latter mineral is found in very large crystals scattered in the surface rubbish, and is collected and sold by the inhabitants.

The metamorphic rocks reappear at Moose river, and contain the continuation of the iron bed of Nictau, which is here of somewhat larger dimensions, but more altered by heat and displaced by faults. The strike of the beds near Moose river bridge is N. 70° E. At Bear river the slates contain bands of calcareous matter abounding in fossils, and beds of hard sandstone; their strike is N. 50° E. At the Joggin near Digby, the slates are broken up and much altered by masses or dikes of porphyritic rock. At one place here I found the strike of the bedding to be N. 15° E., while that of the slaty structure is N. 45° E. Westward of this place the slates in a highly metamorphic condition continue with general N. E. and S. W. strike to the coast of

Clare, where a considerable breadth of country is occupied with olive and gray slates, quartz rock, and occasional dikes of greenstone. At Montengan these beds include veins of iron pyrites, one of them a foot in thickness. I have not been able to ascertain with certainty whether any well defined boundary separates the group now under consideration from the metamorphic district of the Atlantic coast; but I think it probable that the limit of the altered Devonian rocks in this direction is near Beaver river.

With respect to the age of these rocks, it is certain that the fossiliferous parts are Devonian. Some portions of the altered rocks may however be older, say Upper Silurian. The first upheaval and alteration of the beds must have occurred long before the beginning of the carboniferous period, but igneous action continued, especially in the eastern part of the province, during and perhaps after that period. In their original state these slates and quartz rock, and their iron ore, which appears in precisely the same geological position at Pictou and Nictau, must have been shales, sandstone, and iron sand, abounding in fossil remains, and with layers of calcareous matter mostly made up of shells. Over large tracts the fossils have been obliterated by metamorphism, and a perfect slaty structure has been induced.

In Cape Breton, rocks similar to those above described constitute the several irregular tracts of metamorphic and igneous country to which the colour of this group has been assigned. Syenite and porphyry are extensively developed in a line extending from St Peter's along the east side of the Bras d'Or, in the country between little Bras d'Or and the East Arm, in the high ridge extending to Cape Dauphin, in the hills near the Bedeque, Middle, and Margarie rivers, in those near Mabou, and in the irregular tract at the sources of the Inhabitants river and River Denys. Slates are associated with them in these places, but I am not aware that they contain any fossils.

I am informed by Mr Brown that the elevated region occupying the extreme northern part of Cape Breton, and of which I have seen only the southern borders, consists, at least in the vicinity of the coast, principally of red syenite and mica slate. Its interior is entirely unknown to geologists; but from its appearance as viewed from a distance, I infer that it consists of a number of elevated ridges similar to those of the Cobequid mountains, and probably attaining an equal elevation. The patches of lower carboniferous rocks which appear at intervals along its margin, indicate that, like the Cobequids, it formed a rocky island in the seas of the carboniferous period.

Metamorphic Rocks of New Brunswick.

Though I have coloured the greater part of these with the tints appropriate to the Devonian and Upper Silurian rocks, I am by no means confident that this is their true age. In the map attached to Professor Johnston's Report, and which was prepared by Dr Robb, in part from his own observations, and in part from those of Dr Gesner, these rocks are separated into two divisions, named respectively Cambrian and Lower Silurian, and the associated igneous rocks are designated "Trap, Syenite, Felspar rock, Porphyry," &c.

These igneous rocks are identical in character with those of the Cobequid hills, and I have no doubt are of the same age; but the age of the associated stratified rocks is very uncertain. I am not aware that they contain any fossils, and their lithological character is not precisely the same with that of other rocks of known age in these provinces. The relations of these rocks to the lower carboniferous beds at Chepody show, however, that they are at least of Devonian age; and the slates of this mountain are not essentially different from those of the Devonian hills of Nova Scotia, yet they may be much more ancient. In the neighbourhood of St John, the rocks, though included in the same tint in the geological maps, are altogether different. Here there are not only slates but limestones of enormous thickness, indurated shales, and a bed of plumbago. These beds may represent the limestones of the lower or upper silurian series, so extensively developed in the United States and Canada; but I confess that their appearance strongly impressed me with the suspicion that they may be much metamorphosed lower carboniferous beds. Since, however, I have not found them to contain any fossils, and have had no opportunities of studying their relations to the unaltered carboniferous rocks in the vicinity, and since I find it stated in Dr Gesner's Report that in some localities not very distant from St John similar rocks unconformably underlie the carboniferous sandstones, I must be content in the mean time to consider them as silurian rocks of uncertain age. I do not think that at present there is any good ground for separating the so-called Cambrian rocks from those last mentioned, though it is quite probable that they may belong to an older formation, or that they may be older members of the same formation.

For the distribution of these rocks, as indicated in the map, I am indebted principally to the map prepared by Dr Robb.

General Remarks.

The syenitic group of metamorphic rocks includes the most elevated land of eastern Nova Scotia. The Cobequid range, attaining at several points a height of 1200 feet, is the most elevated chain of hills in the province; and forms, in its whole length, the watershed dividing the streams flowing into Northumberland Strait and Chiegnecto Bay from those flowing into Cobequid Bay and Mines Basin and Channel. In like manner, the complicated group of hills extending westward from Cape Porcupine and Cape St George, though less elevated than the Cobequid hills, contains the sources of all the principal rivers of the counties through which it extends. The largest of these is the St Mary's river. Its western branch, originating in the same elevated ground that gives rise to the Musquodoboit, the Stewiacke, and the Middle River of Pictou, flows for about thirty miles nearly due east along the valley which here separates the granitic and syenitic groups. Its east branch flowing from the hills in the rear of Merigomish, and passing near the lakes from which the principal branch of the East river of Pictou flows, receives tributary streams from the metamorphic promontory stretching towards Cape Porcupine, and unites with the west branch at the northern margin of the granitic metamorphic band. The united stream then flows through a narrow valley in the granitic group to the Atlantic.

Judging from the direction of the principal streams, as for instance the Liverpool river, it would appear that in the western counties, as well as in the eastern, this group of metamorphic rocks, with its associated igneous masses, forms the most elevated ridges. In the southern part of New Brunswick also, and in Cape Breton, we everywhere find these rocks forming rocky ridges separating the river valleys.

M. Jules Marcou, in the very excellent summary of American geology which accompanies his geological map, endeavours to apply to these elevations De Beaumont's theory of the parallelism of mountain ranges of like age. According to this view, the Cobequid mountains and the hills on the east side of the Bras D'Or lake belong to a system of elevations older than the lower silurian rocks; and the Merigomish and Antigonish mountains, with the hills of western Cape Breton, to a later dislocation, dating at the close of the silurian period. It appears to me that both these dates are by much too ancient. I have already stated that the rocks of the Cobequid mountains have been altered and elevated before the carboniferous period; but, on the other hand, these altered rocks themselves are in part Devonian, and there is no reason to believe any of them to be older than upper silurian. I would therefore refer the great line of dislocation of the Cobequids, which runs nearly W. 10° S., as well as the nearly parallel lines of the south mountains of King's county, the range ending in Cape Porcupine, and most of the hills of Cape Breton, to the close of the Devonian period. These ranges have however been broken and deranged in places, as at the eastern end of the Cobequids, the Antigonish mountains, the hills near Guysboro', and in the south-west of Cape Breton, by disturbances probably coeval with the great Alleghany range, that is, at or toward the end of the carboniferous system, and there is evidence that between this time and the end of the Devonian period, igneous action was constantly more or less felt, and was also accompanied by elevating movements. Hence these later movements in part, as along the Cobequid range, have conformed to the course of the older movement, and in part have broken out into irregular projecting ridges, having a tendency to a north-east and south-west direction. In short, the study of these elevations in Nova Scotia tends to show, that though there may be a certain parallelism between elevatory movements of the same period, when they take place in districts previously undisturbed, yet that in regions broken up by previous dislocations, they may either conform in direction to these, or break forth irregularly from them along lines of least resistance produced by previous transverse fractures.

Before leaving these rocks, I must state, that their boundaries, as marked on the map, are often very rude approximations to the truth. It is impossible in the present state of our knowledge to distinguish accurately between these older rocks and the carboniferous beds which have in many parts of their borders been metamorphosed with them, or to indicate accurately the position and limits of the irregular masses and dikes of igneous rocks. An immense amount of labour will be required before these disturbed and altered rocks can be accurately mapped, or their intricacies fully unravelled.

Useful Minerals of the Devonian and Upper Silurian Rocks.

Iron, in veins traversing the altered rocks, abounds in this district; and it also occurs in thick beds coeval with the neighbouring slates, and filled like them with fossil-shells. I shall first notice the principal deposits, which are *veins* properly so called. These, though occurring in many places, have been worked only along the southern slope of the Cobequid hills in Londonderry, in the vicinity of the Great Village and Folly rivers. This deposit appears to have been noticed as early as the time when the land on which it occurs was granted by the Crown; and it received some attention from Mr Duncan and other gentlemen in Truro, nearly twenty years ago. No steps were however taken toward its scientific exploration until 1845. In the summer of that year I received a specimen of the ore for examination, and in October of the same year I visited and reported on the deposit. In the same autumn it was examined by Dr Gesner. In 1846 I again visited it, and reported on it to C. D. Archibald, Esq. of London, and other gentlemen associated with him; and in the summer of 1849 I had the pleasure of again going over the ground and examining the vein at some new points, in company with J. L. Hayes, Esq. of Portsmouth, U. S. Since 1845 the extent and economical capabilities of the deposit have been discussed by several writers, both in this province and in Great Britain; and it has been opened, and smelting furnaces erected by an association of capitalists.

I shall begin by describing the vein as it occurs on the west branch of the Great Village river, at the site chosen by C. D. Archibald, Esq., for the furnace and buildings of the "Acadia Mine." In the western bank of this stream, at the junction of the carboniferous and metamorphic series, a thick series of gray and brown sandstones and shales, dipping to the south at angles of 65° and 70°, meet black and olive slates, having a nearly vertical position, and with a strike N. 55° E. The dip of these slates, where apparent, is to the southward, and the strike of the slaty cleavage and of the bedding appears to coincide. Near the falls of the river, a short distance northward of the junction just noticed, the slates give place to gray quartzite, which, with some beds of olive-slate, occupies the river-section to, and for some distance beyond, the iron vein.

The vein is well seen in the bed of the stream, and also in excavations in the western bank, which rises abruptly to the height of 327 feet above the river-bed. In the bottom of the stream it presents the appearance of a complicated network of fissures, penetrating the quartzite and slate, and filled with a crystalline compound of the carbonates of lime, iron, and magnesia, which, from its composition and external characters, I refer to the species *Ankerite*. With this mineral there is a smaller quantity of red ochrey iron ore, and of micaceous specular iron ore.

In ascending the western bank of the stream, the vein appears to increase in width and in the quantity of the ores of iron. In one place, where a trench was cut acrosss it, its breadth was 120 feet. Though its walls are very irregular, it has a distinct underlie to the south, apparently coinciding with the dip of the containing rocks. As might have been anticipated from its appearance in the river-bed, it presents the aspect of a wide and very irregular vein, including large angular fragments of quartzite, and of an olivaceous slate with glistening surfaces. These fragments are especially large and abundant in the central part of the vein, where they form a large irregular and interrupted rocky partition.

That the reader may be enabled to understand the description of this singular deposit, I give the composition of the various substances contained in it, as ascertained by my own analyses and examinations.

1. *Specular Iron Ore*, or nearly pure peroxide of iron, in black crystalline scales and masses.

2. *Magnetic Iron Ore*, a compound of the peroxide and protoxide of iron. This and the first-mentioned ore, as they occur intermixed in this vein, are capable of affording from 60 to 70 per cent. of pure iron. Both of these ores have been introduced into the vein by igneous fusion or sublimation.

3. *Ochrey Red Iron Ore*. This is the most abundant ore in the vein, and is of great value on account of its richness and easy fusibility. It is also the material of which the mineral-paint produced by this region is manufactured. It varies somewhat in quality, but the purest specimens are peroxide of iron, with scarcely any foreign matter.

4. *Ankerite*, or carbonate of iron, lime, and magnesia. This is the most abundant material in the vein, and is usually of a grayish-white colour, though sometimes tinged red by the peroxide of iron. A specimen of the reddish variety, containing small scattered crystals of specular iron, gave on analysis—

Peroxide of iron	33·0
Carbonate of lime . . .	46·0
Carbonate of iron . . .	19·5
Carbonate of magnesia . .	·8
Silicious sand	·4
	99·7

The white variety consists of—

Carbonate of lime	54·
Carbonate of iron	23·2
Carbonate of magnesia . .	22·
Silicious sand	·5
	99·7

With this mineral is found a variety of *Spathose Iron*, or sparry carbonate of iron, containing about 20 per cent. of carbonate of magnesia. It is of a light yellow colour, and runs in little veins through the Ankerite. I have no doubt that all these substances have been molten by heat, and injected from beneath into the irregular fissure in which they are now found. The ochrey red ore, previously mentioned, appears to be a result of the subsequent action of heat on the spathose iron. The ankerite and spathose iron are valuable for mixing with the other ores, affording at once lime for a flux and much iron.

5. *Yellow Ochrey Iron Ore.* This is found in great quantity on the surface of the vein, and has resulted from the rusting of the ankerite, which soon becomes covered with a yellow rusty coat when exposed. The yellow ochre is a peroxide of iron combined with water, and when calcined it affords a good red pigment. On analysis, it gave—

Peroxide of iron	74·52
Alumina	4·48
Carbonate of lime and magnesia	·40
Silica and silicates	6·20
Water, mostly combined, . .	14·40
	100·00

6. *Brown Hematite* occurs in large balls along the outcrop of the vein. It has been produced by the solvent action of acid water on the carbonate of iron, and the subsequent precipitation of iron from these solutions. It is a valuable ore, but is probably confined to the surface of the vein.

7. *Sulphate of Barytes* occurs in small crystals lining fissures, and in compact veins in the ankerite. Though quite insoluble, this substance can be decomposed by heated solutions of alkaline carbonates; and when these are cooled it is re-formed and deposited.* It has probably been introduced in this way into this vein.

I shall endeavour in the following remarks to state the manner in which these minerals occur in the complicated mixture which fills this vein, and their probable origin. Let the reader then imagine that he is standing on the side of the deep ravine of the Great Village river, looking into a rocky excavation in which the minerals above mentioned appear to be mixed together in the most inextricable confusion, in great irregular cracks of the slaty rocks, and he will be able, perhaps, to wade through the following description.

The ankerite should evidently be considered the veinstone, as it surrounds and includes all the other con-

* Bischoff, quoted by De la Beche. Geol. Obs. p. 669.

tents of the vein, and greatly exceeds them in quantity. Where not exposed, it is white and coarsely crystalline. On exposure it becomes yellowish; and near the surface, as well as on the sides of fissures, it is decomposed, leaving a residue of yellow ochrey hydrous peroxide of iron. In some parts of the vein, the ankerite is intimately mixed with crystals and veinlets of yellowish spathose iron. The red ochrey iron ore occurs in minor veins and irregular masses dispersed in the ankerite. Some of these veins are two yards in thickness; and the shapeless masses are often of much larger dimensions. Specular iron ore also occurs in small irregular veins, and in disseminated crystals and nests. At one part of the bank there appears to be a considerable mass of magnetic iron ore, mixed with specular ore; this mass was not, however, uncovered till after I had left the ground.

The whole aspect of the vein, as it appears in the excavations in the river-bank, is extremely irregular and complicated. This arises not only from the broken character of the walls, the included rocky fragments, and the confused intermixture of the materials of the vein; but also from the occurrence of numerous transverse fissures, which appear to have slightly shifted the vein, and whose surfaces usually display the appearance named "slickenside," and are often coated with comminuted slate or iron ore. In some places these are so numerous as to give an appearance of transverse stratification. One of them was observed to be filled with flesh-coloured sulphate of barytes, forming a little subordinate vein about an inch in thickness.

The general course of the vein, deduced from observations made by Mr Hayes and myself at the Acadia mine and further to the eastward, is S. 98° W. magnetic, the variation being 21° west. At the Acadia mine this course deviates about 33° from that of the containing rocks. In other localities, however, the deviation is much smaller; and in general there is an approach to parallelism between the course of the vein and that of the rock-formation of the hills, as well as that of the junction of the carboniferous and metamorphic systems. The vein, for a space of seven miles along the hills, is always found at distances of from 300 yards to one-third of a mile northward of the last carboniferous beds, and always in the same band of slate and quartzite.

Westward of the Acadia mine the course of the vein over the high ground is marked by the colour of the soil, as far as Cook's brook, about a mile distant. The outcrop of the ore is not exposed in this brook, but large fragments of specular ore have been found in its bed, and a shaft, sunk on the course of the vein, has penetrated more than forty feet through yellow ochre containing a few rounded masses and irregular layers of ankerite. At this point the decomposition of the ankerite and spathic iron has extended to a much greater depth than usual, and is so perfect that a specimen of the yellow ochre was found to contain only ·4 per cent. of the carbonates of lime and magnesia; the remainder being hydrous peroxide of iron, alumina, and silicious matter.

Still further west, in Martin brook, I have observed indications of the continuation of the vein. Beyond this place I have not traced it; but I have received specimens of specular iron ore and ankerite from the continuation of the same metamorphic district, as far west as the Five Islands, twenty miles distant from Acadia mine.

On the east side of the west branch of the Great Village river, the ground does not rise so rapidly as on the western bank, and the vein is not so well exposed. On this side, however, a small quantity of copper pyrites has been found in or near the vein, but it does not seem to be of any importance. Indications of the vein can be seen on the surface as far as the east branch of the river. In the east branch, red and gray conglomerates, dipping to the south, and forming the base of the carboniferous system, are seen to rest unconformably on olive, black, and brown slates, whose strike is S. 75° W. The continuation of the iron vein has not yet been observed in the bed of this stream.

Further eastward, on the high ground between the Great Village and Folly rivers, indications of the ores of iron have been observed; especially near the latter river, where in two places small excavations have exposed specular and red ores, and where numerous fragments of brown hematite are found scattered on the surface.

The ravine of the Folly river affords a good natural section of the quartzite and slate of the hills, as well as of the carboniferous beds of the lower ground. This section, as far as the base of the hills, is described in Chapter XI. The lowest carboniferous bed is a thick, coarse, gray and brownish conglomerate, dipping S. 20° W. It rests unconformably on a bed of slate very similar to that seen in a like position at the Great Village river, and which differs considerably in appearance from most of the slates of these hills. The strike of the slate is S. 70° W.; and that of the bedding and slaty structure appear to correspond. In a layer of greywacke included in this slate I observed small and well-rounded pebbles of light-coloured quartz. This slate is succeeded by thick beds of gray quartzite and hard olivaceous slates. These occupy the river-section for about 700 yards, or as far as the "Falls," where the river is thrown over a ridge of quartzite fifty-five feet in height; a small rill pouring in on the eastern side from a much greater elevation. Between the conglomerate and the waterfall the quartzite contains a few narrow strings of ankerite, and at the fall there is a group of reticulating veins, some of them six inches in thickness. They contain a little iron pyrites. These are the only indications of the iron vein observed in this section; and as the group of beds in which it should occur is well exposed, it is probable that it is represented here only by these small veinlets distributed over a great breadth of rock. Above the fall the quartzite and slate continue to alternate for a considerable distance, the dip being generally to the southward, in one place at as low an angle as 55°. About a quarter of a mile above the fall they are traversed by a dike or mass of fine-grained hornblendic igneous rock.

On the elevated ground east of the Folly river the vein is again largely developed, and two excavations expose a part of its thickness on the property of the Londonderry Mining Company. The excavation nearest to the river shows a thickness of 190 feet of rock on the south side of the vein. This consists of gray quartzite, olive slate, and about three feet of black slate. These beds are traversed by a few small strings of ankerite, which increase in dimensions on approaching the broken and irregular wall of the vein. About seventeen feet of the south side of the vein consist principally of ankerite. Adjoining this on the north is red iron ore, with nests of specular ore, veins and blocks of ankerite decomposed in part to yellow ochre, and fragments of rock. Ten feet in thickness of this red ore are seen without exposing the north wall of the vein.

On the surface in this vicinity are large fragments of brown hematite, which mark the course of the vein. In the eastern excavation, this mineral is seen in place near the surface and occupying fissures in a fragment of quartzite. In this second excavation the red ore is more largely mixed with the micaceous specular variety, and also includes large rounded blocks of ankerite and angular fragments of rock. The width exposed here is thirteen feet, and neither wall is seen. The ankerite is decomposed to the depth of eight feet. The same appearance of transverse vertical layers seen at the Acadia mine is observed here, and is probably due to the same cause.

Still further east, on the property of C. D. Archibald, Esq., and on ground equally elevated, three excavations have shown a still greater development of the vein. A trench fifty-three feet in length, and nearly at right angles to the course of the vein, shows in its whole length a mixture of red and specular ores with ankerite. Another excavation, ninety-five feet to the northward of the first, exhibits ankerite tinged of a deep red colour by peroxide of iron, and traversed by reticulating veins of red iron ore. A third opening, 365 feet southeastward of the first, shows white and gray ankerite, having some of its fissures coated with tabular crystals of white sulphate of barytes. The walls of the vein are not seen at this place; but 150 paces south of the first trench a thick dike of greenish igneous rock, apparently a very fine-grained greenstone, appears, with a course of S. 102° W. This dike is not seen westward of this place, but it can be traced for a considerable distance to the eastward. In the Mill brook, two miles east of Folly river, it appears in connexion with a bed of black slate near the margin of the metamorphic system, and probably a continuation of that seen in a similar position in the Folly and Great Village rivers. At the Mill brook the dike is about 100 feet in thickness.

In the bed of the Mill brook, the vein is seen in the form of a network of fissures chiefly filled with ankerite; and in its eastern bank it attains a great thickness. In the bank of another brook still further to the eastward and in the same line of bearing, it appears to be of large dimensions, and contains abundance of red iron ore and red ankerite. I have not traced it further to the east, but I have no doubt of its continuance to a great distance in that direction.

The geological history of this deposit embraces the following occurrences:—*1st*, The formation of a wide irregular fissure, along a great part of the length of the Cobequid mountains. *2dly*, The filling of this fissure with a molten mass of ferruginous and calcareous matter. *3dly*, The breaking up of the vein thus formed by cross-fractures and faults. *4thly*, The partial roasting of its contents by heat, so as to produce the red ores. *5thly*, The action of heated waters passing through its crevices, and depositing sulphate of barytes and brown hematite.

This deposit is evidently wedge-shaped, being largest and richest on the surface of the highest ridges. It contains, however, an immense quantity of valuable ores of iron, though its irregular character opposes many difficulties to the miner. Difficulties have also been found in smelting the ore to advantage; but these are often incident to the first trials of new deposits, to which the methods applicable to others, of which the workmen have had previous experience, do not apply. It is to be hoped, however, that these preliminary hindrances have been overcome, and that the mine will soon become highly profitable to its proprietors. I quote the following general estimate of the value of the deposit from the elaborate report of J. L. Hayes of Massachusetts.

"From the descriptions which I have above given, it is evident, that although the unlimited extent of the ore at any particular point can only be determined by working the deposits, yet an immense field is open for explorations and working.

"Although it is quite probable that an abundant supply of ore will be found upon the mountain last described at a price which will not exceed 2 dollars to the ton of iron; if this should not be the case, an ample supply can be furnished from the other localities at an expense which, including raising and hauling, could not exceed 4 dollars to the ton of iron. I would advise the opening of the veins at different points upon the line, to determine the cheapest point for mining, and the ores which can be used most advantageously. If this is done, the price of the ore cannot be fairly set down at the sum for which it can be obtained from the nearest locality, but at an average of the prices of the ores from different localities, delivered at the point selected for the furnace. This may be estimated at 3 dollars to the ton of iron.

"The value of this locality with respect to ore may be judged of by comparing it with establishments in the United States. In Berkshire county, Massachusetts, at some establishments which have been successfully conducted, the price of the ore is between 5 and 6 dollars to the ton of iron. In Orange county, New York, ore yielding between 40 and 50 per cent. costs between 4 and 5 dollars to the ton of iron. At one locality in New York the ore costs 10 dollars to the ton of iron. At some establishments on Lake Champlain, ore costing 1 dollar per ton at the mine, is carried twelve miles to the furnace. The ore at the Baltimore furnaces costs over 7 dollars to the ton of iron. This is about the average cost of the ore at the furnaces in Pennsylvania. Estimating the cost of the ore even at 4 dollars to the ton of iron, there will be advantage over the average American localities.

"The cost of ores at some of the Swedish and Russian furnaces is still greater. In certain parts of the Ural mountains the minerals are carried by land to the forests a distance of from 40 to 80 miles. Some of the forges of Sweden are supplied with minerals from Presburg and Dannemora, which are transported by land-carriage, the lakes, and the sea, to distances exceeding 370 miles.

"There is no trace of sulphur, arsenic, or any foreign matter which can deteriorate the quality of the iron, or of titanium or chrome, which would render the ores refractory. The red ochrey ore, the most abundant variety, being sufficiently porous to present large surfaces to the reducing gases in the blast furnace, and yet sufficiently compact not to choke the furnace, but to allow the free passage of the blast, can be used with peculiar advantage. The daily make of iron from these ores will be large, and the consumption of combustible comparatively small.

"I have no doubt that iron of the first quality for purity and strength, and which will demand the highest prices in the market, can be made from these ores. If Mr Mushet's opinion, based upon his own experiments, that these ores will furnish steel-iron equal to the best Swedish marks, should prove correct, these ores possess a rare value; for, of the many charcoal iron establishments in the United States, I know but one which furnishes iron suitable for making the first quality of steel."

Mineral paints and *artificial slate* of excellent quality are manufactured from the iron ochres of the Folly Mountain, and are extensively used for protecting wooden buildings, &c.

Veins of iron ores, similar in character to those above described, occur in nearly every part of this metamorphic district; they are, however, of small magnitude, and I am not aware that they are in any place of workable dimensions.

In addition to these *veins* of iron ore, conformable beds, as already mentioned, exist in the Devonian slates, and have been opened at Moose river, Nictau, and the East river of Pictou, at the localities indicated on the map. They consist of scales of specular iron, firmly cemented together, and intermixed with silicious and calcareous matter. At Moose river the bed does not appear to be very important, and has been in part converted by heat into magnetic iron ore. At Nictau the bed is stated to be six feet in thickness, and the ore is of excellent quality.* Mining operations have recently been recommenced at this place. At the East river of Pictou, the bed appears to be of great magnitude, but the ore is more silicious than at Nictau, and contains

* A specimen in my cabinet contains 55·3 per cent. of iron.

only about forty per cent. of metal. It is not at present worked. These beds of ore could no doubt be detected in many intermediate localities, and must eventually become of great economical importance. Though the ores are less rich than those of the Cobequid mountain, the deposits are likely to be more continuous and persistent.

The great bed of ore on the East river of Pictou is especially worthy of the attention of capitalists engaged or about to engage in smelting operations, as it is only ten miles distant from the Albion coal-mines, and is in the vicinity of abundance of limestone and building-stone. The hematite and clay ironstone of the same region, might also be profitably used with the specular ore of the great bed.

Copper ores occur in several parts of this district. In the country eastward of the Lochaber lake, in the county of Sydney, large fragments of copper and iron pyrites are found in the surface gravel, and have no doubt been derived from a vein containing this ore, along with ores of iron similar to those of the Cobequid hills, and which are found attached to the loose fragments. These indications were examined by the author in 1848, and made known to the Mining Association. A Cornish miner was afterwards employed by the association to explore the locality, but his labours were unsuccessful; and as yet nothing has been found except the loose masses already referred to, some of which are from two to three feet in diameter. The strike of the rocks at this place is S. 70° W. to S. 20° W., and the district in which the ores occur, consists of olive, gray, and black slates, with beds of quartzite and dikes of greenstone and compact felspar. In some places the slates are filled with small veinlets of specular iron ore and ankerite. The pyrites contains from four to seventeen per cent. of copper, the average of several specimens being 10·8 per cent. This would be a valuable ore if found in sufficient quantity and of easy access; there appear, however, to be serious difficulties in the way of opening the deposit, more especially its low situation and the depth of the surface cover.

Copper pyrites, yielding 31·6 per cent. of copper, and therefore of very rich quality, has been found on the south branch of Salmon river; but I am not aware that it occurs in sufficient quantity for mining purposes. This ore has also been found in small quantity near the Acadia iron-mine, and in the barytes veins at the Five Islands.

Sulphate of Barytes.—This mineral occurs in considerable quantity, in numerous irregular veins traversing the slates in the banks of the East river of the Five Islands. I have little doubt that these veins are strictly a continuation of the great iron veins already described; but here barytes predominates, and only a small quantity of specular iron is present and a very little copper pyrites. The barytes at this place is pure white, and often in very beautiful crystalline masses. Its cavities are coated with fine crystals of carbonate of lime of the variety known as dog-tooth spar. Large quantities of barytes have been extracted at this place, by levels and open excavations in the steep sides of the ravine, and have been exported to the United States; but I believe the demand has not been found sufficient to warrant a continuance of the works on a large scale. The presence of copper ores at this place, associated with such a veinstone as sulphate of barytes, affords some promise that if the excavations were continued, valuable quantities of such ores would be discovered.

Graphite or *Plumbago* has been found in veins, and also apparently in a small conformable bed, probably a coal metamorphosed by heat, associated with the limestone, at St John, New Brunswick. An opening has been made near the Falls, and I have seen specimens of very good quality that had been extracted from it; but when I last visited the place the operations had been abandoned.

Oxide of Manganese has, as I am informed, been found in the eastern part of the metamorphic region of Southern New Brunswick, in and near Chepody mountain, and at other places.

Limestone exists in large quantity in the neighbourhood of St John, and is largely quarried and burned. Some of its varieties afford a good gray marble. *White* marble is also found in the metamorphic slates at Five Islands, as well as a coloured marble of a purplish hue, with green spots tinged by serpentine. These beds at Five Islands have not been sufficiently opened fairly to test their quality. The white marble affords small specimens of great purity and of very fine grain. The coloured variety has been objected to on the ground of unequal hardness.

Slate, apparently of good quality, is found in New Canaan, in Rawdon, in the ridge south of the Stewiacke river, and on the Middle river of Pictou. It is not at present quarried in any of these places.

Syenite and *Porphyry*, suitable for building and ornamental purposes, occur in various parts of the Cobequid mountains, and on the east side of the Bras d'Or, and other places in Cape Breton. Owing to their inland position, and the want of any internal demand, these rocks are not at present quarried.

Smoky Quartz, in large and beautiful crystals, is found in the surface debris at Paradise in Annapolis county; and its native matrix is a reddish compact felspar, which occurs in veins in the granite of that district.

It may be anticipated that these igneous and metamorphic hills, so varied in their composition and at present so little open to detailed investigation, will be found to contain many useful minerals in addition to those above mentioned; and that as population and enterprise increase, they will become important mining and manufacturing districts.

The soils of this district are in general good. They produce in their natural state a fine growth of hardwood timber, sufficient for a long time to supply the demands of the shipyards and iron furnaces, and when cultivated they are remarkably favourable to the growth of hay and grain crops. They are well supplied with lime and phosphates; and when deep are less easily exhausted than most other kinds of upland. Hence in the more fertile parts of these hills, as in Southern Horton, Earlton, New Annan, the Pictou hills, Lochaber, and Northern Cape Breton, there are fine and flourishing agricultural settlements, which, in spite of a climate a little more rigorous, are advancing more rapidly in wealth than most of the lower districts.

CHAPTER XV.

METAMORPHIC DISTRICT OF THE ATLANTIC COAST.

GENERAL DESCRIPTION—LOCAL PECULIARITIES AND DISTRIBUTION—GEOLOGICAL AGE AND TIME WHEN METAMORPHOSED—WASTE AND DERIVATION OF NEWER ROCKS—USEFUL MINERALS—CONCLUDING REMARKS.

ALL that part of Nova Scotia lying to the southward of the districts last described, consists of altered rocks, such as slates, quartz-rock, and gneiss, associated with dikes and masses of granite, which here takes the place of the syenite, greenstone, and porphyry that prevail in the inland hilly districts that we have just left. Hence this metamorphic district of the Atlantic coast may be named, for the sake of distinction, the *Granitic* Metamorphic District. Similar rocks occur in New Brunswick, as shown on the map; in that province, however, I have had no opportunity of examining them.

Hitherto each successive formation has been proved to be older than that which preceded it, by the evidence of direct contact, in such a way that the older could be seen to underlie the newer. Here we lose this chain of evidence. I have found no section in which the Devonian or Upper Silurian rocks, described in last chapter,

GRANITE HILL & LAKE NEAR S^{T} MARY'S RIVER. 1845.

Atlantic Coast Metamorphic District.

could be seen to rest on those now to be described. Yet I believe the group of rocks now under consideration to be the older of the two, for the following reasons.

On the St Mary's river, fragments of slate and quartz-rock from this formation, are found in the lower carboniferous conglomerate, proving that these rocks were metamorphosed before the commencement of the carboniferous period. They must therefore belong at least to the devonian group. They differ, however, so materially from the rocks of that age, that they cannot be assigned to it with any probability. We must therefore go back at least to the Silurian period for the time of their deposition; and possibly they may belong to that still older or Azoic series which has been recognised in Canada. Farther, while there is evidence that much of the igneous rock of the devonian hills was erupted during the carboniferous period, there is no evidence whatever that any igneous action occurred within the granitic group as late as the commencement of that period; consequently the igneous as well as the stratified rocks of the present group are older than those of that last described.

Large though this district is, there is by no means so great a variety in its rocks as in those of the district last described; and most of them are nearly related to each other, being composed of the same materials variously arranged.

1. *Granite*, as it occurs in this district, is a crystalline mixture of white, or more rarely flesh-coloured, felspar,* with smoky or white quartz and gray or black mica. It varies in its texture, and is sometimes por-

* Orthoclase, but with soda as well as potash. The granite of Annapolis, mentioned in last chapter, has in some places reddish quartz.

phyritic; that is, it consists of a base of fine-grained granite, with large crystals of felspar forming distinct spots. It often contains altered fragments of the neighbouring slates, and penetrates in veins into the adjoining rocks, which in its vicinity are always more highly metamorphosed than usual.

2. *Gneiss* is a fine-grained granite, arranged in laminæ or layers, as if it had been a bedded rock fused into a granitic state by heat.

3. *Mica-slate* consists of quartz and plates of mica, forming a highly fissile rock with shining surfaces, and usually of a gray or silvery colour. In the coast-metamorphic district of Nova Scotia, it appears in many and beautiful varieties. When chlorite, talc, or hornblende take the place of mica, rocks of somewhat similar character, named Talcose, Chloritic, or Hornblendic slates result. These are, however, comparatively rare in this district.

4. *Quartz-rock*, or *Quartzite*, consists of grains of flinty sand fused together, and with occasionally a little mica. It is probably altered sandstone.

5. *Clay Slate* is common slate, usually in this district of bluish and black colours, and varying very much in texture and hardness.*

Between these rocks there are many intermediate forms. Granite often passes by imperceptible gradations into gneiss—this into mica slate—this into quartzite—and this into coarse or flinty clay slates. There appears every reason to believe that all these rocks, except the granite, are merely variously metamorphosed forms of common sandstones and clays.

The granitic metamorphic group forms a continuous

* See page 310, where, however, I omitted to mention *pressure* as one cause of slaty structure.

belt along the Atlantic coast of the province, narrow at its north-eastern extremity, and attaining its greatest development in the western counties. Its southern or coast side has a general direction of S. 68° W.; its inland side, though presenting some broad undulations, has a general direction of about S. 80° W. Its extreme breadth at Cape Canseau, its north-eastern extremity, where it is bounded on one side by the ocean, and on the other by Chedabucto bay, is only about eight miles. In its extension westward, it gradually increases in width, until at the head of the west branch of the St Mary's river, eighty miles distant from Cape Canseau, it is about thirty miles in breadth. In the western counties it again increases in width, and though its northern boundary is not well ascertained, its breadth can scarcely be less than fifty miles. Its total length is 250 miles.

The general character of the geology of this district may be very shortly stated. It consists of thick bands of slate and quartzite, having a general N.E. and S.W. strike, and highly inclined. In several places large masses of granite project through these rocks, and in their vicinity the quartz rock and clay slate are usually replaced by gneiss and mica-slate, or other rocks more highly metamorphosed than usual. Bearing in mind this general character, we may proceed along this district from west to east, noting the more interesting points of its structure as they occur.

The county of *Yarmouth* presents a succession of low ridges of slate and quartz-rock, separated on the coast by narrow inlets, and inland by valleys, often containing lakes and bogs. The prevailing strike appears to approach more nearly to north and south than in other parts of this district. Near the town of Yarmouth it was observed to be N. 20° E., and at Pubnico nearly N. and S. Near the town of Yarmouth there are hornblende and chlorite slates, and inland, in the direction of Carleton, clay-slates appear to prevail. Veins of white quartz abound in these rocks. On the east side of the Tusket river quartz rock prevails, and forms a stony country. Toward Pubnico, mica slate and micaceous quartz rock appear, and are traversed by granitic veins, leading us to the massive granite of Shelburne county. Granite is also said to occur inland at Kempt; but I have not visited this place.

On entering *Shelburne*, we find granite at Wood's and Shag harbours, and extending inland for some distance. At Barrington there is still abundance of granite and mica slate, with strike N. 23° E. At Port La Tour, the mica slate and gneiss abound in large prismatic crystals of a greenish magnesian mineral, allied to steatite. These crystals, which are perhaps pseudomorphous, project from the weathered surface of the rock. At the town of Shelburne there is abundance of a fine-grained granite of excellent quality, and toward the mouth of the harbour gneiss occurs, with small crystals of garnet; its strike is S.W. Veins of coarse-grained granite penetrate these rocks, and in some places, these veins present the singular variety to which the name *graphic granite* has been applied, from its resemblance to written characters. In this variety of granite, quartz and felspar alone are present, and the quartz in hardening has arranged itself in plates between the felspar crystals, so that when the mass is polished, the sections of these quartzose plates present the appearance of ancient Samaritan on modern phonographic writing. In the graphic granite of Shelburne, the characters are in gray quartz, and the ground is white or flesh-coloured felspar. In surface-gravel, near the town of Shelburne, I found pebbles of the beautiful mineral rose-quartz, but did not observe it in place.

At Jordan and Sable rivers, in the eastern part of this county, gneiss and mica-slate appear in many fine varieties, and contain abundance of crystals of *Staurotide;* and Schiller spar and talc sometimes enter into the composition of these rocks as well as mica.

On entering *Queen's* county we find granite at Port Joli and Port Mouton, and toward the town of Liverpool these give place to quartz-rock, which, with some beds of micaceous slate, here occupies a great breadth, and produces a very stony and barren country, encumbered with large boulders. This rocky surface, at the distance of about ten miles from the coast, gives place to a fine undulating wooded country, supporting populous agricultural districts, and traversed by the Liverpool and Port Medway, two of the largest rivers in the province, with numerous and large lakes at their sources. The source of the Liverpool river is in the high lands near Annapolis, not more than ten miles from the shores of Annapolis Basin; and the distance in a direct line from its source to its outlet is more than fifty miles. Lake Rosignol, one of the many fine lakes that stud its course, is twelve miles in length and five in its greatest breadth.

The prevailing rock in this *northern district* of Queen's county is clay-slate, having a general south-west strike, and almost everywhere polished and marked with diluvial striæ. This inland slate-district appears to be continuous with that of Lunenburgh on the east, and that of Yarmouth on the west; so that in this part of the province, the granitic rocks appear to be confined to the vicinity of the Atlantic coast, and to the inland hills near the Annapolis valley, while a fine undulating slate country, diversified with numerous lakes, occupies the interior. In such a situation, more modern rocks than those of the Atlantic coast may be expected to occur. I searched in vain, however, for fossils in the northern district of Queen's, but obtained from a gentleman resident there a fragment of hard quartzose rock, which he believed to have been found *in situ*, and which contains some fragments of fossil-shells, apparently of a species of ribbed spirifer, common in the Devonian districts.

On the eastern side of Queen's county, the quartzite and mica-slate are associated with granite, and beyond this they give place to clay-slate, which occupies the county of *Lunenburgh* as far as Cape Aspatogoen, and inland as far as I have any acquaintance with its structure. The country here has much of the aspect as well as the agricultural value of that of Northern Queen's, and presents in these respects a favourable contrast to most other parts of the Atlantic coast. The slates of this county are usually blue or black, and often charged with iron-pyrites, which, when weathered, gives them an intense rusty yellow colour. This appearance is especially prevalent in some places in the western part of the county. The general strike is S.W. and N.E.

It is on the margin of this slate-district of Lunenburgh, and at the bottom of a deep bay penetrating into it, that the limited tract of lower carboniferous rocks, already noticed as occurring at Chester Basin, appears. These carboniferous beds dip at a moderate angle S.S.E., and give no evidence that this metamorphic district has suffered any considerable disturbance since their deposition. At Mahone bay, however, I observed a large quantity of fragments of reddish amygdaloidal trap, which cannot be far from their original site, and probably belong to some trappean eruption of the carboniferous period.

Aspatogoen, which is a rocky promontory, about 500 feet in height, separating Mahone from Margaret's bay, consists of granite, and is the extremity of a thick dike or ridge of that rock, extending to the northward across the stratification of the country. It is the highest land on the Atlantic coast of Nova Scotia.

Margaret's bay is another deep indentation, between the granitic mass of Aspatogoen and a broader but lower tract of the same rock, extending to the north-west arm of *Halifax* harbour. Around Margaret's bay, as at Chester, there are small patches of lower carboniferous rocks; but these are for the most part concealed under granitic debris drifted from the neighbouring districts.

The granitic district east of Margaret's bay, and terminating at Cape Sambro, like that of Aspatogoen, has a north and south direction. It contains several varieties of common and porphyritic granite, with veins of coarse grained, and more rarely of graphic granite. Near the north-west arm, there are good opportunities of observing its junction with the slates which succeed it to the eastward. The slate is not here converted into mica-slate; but, in the vicinity of the granite, it is hardened and rendered crystalline, and in some places passes into a rock resembling hornblende-slate. In other places it appears as a hard flinty slate, filled with slender prismatic crystals apparently of staurotide. In close contact with the granite, the slates assume the appearance of gneiss, and are traversed by granite veins, which often contain crystals of schorl and garnet, indicating that these veins received additions of foreign substances, as boracic acid, iron, &c., in passing through the stratified rocks. The granite itself is here porphyritic, and occasionally contains fragments of the rocks through which it has passed, fused into gneiss and mica-slate. All these appearances indicate that the intensely heated and molten granite was the cause of the alteration of the slates.

Eastward of Halifax, the whole country as far as Musquodoboit river, and northward to the northern limits of this district, consists principally of alternate thick beds of coarse clay-slate, often highly pyritous, and quartzite; granitic bosses projecting through it in a few places. The strike of the beds in this part of the province approaches more nearly to E. and W. than at the places previously described. At many localities, however, it retains its usual S.W. and N.E. direction. Thus, at the tower at Point Pleasant, the strike of the bedding is N. 30° E., and that of the slaty structure N. 75° E. On the shore near the same place, the strike is N. 60° E., and the dip is to the north-west. Nearer the city, the dip of the true bedding is in some places to the south, the strike being nearly E. and W. The cleavage is, however, here much better defined than the bedding, which is indicated principally by lines of different colour, and appears to undulate very much. On the road from Halifax to Windsor, at Dartmouth, and at Musquodoboit river and harbour, the strike both of the bedding and slaty cleavage approach to E. and W. magnetic.

On the Musquodoboit river, granite reappears, and extends to the eastward, at least as far as the Great Ship

Harbour lake. Beyond this place, as far as the extreme eastern end of the district, quartzite and mica-slate, with masses and bands of granite and gneiss, prevail; but I have scarcely any knowledge of their distribution, except in the vicinity of the St Mary's river, and in the peninsula of Cape Canseau.

The valley of the lower St Mary's river is a rugged and rocky gorge, excavated at right angles to the structure of the country, and affording an outlet for the waters of several streams that, seeking a passage across the hilly barrier of the metamorphic district, form a small lake at the entrance of this common channel. At the mouth of the river, a considerable breadth is occupied by micaceous slates, with bands of quartzite. The strike of these rocks is N.E. and S.W., and in the places where I observed their dip, it is to the S.E. at high angles. Behind the village of Sherbrooke, and two miles eastward of the river, a mass of granite projects through these rocks, but does not occur in the river section. This granite is well seen in the lakes emptying into Indian harbour. On the river itself, the slates and quartz rock continue with considerable regularity of strike; the latter becoming quite predominant, and rising into considerable eminences as it approaches the "Forks," where it suddenly descends into the carboniferous valley of the St Mary's.

Eastward of the St Mary's river, this district gradually narrows toward its extremity at Cape Canseau, but still presents on its northern margin a range of abrupt eminences, and on the south a low, rugged, and indented coast. Indeed, the steep rounded swell with which its northern side descends at the head of Chedabucto bay, and the precipitous headlands beyond Crow harbour, are the finest appearances in point of scenery which it presents in its whole extent.

A large part of the peninsula, terminating at Cape Canseau, is occupied by white fine-grained gneiss, with veins and masses of granite, sometimes of a reddish colour. There is also much mica-slate, and dark coloured clay-slate, filled with crystals of the singular mineral chiastolite or cross-stone. Near the extremity of Cape Canseau, specimens of this mineral occur, of a reddish or fawn colour, three or four lines wide, and exhibiting the characteristic black cross in considerable perfection. I have not found this mineral in any other part of Nova Scotia.

Having thus shortly surveyed this large though little explored district, I may notice its probable geological age, the waste it has undergone, and the materials it has contributed to newer formations, its useful minerals, and the peculiarities of its surface and soils.

The geological age of the formation above described is, in one direction at least, somewhat uncertain. We have already seen that it must be older than the carboniferous system, and I have stated in the commencement of this chapter some reasons for believing it to be also older than the Devonian rocks which immediately underlie that system. One of these reasons was the difference in mineral character of its beds from those of the inland metamorphic hills. This difference we can now better appreciate, after having studied both in detail. Quartz rock we have found to occur in both formations; but it exists in much greater abundance, and in more massive beds, in that last described. Clay-slate also occurs in both; but in the first described it presents much greater variety of colour and texture, it is associated with many coarse beds, which have been usually named greywacké, and greywacké-slates, and in many places it approaches to the character of a steatitic slate. These inland slates are also highly metalliferous, abounding in veins of iron ore, and containing at least one great conformable bed of that mineral, while copper ores also appear in a variety of places. They also contain numerous calcareous bands and layers of limestone. In all these respects the slates of the Atlantic metamorphic district are strikingly different. They are thick-bedded and uniform in their appearance, destitute of calcareous matter and metallic minerals, and pass into micaceous slate, which is rarely seen in the other district. These and other differences of detail must prevent any observer acquainted with both districts from supposing their rocks to be geologically equivalent.

The rocks of the district at present under consideration are thus not so recent as the Devonian period; but they may belong to any of the older groups, or to more than one of these. No fossils have been found in them, and we therefore want the surest means, next to actual superposition, of comparing them with the Silurian and other ancient rocks of other parts of America. If we take mineral character as our guide, it is at once apparent that no analogy can be established between these rocks and the thick limestones which characterize the Upper Silurian, and the middle portion of the Lower Silurian, in the United States and Canada. If, however, we suppose the limestone to be wanting in Nova Scotia, the quartz rock and slate of the Atlantic metamorphic district would very well represent the Potsdam sandstone, and Utica and Hudson river shales, in an altered condition; and this I am at present inclined to believe the most probable view of their age. On the other hand, there can be no doubt that the gneiss, mica-slate, and other more highly metamorphosed rocks of this district, are not very dissimilar in mineral character from the *Laurentian* group of Canada, which Mr Logan has ascertained to underlie unconformably the lowest Silurian rocks. This similarity, however, being mainly a result of metamorphism, is of no great value in determining the relative ages of beds situated in different regions.

The metamorphism of these rocks must have occurred prior to the carboniferous period, and there can be no doubt that the granitic rocks have been the agents in effecting it, if they are not themselves portions of the stratified beds completely molten and forced by pressure against and into the fissures of the neighbouring unmelted rocks. It will be observed that many of these granitic masses have a north and south direction, whereas the general strike of the beds is N. E. and S. W. This would indicate either that the lines of greatest igneous intensity and intrusion of molten matter, had no direct connexion with the elevating and disturbing forces, or that these granitic masses are merely outliers from a great N. E. and S. W. granitic axis, at one time the summit of a line of hills of which only the margin remains visible, the axis itself having sunk again into the bowels of the earth, before the commencement of the carboniferous period.

M. Marcou, reasoning on the general direction of the strike of this district, supposes it to be of the date of the Alleghany chain, that is, the close of the carboniferous period. The facts already stated show that the elevation and metamorphism of these rocks must be much older. Taking geographical direction as a guide, they may perhaps belong to his second system of dislocations, which he refers to the Lower Silurian period.

Whatever view may be taken of the age of the granitic rocks of this group, it is certain that they are strictly *hypogene* rocks, that is, that they belong to the deep-seated foci of subterranean heat, and are not superficial products of volcanic action. They are substances such as we might expect to find, could we penetrate miles below the surface, beneath modern volcanoes. They were therefore probably at one time buried deeply, and have been brought up by movements of dislocation, and by the removal of their superficial portions by aqueous agents. They have without doubt furnished much of the material that has been employed in building up the more recent formations of the country.

This leads to the question, Can we discover in the subsequent rock-formations evidences of such an origin, and can the changes which these derived materials have undergone be satisfactorily explained? This subject, the genealogy of rocks as it may be termed, is of some interest, and I may glance at it in its bearing on the geology of Nova Scotia.

The granite of Nova Scotia and its associated gneiss and mica-slates are among the oldest rocks found in the province, and we may therefore take them and their derived rocks for illustrations. The products of the decomposition of granite are quartz sand, scales of mica, and fine clay which results from the decomposition of felspar. Such materials, when washed down and deposited in water, will form coarse and fine sandstones, micaceous sandstones and flags, arenaceous and argillaceous shales; and these may, by heat and pressure, be converted into quartzite, mica-slate, and clay-slate. From pure white granite the derived detritus would be colourless or nearly so. But the mica and felspar of many granites contain iron, and the sulphuret of iron is also present in some granites. In these cases the derived sediment will have a yellow or buff colour, from the presence of the yellow oxide of iron; or in some cases the clay may have a red colour from the peroxide of iron present in red felspar. Of course, when the granites contain hornblende or are syenitic, much more iron may be present in the derived sediment. In nature nearly all soils of granitic origin are more or less coloured in these ways. In this manner, buff, brown, and red clays, and buff and brown sandstones may be produced.

Igneous action may produce still farther changes. The yellow sand which results from the decay of granite is merely stained on the surface by the ferruginous colouring matter, and a very slight degree of heat is sufficient, by expelling the water of the iron rust, to convert this yellow stain into a bright red. This change is superficially produced by forest fires, and might readily occur when decomposing granitic rocks have been subjected to the influence of intensely heated or molten masses, with access of air or water. Red sands and clays produced in this way, and washed into the sea, become red sandstones and shales. Such red deposits are, however, liable to still farther change. If long washed about in the sea, the red coat is worn from the sands and added to the fine clays, so that whitish sandstones may alternate with red shales. If vegetable or animal matter is present, the changes of colour referred to in treating of the marsh mud may take place, and dark coloured or gray beds may result, or greenish stripes and bands may appear in the mass of red deposits.

Farther, if beds coloured by the peroxide of iron are subjected to the influence of internal heat at considerable depths below the surface, part of the oxygen of the colouring matter may be expelled, and black, blue, or dark green rocks result; while cleavage and other changes may result from pressure and percolation of mineral waters.

It will thus be perceived that from granitic rocks alone it is possible to deduce a variety of red, yellow, brown, white, and gray sandstones, shales, quartz rocks and slates. Many other rocks, however, beside granite have been decomposed, especially to form the more modern deposits, and other colouring matters beside iron have occasionally been present; hence more complicated results than those above stated have been produced. Enough has been said, however, to show how much derived deposits may differ in appearance from those which have furnished their materials; and also the mode in which the waste of the oldest rocks has been disposed of; as well as to illustrate the connexion of red deposits with periods in which igneous causes have been active, and the prevalence of gray and dark-coloured sediment at times when deposition has been slow or organic matter abundant. Other facts and reasonings on this subject will be found in the author's paper on the Colouring Matter of Red Sandstones.

The useful minerals found in the coast metamorphic district are few. *Granite* of excellent quality for building is quarried at the north-west arm near Halifax and at Shelburne, and exists in abundance at Musquodoboit river and toward Cape Canseau. Gneiss, mica-slate, and the more compact varieties of clay-slate, also afford good building materials, and roofing slates could probably be procured. In New Brunswick good granite is obtained from the band which terminates above Long Reach on the St John river.

I am not aware that any metallic mineral, except iron pyrites, has been found in these rocks; though reports of valuable discoveries have at various times been circulated.

Since the gold discoveries in California and Australia, reports of similar discoveries have locally arisen at different times in Nova Scotia; but, so far as I am aware, have always proved deceptive. Iron pyrites, or the bright golden scales which occur among the debris of granite containing black ferruginous mica, have usually been mistaken for the precious metal. Quartz veins, however, occur abundantly in some parts of this district, and it would not be wonderful if some of them should be found to be auriferous. It is, however, much more probable that such discoveries may be made in the inland matamorphic district described in last chapter, than in that now under consideration, as its rocks bear a much closer resemblance to those of the auriferous districts in other parts of America. Most parts of Nova Scotia have been too well explored to leave much probability that any extensive surface deposits of the precious metal exist; but that it does not occur in small quantities cannot with safety be asserted, until careful trials of the sands and gravels of the streams flowing from the metamorphic districts shall have been made. The gold deposits of the River Chaudiere in Lower Canada, afford an instance in which, while individual search has proved quite unprofitable, washing operations on a large scale with the aid of machinery have repaid the labour and capital employed. Unless some accidental discovery should indicate a promising locality, it would be unwise for individuals to engage in such trials; but if a public survey should be undertaken, they would form a part of its duties.

A few years since an article appeared in Blackwood's Magazine on the subject of gold discoveries, in which it was boldly affirmed, that gold would be found in the hills south of the Annapolis valley, and comparisons, having very little foundation in the facts of the case, were instituted between this valley and that of the Sacramento. In the colony this article was incorrectly ascribed to an eminent geologist who had visited the province, much excitement arose on the subject, rumours of actual discoveries of gold appeared in the local papers, persons were induced to abandon their employments to engage in the search, and there seemed every probability that a rush of gold-hunters would take place to the land of promise. The first adventurers, however, having been disappointed, and some pains having been taken to expose in the public prints the errors of the article in question as to matters of fact, the excitement subsided with little loss to the community. The circumstance, however, shows how much injury to the reputation of science and to the welfare of individuals, may result from injudicious predictions of this sort.

Clay suitable for bricks and coarse pottery is found at Chezzetcook and other places on the Atlantic coast, and manufactured to some extent. As the felspar of granite affords by its decomposition fine porcelain clays, it is quite possible that deposits of this kind might be found in some of the numerous hollows in the coast metamorphic district.

Iron Ochres of yellow and reddish colours, and also *Bog Ores* of iron and manganese, are found in the low grounds of this district in many places; but I am not aware that any of these deposits are large or valuable. Little attention has as yet been bestowed on these and other minor economical products of this district, and it is therefore possible that their value may be greater than is now supposed.

With respect to surface and industrial capabilities, the different rocks occurring in this district present very various aspects. The clay slate often has a regular undulating surface, and a considerable depth of shingly or clay soil of fair quality, though usually deficient in lime. These slate districts, however, often contain beds of quartz-rock which form rocky ridges, from which boulders have been scattered abroad, and which, by damming up the surface waters, produce lakes and bogs, an effect also often produced by the ridged structure of the slate itself, and the impervious subsoil which it affords. Wherever, as for instance in Northern Queen's and Lunenburgh, the slate is sufficiently elevated for drainage, and not encumbered with surface stones, it supports fine forests and valuable farms. Where quartz-rock prevails, the soil is almost invariably extremely stony and barren. Instances of this occur in Southern Queen's, near Halifax, and in the hills near the St Mary's river. The mica-slate is little better, for though it does not furnish fragments to cumber the surface, it scarcely affords any soil.

The granite and gneiss in some places appear in precipitous hills of considerable elevation, and in others form low and uneven tracts. Their decomposed surface affords a sandy quartzose soil, often strewn with large rounded blocks of granite, which in some instances cover the whole surface, so that a granitic hill appears to be merely a huge mound of boulders. This appearance results in most cases from the nodular character of the granite, or from its consisting of great balls of hard resisting rock, united by a material of more perishable character. Where the granite or gneiss is wholly of a resisting character, their surface is sometimes almost entirely bare, or coated only with a layer of peaty vegetable soil. This occurs to a great extent in the peninsula of Cape Canseau. The granitic soils in their natural state often support fine groves of oak and other deciduous trees; but the bare summits, destitute of soil, are clothed only with stunted spruces and various shrubs and mosses. Where the original vegetation has been destroyed by fire, the granite hills often become perfect gardens of flowering and fruit-bearing shrubs. I have collected in a day in August, on a single granitic eminence, sixteen species of edible wild fruits. The alkaline matter afforded by the waste of the granite is especially favourable to the growth of these plants, as well as of ferns; fields of which (chiefly the common brake, *Pteris Aquilina*) may be seen in the valleys among the granitic hills to attain the height of four feet.

As a fitting sequel to my account of the present state of our knowledge of Acadian geology, I may shortly mention, in conclusion, the most promising directions of future inquiry, and the extent of the work that remains to be done.

The carboniferous system has for some time been the most productive field of investigation, and its structure in those localities where the best sections occur is well known. Its geographical limits, however, and its structure in the more inland and less exposed localities, require much farther study; and the extent and value of the coal-seams, ironstone, manganese ores, limestone, gypsum, freestone, &c., are yet imperfectly known, and well merit public as well as private efforts for their exploration. The fossil remains of this system still afford a large field for discovery. The great interest of the discoveries already made, shows that Nova Scotia is equal to any country in the world in the opportunities which it offers in this department; and in a country where so many curious relics of the ancient world are constantly being exposed and washed away in the coast cliffs, even persons themselves unacquainted with geology may advance the interests of science by preserving such specimens, and making them known to those who can decide on their scientific value.

The metamorphic districts present a large and almost unexplored field. The valuable metallic deposits already found in them encourage the expectation that farther useful discoveries may be made. The unravelling of the relations of these disturbed and altered beds would require long labour and much thought from the most practised and acute observers. The fossils which occur in the less altered portions of their margins are very numerous, and well deserve the attention of palæontologists, as belonging to an outlying portion of the great Devonian and Upper Silurian area of North America, far removed from the districts in which the fossils of that period are best known. This ground may in part be occupied by private observers and mining surveyors, but I have no hope that it will be fully worked out without the aid of a public survey.

The trap and new red sandstone of the Bay of Fundy are a vast storehouse of curious and beautiful minerals, of great interest to students in mineralogy. These rocks also furnish excellent opportunities for studying the phenomena of volcanic action as it existed in the secondary period. The solitary reptilian jaw found in Prince Edward Island holds forth the hope that, in the many miles of coast cliff of the new red in that island and in Nova Scotia, other discoveries of similar character may await zealous collectors.

In the surface gravels and drift, and in fissures of rocks laid open by excavations, fossil remains, whether of large mammals like the mastodon, or of shells or land plants, should be carefully sought for. The deposition of marine mud in the Bay of Fundy has afforded many interesting illustrations of geological facts, and may afford more; and the agency of coast-ice in removing masses of rock, and otherwise acting on the shores and cliffs, is a subject at present of much interest, and one of which the shores of the Acadian provinces present many illustrations.

The above are probably only a few of the directions in which inquiry may be profitably prosecuted; but they may serve to indicate the extent of the field which remains to be explored. The discoveries already made show that it has pleased the Great Architect to place in the Acadian provinces many remarkable monuments of His creative work, and to enrich them with no small portion of the "precious things of the earth and of the lasting hills."—And here, as in other lands, those who in an earnest and truth-loving spirit, and in due subordination to their social duties and the higher ends of their spiritual being, engage in the study of these wonders of the ancient world, will not be unrewarded.

APPENDIX.

(A) LIST OF ACADIAN FOSSILS.

In preparing this list I have referred principally to the following sources: 1st, Lists of fossils published by Sir Charles Lyell in his Travels and papers on the coal-formation of Nova Scotia, and determined for him by De Verneuil and Bunbury; 2d, A list of eighty-seven species of plants from the coal-field of Sydney, communicated by Mr Brown for insertion in this work. The plants marked Sydney are from this list, and those with an asterisk prefixed are new species discovered by Mr Brown and described by Mr Bunbury; 3d, Notes on some Devonian fossils from Nova Scotia, furnished by Professor Hall of Albany; 4th, Specimens in the collection of the author, in so far as he has been able to determine the genera to which they belong. The list is necessarily very imperfect; and materials exist for largely increasing it, could the attention of palæontologists be directed to the subject.

NEW RED SANDSTONE.

Reptile.

Bathygnathus Borealis (Leidy). A large carnivorous Saurian, allied to Thecodontosaurus. New London, Prince Edward Island, 1852.

Articulata.

Trails of marine worms, Red Sandstone, Folly.

Plants.

Coniferous wood, Araucarian type. Orwell Point and Des Sables, P. E. I.

Calamites ? Orwell Point, P. E. I.

CARBONIFEROUS SYSTEM.

(a) *Coal-formation.*

Reptiles.

Dendrerpeton Acadianum (Owen and Wyman). Allied to perennibranchiate batrachians, as Menopoma, &c.; discovered at South Joggins by Sir C. Lyell and Mr Dawson, 1852.

Vertebræ apparently of a smaller reptile; at same time and place.

Baphetes Planiceps (Owen). A large batrachian allied to Labyrinthodon; discovered at Albion Mines by Mr Dawson, 1851; described in 1854.

Tracks of Reptilian animals, discovered at Tatamagouche by Mr Dawson, 1843; at Parrsboro' by Dr Harding, 1850; at S. Joggins by Mr Dawson, 1853.

Fishes.

Palæoniscus, Holoptychius, Megalicthys—species referable to these and several other genera not yet determined. Joggins, Pictou, Sydney, &c.

Articulata.

Cypris or Cytherina—several species. Joggins, Pictou, Onslow, &c.

Spirorbis—attached to fossil plants. Joggins, &c.

Mollusca.

Land shell, allied to Pupa. South Joggins, in the interior of a fossil-tree, with remains of Dendrerpeton, discovered by Sir C. Lyell and Mr Dawson, 1852.

Modiola, two or more species. Joggins, &c.
Unio ? two or more species. Joggins, Pictou.

Plants.

Pinites, allied to or identical with P. Brandlingii (*Witham*) and other species, all when sufficiently well preserved showing the Araucarian structure. Albert Co., N. B., Joggins, Wallace, Pictou, &c. In this genus, I would also include slender scaly branches, similar to those of Lepidodendron, but not dichotomous, found in the upper coal-formation at Tatamagouche and Cape John.

Knorria Imbricata (Sternb.), Sydney.
Taxina (Sternb.), Sydney.
Another species, Pictou.

Lepidodendron Elegans (Brong.), Joggins, Sydney, Pictou, &c.
Gracile (Brong.), Sydney, Joggins.
Undulatum, Sydney.
*Binerve (Bunbury), Sydney.
*Tumidum (Bunbury), Sydney.
Plumarium (Lind. & Hut.), Sydney.
Selaginoides (Stern.), Sydney.
Obovatum (Stern.), Sydney.
Sternbergii (Brong.), Sydney.
Harcourtii (Witham), Sydney.
Ornatissimum, Joggins.
Several undescribed species, Sydney.

Ulodendron Minus (L. & H.), Sydney, Joggins, Salmon R., Pictou.
Majus (L. & H.), Joggins.
Several undetermined species of Ulodendron and Lepidophloios ? ; also Bothrodendron (L. & H.), which is evidently the ligneous surface of Ulodendron.

Lepidostrobus Variabilis (L. & H.), Sydney, Pictou.
*Trigonolepis (Bunbury), Sydney.

Lepidophyllum Intermedium (L. & H.), Sydney.
Lanceolatum, Pictou.
Another species or variety, Pictou.

Cyperites Bicarinata (L. & H.), Sydney.

Sigillaria Laevigata (Brong.), Sydney.
Elongata (Brong.), Sydney.
Reniformis (Brong.) Sydney, Joggins.
Organum (L. & H), Sydney, Joggins, Pictou.
Saulii (Brong.), Sydney.
Menardi (Brong.), Sydney.
Flexuosa (L. & H.), Sydney.
Alternans (L. & H.), Sydney, Joggins.
Pachyderma (Brong.), Sydney.
Scutellata, Joggins.
Several undetermined species, Sydney, &c. The erect trees in the Joggins and Sydney section show that the sigillariæ formed forests in swampy flats; that their roots were of the stigmaria structure, and always four in number, dividing dichotomously and spreading to a great distance; that their bark was strong and durable, and their wood perishable; that their growth was exogenous, and that the bark expanded in such a manner as to preserve the regularity of the scars and furrows; but that these changed so much in their forms and proportions in different stages of growth, that characters which might readily, if taken separately, be referred to distinct species, occur in different parts of the same trunk. (See papers on Sydney and S. Joggins by Mr Brown and the author, referred to in Chapter I.)

Favularia Nodosa ? Joggins.
Another species, Pictou.
In some specimens the trunk is crossed by bands of confused or deformed scars, as if the upward growth of the trunk had been arrested at intervals.

Stigmaria, or roots of sigillaria of different species, with their long cylindrical rootlets, Sydney, Joggins, Pictou, &c.

Sphenopteris Obtusiloba (Brong.), Sydney.
Artemisifolia (Brong.), Sydney.
Braunii (Goep.), Sydney.
Latifolia (Brong.), Sydney.
Erithmifolia (L. &. H.), Sydney.

Sphenopteris Obovata (L. & H.), Sydney.
Multifida (L. & H.), Sydney.
Polyphylla (L. & H.), Sydney.
Crenata (L. & H.), Sydney.
Cyclopteris Obliqua (Brong.), Sydney.
Oblata (L. & H.) Sydney.
Neuropteris Cordata (Brong.), Sydney, Pictou.
Angustifolia (Brong.), Sydney.
Ingens (L. & H.), Sydney.
Flexuosa (Brong.), Sydney.
Gigantea (Stern.), Sydney, Pictou.
*Rarinervis (Bunbury), Sydney.
Conjugata (Goep.), Sydney.
Alternata (L. & H.), Sydney.
Goepertiana (Goep.), Sydney.
Soretii (Brong.), Sydney.
Heterophylla (Brong.), Sydney.
Odontopteris Schlotheimii (Brong.), Sydney.
*Subcuneata (Bunbury), Sydney.
Dictyopteris *Obliqua (Bunbury), Sydney.
Pecopteris Longifolia (Brong.), Sydney.
Serlii (Brong.), Sydney.
Nervosa (Brong.), Sydney.
Toeniopteroides (Bunbury), Sydney.
Plumosa (Brong.), Sydney.
Abbreviata (Brong.), Sydney.
Polymorpha (Brong.), Sydney.
Cyathea (Brong.), Sydney.
Bucklandii (Brong.), Sydney.
Oreopteroides (Brong.), Sydney.
Equalis (Brong.), Sydney.
Arborescens (Brong.), Sydney.
Villosa, Pictou.
Lonchitica, Joggins.
Muricata, Pictou, Joggins.

The six last genera are all ferns, many of them of small size and probably herbaceous; others possibly fronds of tree ferns. I have from the coal-formation of

Pictou, a fragment of a trunk with large irregular leaf scars, which probably belonged to an arborescent fern. The largest single leaflet in my collection, apparently the terminal one of a frond of some species of Neuropteris, is five inches in length and three in breadth near the base.

Sphenophyllum Schlotheimii (Brong.), Sydney, Pictou.

Erosum (L. & H.), Sydney.

The beautiful whorls of wedge-shaped leaves of these plants, are often very well preserved in the shales of Sydney and Pictou. At Pictou they are found with leaves of the next genus in such a manner as to countenance the opinion, expressed by Dr Newbury of Ohio, that some of the species of Asterophyllites are only the lower and probably submerged leaves of Sphenophyllum.

Asterophyllites Foliosa (L. & H.), Sydney.

Equisetiformis (Brong.), Sydney.

Tuberculata (Brong.), Sydney.

Galioides ? (Brong.), Pictou. This species, the leaves of which are broad and obtuse, is found mixed with Sphenophyllum Schlotheimii at Pictou.

Bechera Grandis (Stern.), Sydney.

Tenuis (Bunbury), Sydney. Probably a variety of B. Grandis.

Annularia Brevifolia (Brong.), Sydney.

Calamites Approximatus (Brong.), Sydney.

Ramosus (Artis), Sydney.

Suckowii (Brong.), Sydney, Joggins.

Nodosus (Schlot.), Sydney, Pictou.

Cannaeformis (Schlot.), Sydney, Joggins.

Dubius (Brong.), Sydney.

Cistii (Brong.), Sydney.

Steinhauerii, Joggins.

The Joggins section shows that the calamites were tall equisetiform plants, with stiff verticillate linear leaves. They formed thick brakes in and around the sigillaria woods, especially on mud and sand flats subject to inundation; and as the surface was raised by the deposition of sediment, the buried joints of the calamites gave out tufts of long cylindrical irregularly branching roots, and also secondary stems; so that each plant spread into a group of stems sending forth a mass of roots into the mud beneath. Some of the coarser species had large and numerous roots. The roots of the smaller species were slender and apparently perishable.

Equisetum Infundibuliforme (Bunbury), Sydney.

Hippurites Longifolia (L. & H.), Sydney.

Pinnularia Capillacea (L. & H.), Sydney.

Myriophyllites (the root) (Artis), Sydney.

Poacites, Sydney, Joggins, Pictou, &c. These large finely striated leaves are perhaps more generally diffused than any other fossil plant in the coal-formation of Nova Scotia. The superior extremity terminates in a point; the lower extremity is occasionally curved as if it had clasped a round stem.

Artisia Approximata (Brong.), Pictou, Sydney, Joggins, Port Hood, &c.

Other more coarsely wrinkled species. Pictou, Joggins, &c.

The fossils of this genus are casts of the pith of plants, some of them of a rush-like character, others trees, probably Conifers or Lepidodendra.

(b) *Lower Carboniferous Series.*

Reptile.

Footprints discovered by Mr Logan at Horton, 1841.

Fishes.

Scales, teeth, and spines of Holoptychius and other genera (species undetermined), Horton Bluff, &c.

Palæoniscus, several species, in entire specimens at Hillsborough, New Brunswick.

Articulata.

Trails of marine worms, Horton, Halfway River, &c.
Cypris or Cytherina, Horton Bluff.
Spirorbis, attached to marine shells, Windsor.
Trilobite or Limulus, De Bert River.

Mollusca.

Nautilus, allied to N. Leplayii (Demidorf), Brookfield, Windsor, Napan.
Cyrtoceras, Windsor.
Orthoceras, analogous to O. Gesneri (Martin), Windsor.
 A second species, Windsor.
Conularia, allied to C. Quadrisulcata, Shubenacadie, Windsor, Cape Breton.
Littorina ?, Shubenacadie, Gay's River, Pugwash.
Cirrus Spiralis ?, Windsor.
Euomphalus Levis ?, Windsor, East R., Gay's R.
Natica, like N. Dicistria, Windsor, Gay's R.
Several small spiral univalves, undetermined.
Terebratula Elongata (Schlot.), all the L. C. limestones.
 Sufflata, probably variety of T. Elongata, all the L. C. limestones.
 Several other species, one with sinus like T. Diodonta, Windsor, De Bert, Shubenacadie, East R., &c.
Spirifer Glaber, Windsor, Brookfield, East R., Cape Breton, Merigomish, &c.
 Cristatus ?, Windsor.
 Minimus ? (Sow.), Windsor, Brookfield, Shubenacadie, De Bert.
 Octoplicatus, Windsor, East R.
Productus Martini, almost everywhere.
 Lyelli (De Ver.), almost everywhere.
 Scotica ?, or variety of P. Lyelli, almost everywhere.
 Spinosa (Sow.), C. Breton.
 Antiquata (Kon.), Brookfield.
Cardiomorpha Archiacana, Windsor.

Pecten Plicatus, Windsor, Brookfield, Shubenacadie..
Three other species, Brookfield, De Bert, Shubenacadie.
Avicula Antiqua (Munst.), Gay's R., Shubenacadie, &c.
Five other species.
Modiola, allied to M. Pallasii, Windsor, Brookfield, Shubenacadie.
Another species.
Cucullaea, N.S., Windsor.
Isocardia Unioniformis (Phil.), Brookfield, Stewiacke.
Cypricardia, N.S., Windsor, &c.
Several other bivalves undetermined.
Fenestella Membranacea, Windsor, Shubenacadie, Brookfield, Pictou, &c.
Another species or well-marked variety.

Radiata.

Crinoidal joints, Windsor, Shubenacadie, Pictou, C. Breton, &c.
Ceriopora Spongites, Windsor, Brookfield, Shubenacadie.
Favosites Ramosa, Windsor, Shubenacadie, &c.
Cyathophyllum, East River.

Plants.

Lepidodendron Elegans ?, Horton, &c.
Harcourtii ?, Horton, &c.
Another species.
Poacites, Horton, &c., Hillsborough.
Stigmaria, Horton.
Calamites, St Mary's River.

The above list shows a very marked resemblance in the carboniferous fauna and flora of Nova Scotia to those of Europe. A majority of the species are identical with European forms, and most of the others are closely allied to European species. This circumstance has been commented on by Sir C. Lyell and Mr Bunbury. The latter remarks that it points to a greater similarity of climate than at present obtains, and to the possible connexion of the coal-formation areas of Europe and America by groups of islands. It may be considered corroborative of this last conjecture, that, at the period in question, Nova Scotia and Cape Breton constituted, as already explained in this work, a group of hilly islets of metamorphic rocks, separated by sea channels, but bordered, and perhaps connected in one portion of the period, by alluvial flats clothed with vegetation. As compared with existing nature, the coal-formation flora is remarkable for the almost exclusive prevalence of the higher orders of cryptogamous or flowerless plants, as the ferns and Lepidodendra, and of the gymnospermous or naked-seeded dicotyledonous plants, represented in the coal-period by the Pines, and possibly also by the Sigillariæ and Calamites, which, though I have referred to them in the text as probably cryptogamous and allied to tree-ferns and Equiseta, are now supposed by some eminent botanists to be more nearly related to the Cycads. They were possibly connecting links between the Gymnosperms and the higher Cryptogams. With the exception, perhaps, of Poacites, and a few other plants which have the aspect of Monocotyledons, the two largest and most important classes of the modern vegetable world have no known representatives in the coal-measures. The terrestrial fauna of the coal-period as yet contains only a few reptiles, one land-shell, and some insects which have been found only in Europe. It would be rash to maintain that animal life on the land was confined to these forms; but it must be observed that the vegetation of the period, though luxuriant, was not well fitted to sustain the higher herbivorous animals.

DEVONIAN AND UPPER SILURIAN SYSTEMS.

The fossils in these rocks are very numerous, but many of them can be found only in a fragmentary or distorted state, or in the form of casts; and it is only very rarely that they occur in a state of preservation approaching to that in which the fossils of these rocks exist in the United States. Owing to this, much care and skill are required in their determination, and I have not attempted to compare them with the published figures and descriptions of fossils of the same age found in other countries. Of the specimens which I have sent to Professor Hall, that eminent palæontologist has recognised the following shells as identical with New York species, or very closely allied to them.

Leptæna Carinata
— Depressa
Avicula Boydii
Nucula Bellatula?
— Obliqua

Beside these there are Trilobites, especially a species of Phacops allied to P. Caudata; and shells and corals of the following genera, the species being all undetermined:—Orthoceras, Cornulites, Tentaculites, Bellerophon, Pleurotomaria, Orthis, Chonetes, Spirifer, Strophodonta? Lingula, Loxonema, Graptolithus, Dictyonema, Favosites, Cyathophyllum. There are also abundance of crinoidal joints, and in some localities imperfectly preserved remains of plants, probably sea-weeds.

(B) SABLE ISLAND, AND SAND HILLS OF PRINCE EDWARD ISLAND.

In describing the modern deposits, I omitted those of blown sand, which occur somewhat extensively within the region to which this work relates, and therefore notice them shortly here.

Sable Island is the highest part of one of those banks of sand, pebbles, and fragments of shells and coral, which form a line extending under the waters of the Atlantic, and parallel to the American coast, from Newfoundland to the vicinity of Cape Cod; and which are separated from the coast and from each other by valleys of mud. Sable Island Bank is one of the largest of these submarine sand-beds. Its area is equal to one-third of that of Nova Scotia. The depth of water at its margins varies from 35 to 68 fathoms; and from this depth it shoals gradually toward the shores of the island, which is situated near its eastern extremity. Sable Island itself is about 23 miles in length, and from one mile to one and a half in breadth. It is distant about 85 miles from the nearest part of Nova Scotia. Its surface consists entirely of light gray or whitish sand, rising in places into rounded hills, one of which is stated by persons who have visited the island to be 100 feet in height. The whole of this sandy surface has evidently been washed and blown up by the sea and wind; and I have not been able to learn, from any of the accounts of the island, that any more solid substratum exists. Pools of fresh water, however, appear in places, which would seem to imply that there is an impervious subsoil. This may, however, be caused by the *floating* of rain water on water-soaked sand, an appearance which may sometimes be observed on ordinary sand-beaches, where, in consequence of their resting on the surface of the sea-water, these pools or springs sometimes rise and fall with the tide. I am not aware, however, that this occurs at Sable Island. There is also a large salt water lake or lagoon, which at one time formed a harbour; but its entrance was closed by a storm. The surface of the island is covered with coarse grass and cranberry and whortleberry plants; and horses, rabbits, and rats have been naturalized and exist in a wild state. The government of Nova Scotia, aided by an annual sum from Great Britain, supports an establishment on the island for the succour of shipwrecked mariners.

Captain Darby, late superintendent of the establishment on the island, states in a letter contributed to Blunt's Coast Pilot, that within twenty-eight years the western extremity of the island has decreased in length seven miles. He also states that the island has been increasing in height, especially at the eastern end, and at the same time diminishing in width. He believes that the bank and bar extending from the western end have been constantly travelling to the eastward. It would indeed appear from the difference in the longitude of the island, as given in the old charts and by late surveys, that the whole island is moving eastward; a very natural effect of the prevailing westerly winds, which must continually shift the particles of sand from west to east, and may eventually throw the island over the edge of the bank into deep water, and cause it to disappear; unless indeed the whole bank is moving in the same direction under the influence of marine currents. A singular intermixture of animal remains may be produced by this movement of a sand-island, tenanted by land and fresh-water creatures, over the surface of a marine sandbank remote from land, and which otherwise would contain only deep sea shells.

Sand hills and beaches exist in many parts of Nova Scotia and New Brunswick; but nowhere to so great an extent as on the northern side of Prince Edward Island, where the sand resulting from the waste of the soft red sandstones of the island has been moved upward by the waves, and blown by the wind until it forms long ranges of sand-dunes, extending along the coast and crossing the bays, but I believe in no place penetrating far inland; though, since the forest has been cleared, the sand is becoming troublesome on some parts of the coast farms. Across Cascumpec and Richmond bays, and along the intervening coast, a nearly continuous range of sand beaches and hills extends for more than twenty miles; and at New London, Rustico, Covehead, Tracadie, and St Peter's bays, there are similar ranges of sand-hills, amounting altogether to about twenty miles more.

At New London, the only place where I have had an opportunity of examining these sand-hills, they attain the height of forty feet, and are covered with tufts of coarse beach grass. Their northern sides are frequently cut away into escarpments of loose sand; but on the whole they do not appear to be rapidly changing their form or position. The sand is of a gray or light brownish colour, though derived from red sandstone; its coating of red oxide of iron being almost entirely removed by friction.

(C.) EARTHQUAKES.

Slight earthquake shocks have been felt at rare intervals in several parts of the Acadian provinces. The latest occurred on the 8th of February 1855, and was observed throughout Nova Scotia and New Brunswick, and as far to the south-west as Boston. Its point of greatest intensity appears to have been at the Bend of the Petitcodiac, near the extremity of the New Brunswick coast-line of metamorphic hills. At this place there were several shocks, one of them sufficiently severe to damage a brick building, whereas in the other places only one slight shock was experienced. At Pictou and Halifax, the only shock felt occurred a few minutes before 7 A. M., and it appears to have been simultaneous throughout Nova Scotia and New Brunswick.

(D.) SALT SPRINGS.

One of the points of similarity between the lower carboniferous rocks of Nova Scotia and the new red sandstone of England, is the presence of salt in the beds of the former series, indicated by the occurrence of salt springs, which appear at several places in Hants and Cumberland counties, at Salmon river in Colchester, and at the West river of Pictou. Rock salt *in situ* has not been discovered at any of these places; nor are the springs at present applied to any useful purpose.

(E.) ADDITIONAL FACTS RELATING TO THE ORIGIN OF GYPSUM.

The following modern instances of the formation of gypsum by the agency of springs of sulphuric acid, serve to confirm the view stated at page 223 of this work.

Sir H. T. De la Beche, in the Geological Observer, second edition, page 375, quotes from Professor Bunsen an analysis of the water of one of the hot springs of Iceland, and a statement of the effects which it produces on the rocks (hardened volcanic tufa) with which it comes in contact. It appears that these springs deposit on a small scale layers of gypsum embedded in bleached and variegated clays, in which there are also small crystals of iron pyrites. On a large scale, and with access to beds of limestone, they would evidently produce gypseous deposits quite similar to those of Nova Scotia.

In the Reports of the Geological Survey of Canada for 1847-48, and 1849-50, Mr Hunt describes springs containing sulphuric acid and sulphates, and notices their probable agency in forming the deposits of gypsum which occur in the Upper Silurian rocks of Canada and New York. The expansive effects of the formation and crystallization of gypsum, referred to in page 231, have been observed both in Iceland and Canada.

(F.) POPULATION AND MINERAL STATISTICS OF THE ACADIAN PROVINCES.

From the Census of 1851.

	Nova Scotia.	New Brunswick.	Prince Edward Island.
Population	276,117	193,800	70,000
Acres of cleared land	839,322	643,954	About 200,000
Coals, raised	114,992 chals.	2,482 tons	
Gypsum, quarried	79,795 tons	5,465 ..	
Lime, burned	28,603 casks	35,599 casks	
Iron, smelted	250 tons	810 tons	
Grindstones	37,100 ..	58,849 stones	
Bricks, made	2,845,400	No return	
Granite, Freestone, Slate, Barytes, Mineral Paints, &c.	No returns	No returns	

Of the adult male population of Nova Scotia, 31,600 are returned as engaged in Agriculture, and 15,300 in Navigation and the Fisheries. In New Brunswick, the numbers are, Agriculture, 18,601; Navigation and Fisheries, 1454. In Prince Edward Island, Agriculture preponderates still more largely.

SUPPLEMENTARY CHAPTER.

(*August* 1860.)

Since the publication of the "Acadian Geology," the author has been removed from the scene of his former labours, and now dwells in the great Silurian plain of Lower Canada; but he still retains a lively interest in the Geology of his native province, and has endeavoured to carry forward to completion some of the subjects left unfinished in 1855, and to acquaint himself as far as possible with the results of the researches of other observers. A condensed view of the new matter thus obtained will be presented in the following pages.

MODERN AND POST-PLIOCENE FORMATIONS.

When I described the submerged forest at Fort Lawrence,* I was not aware of the extent to which similar phenomena occur on the coast of the United States. At the meeting of the American Association in Montreal, Professor Cook of Rutgers College presented an interesting summary of indications of modern subsidence observed on the coasts of New England, New York,

* Acadian Geology, p. 31.

and New Jersey, and estimated the average rate of sinking at two feet in a century, under the impression that it is still in progress, which would coincide with the view entertained in some parts of the marsh districts of Nova Scotia, that the tides now rise higher than formerly. Additional interest is also thus given to the Fort Lawrence instance, as indicating the great vertical amount of this very extensive subsidence.

In Canada I have had many opportunities of studying the Post-Pliocene stratified clays and sands of the lower St Lawrence. These deposits abound in marine shells, and mark the stages of recession of the sea as the American land rose from the great depression of the period of the Boulder formation, in which nearly the whole continent was submerged. In Nova Scotia the boulder clay exists under the same conditions as in Canada, and so do the overlying stratified sands and gravels; but the intermediate deposit, the "Leda clay" of Montreal, does not appear, nor are there marine shells. This may indicate a more rapid elevation of the Nova Scotia land, not giving time for permanent sea bottoms; or, on the other hand, a slow rise accompanied by very great denudation. The position of Nova Scotia and the appearances of its boulder clay point rather to the latter conclusion. In this case, remnants may exist; and, judging from my experience in Canada, I should suppose that marine remains are most likely to be found at the junction of the boulder clay with the overlying stratified drift, and in places sheltered by hills or ledges of rock. From papers on this subject published since my removal to Canada, I may select the following statements as important to the geology of these formations in Nova Scotia.*

* Canadian Naturalist and Geologist, vols. ii., iii., and iv.

The arrangement of the Pleistocene deposits at Logan's farm near Montreal, and Beauport near Quebec, confirms the subdivision, which I have attempted to establish, of these beds into an underlying non-fossiliferous boulder clay, a deep-water bed of clay or sand (the "Leda clay" of Montreal), and, overlying shallow-water sands and gravels, the "Saxicava sand." This arrangement shows a gradual upheaval of the land from its state of depression in the Boulder-clay period, corresponding with what has been deduced from similar appearances in the Old World. "The upheaval of the bed of the glacial sea," says Forbes, "was not sudden but gradual. The phenomena so well described by Professor Forchammer in his essays on the Danish drift, indicating a conversion of a muddy sea of some depth into one choked up with sand-banks, are, though not universal, equally evident in the British Isles, especially in Ireland and the Isle of Man." *

We now have in all, exclusive of doubtful forms, sixty-three species of marine invertebrates from the Post-Pliocene or Pleistocene clays of the St Lawrence valley. All, except four or five species belonging to the older or deep-water part of the deposit, are known as living shells of the arctic or boreal regions of the Atlantic. About half of the species are fossil in the Pleistocene of Great Britain. A majority of the whole are now living in the Gulf of St Lawrence and on the neighbouring coasts; and I have reason to believe that the dredging operations carried on by the officers of the Geological Survey in the past summer will enable us to recognise all but a few as living Canadian species. In so far, then, as marine life is concerned, the Modern

* Memoirs of Geological Survey.

period in this country is connected with that of the Boulder clay by an unbroken chain of animal existence. These deposits in Lower Canada afford no indications of the terrestrial fauna; but the remains of *Elephas primigenius* in beds of similar age in Upper Canada,* show that during the period in question great changes occurred among the animals of the land; and we may hope to find similar evidences in Lower Canada, especially in localities where, as on the Ottawa, the debris of land-plants and land-shells occur in the marine deposits.

The climate of this period, and the causes of its difference from that which now obtains in the northern hemisphere, have been fertile subjects of discussions and controversies, which I have no wish here to reopen. I desire, however, to state, in a manner level to the comprehension of the ordinary reader, the facts of the case in so far as relates to Canada, and equally to Nova Scotia, and an important inference to which they appear to me to lead, and which, if sustained, will very much simplify our views of this question.

Every one knows that the means and extremes of annual temperature differ much on the opposite sides of the Atlantic. The isothermal line of 40°, for example, passes from the south side of the Gulf of St Lawrence, skirts Iceland, and reaches Europe near Drontheim in Norway. This fact, apparent as the result of observations on the temperature of the land, is equally evidenced by the inhabitants and physical phenomena of the sea. A large proportion of the shell-fish inhabiting the Gulf of St Lawrence and the coast thence to Cape Cod occur on both sides of the Atlantic, but not in the same latitudes. The marine fauna of Cape Cod is parallel, in

* Reports of Geol. Survey; Lyell's Travels.

its prevalence of boreal forms, with that of the south of Norway. In like manner, the descent of icebergs from the north, the freezing of bays and estuaries, the drifting and pushing of stones and boulders by ice, are witnessed on the American coast in a manner not parallelled in corresponding latitudes in Europe. It follows from this, that a collection of shells from any given latitude on the coasts of Europe or America would bear testimony to the existing difference of climate. The geologist appeals to the same kind of evidence with reference to the climate of the Later Tertiary period, and let us inquire what is its testimony.

The first and most general answer usually given is, that the Pleistocene climate was colder than the Modern. The proof of this in Western Europe is very strong. The marine fossils of this period in Britain are more like the existing fauna of Norway or of Labrador than the present fauna of Britain. Great evidences exist of driftage of boulders by ice, and traces of glaciers on the higher hills. In North America the proofs of a rigorous climate, and especially of the transport of boulders and other materials by ice, are equally good, and the marine fauna all over Canada and New England is of boreal type. In evidence of these facts, I may appeal to the papers and other publications of Sir C. Lyell and Professor Ramsay on the formations of the so-called Glacial period in Europe and America,* and to my own previous papers on the Tertiaries of Canada.

Admitting, however, that a rigorous climate prevailed

* Lyell's Travels in North America; Ramsay on the Glaciers of Wales, and on the Glacial Phenomena of Canada. See also Forbes on the Fauna and Flora of the British Islands, in Memoirs of Geological Survey.

in the Pleistocene period, it by no means follows that the change has been equally great in different localities. On the contrary, while a great and marked revolution has occurred in Europe, the evidences of such change are very much more slight in America. In short, the causes of the coldness of the Pleistocene seas to some extent still remain in America, while they must have disappeared or been modified in Europe.

If we inquire as to these causes as at present existing, we find them in the distribution of ocean currents, and especially in the great warm current of the Gulf stream thrown across from America to Europe, and in the arctic currents bathing the coasts of America. In connexion with these we have the prevailing westerly winds of the temperate zone, and the great extent of land and shallow seas in northern America. Some of these causes are absolutely constant. Of this kind is the distribution of the winds, depending on the earth's temperature and rotation. The courses of the currents are also constant, except in so far as modified by coasts and banks; and the direction of the drift-scratches and transport of boulders in the Pleistocene both of Europe and America show that the arctic currents at least have remained unchanged. But the distribution of land and water is a variable element, since we know that in the period in question nearly all northern Europe, Asia, and America were at one time or another under the waters of the sea, and it is consequently to this cause that we must mainly look for the changes which have occurred.

Such changes of level must, as has been long since shown by Sir Charles Lyell, modify and change climate. Every diminution of the land in arctic America must tend to render its climate less severe. Every diminution of land in the temperate regions must tend to reduce the mean temperature. Every diminution of land anywhere must tend to diminish the extremes of annual temperature; and the condition of the southern hemisphere at present shows that the disappearance of the great continental masses under the water would lower the mean temperature, but render the climate much less extreme. Glaciers might then exist in latitudes where now the summer heat would suffice to melt them—as Darwin has shown that in South America glaciers extend to the sea level in latitude 46° 50′,—and at the same time the ice would melt more slowly and be drifted farther to the southward. Any change that tended to divert the arctic currents from our coasts would raise the temperature of their waters. Any change that would allow the equatorial current to pursue its course through to the Pacific, or along the great inland valley of North America, would reduce the British seas to a boreal condition.

The Boulder formation and its overlying fossiliferous beds prove, as I have in a previous paper endeavoured to explain with regard to Canada, and as has been shown by other geologists in the case of other parts of America and of Europe, that the land of the northern hemisphere underwent in the Later Tertiary period a great and gradual depression and then an equally gradual elevation. Every step of this process would bring its modifications of climate, and when the depression had attained its maximum there probably was as little land in the temperate regions of the northern hemisphere as in the southern now. This would give a low mean temperature and an extension to the south of glaciers, more especially if, at the same time, a considerable arctic continent remained above the waters, as seems to be indicated by the effects of extreme marine glacial action on the rocks under the boulder clay. These conditions, actually indicated by the phenomena themselves, appear quite sufficient to account for the coldness of the seas of the period; and the wide diffusion of the Gulf stream caused by the subsidence of American land, or its entire diversion into the Pacific basin,* would give that assimilation of the American and European climates so characteristic of the time. The climate of western Europe, in short, would, under such a state of things, be greatly reduced in mean temperature: the climate of America would suffer a less reduction of its mean temperature, but would be much less extreme than at present; the general effect being the establishment of a more equable but lower temperature throughout the northern hemisphere. It is perhaps necessary to add, that the existence on the land, during this period of depression, of large elephantine mammals in northern latitudes, as, for instance, the mammoth and mastodon, does not contradict this conclusion. We know that these creatures were clothed in a manner to fit them for a cool climate, and an equable rather than a high temperature was probably most conducive to their welfare, while the more extreme climate consequent on the present elevation and distribution of the land may have led to their extinction.

* This is often excluded from consideration, owing to the fact that the marine fauna of the Gulf of Mexico differs almost entirely from that of the Pacific coast; but the question still remains, whether this difference existed in the Later Tertiary period, or has been established in the Modern epoch, as a consequence of changed physical conditions.

The establishment of the present distribution of land and water, giving to America its extreme climate, leaving its seas cool, and throwing on the coasts of Europe the heated water of the tropics, would thus affect but slightly the marine life of the American coast, but very materially that of Europe, producing the result so often referred to in my papers on this subject, that the Canadian Pleistocene fauna differs comparatively little from that now existing in the Gulf of St Lawrence, though in so far as any difference subsists it is in the direction of an arctic character. The changes that have occurred are perhaps all the less that so soon as the Laurentide hills to the north of the St Lawrence valley emerged from the sea, the coasts to the south of these hills would be effectually protected from the heavy northern ice-drifts and from the arctic currents, and would have the benefit of the full action of the summer heat,—advantages which must have existed to a less extent in western Europe.

It is farther to be observed, that such subsidence and elevation would necessarily afford great facilities for the migration of arctic marine animals, and that the difference between the Modern and Newer Pliocene faunas must be greatest in those localities to which the forms of temperate regions could most readily migrate after the change of temperature had occurred.

It has been fully shown by many previous writers on this subject that the causes above referred to are sufficient to account for all the local and minor phenomena of the stratified and unstratified drifts, and for the driftage of boulders and other materials, and the erosion that accompanied its deposition. Into these subjects I do not propose to enter; my object in these remarks being merely to give the reasons for my belief stated in previous papers on this subject, that the difference of climate between Pleistocene and Modern Canada, and the less amount of that difference relatively to that which has occurred in western Europe, may be explained by a consideration of the changes of level which the structure and distribution of the boulder clay and the overlying fossiliferous beds prove to have occurred.

CARBONIFEROUS SYSTEM.

Since 1855 the following papers on the Carboniferous system of Nova Scotia have appeared:—"On the Occurrence of Natro-boro-calcite, with Glauber-salt, in the Gypsum of Nova Scotia," by Professor How of Windsor; * "On the Fossil Plants known as *Sternbergia*;"† "On the Lower Carboniferous Coal Measures of British America;" ‡ "On the Vegetable Structures in Coal; § and "On the Occurrence of Reptilian Remains, with a Land-shell and Myriapod, in the Coal Measures of Nova Scotia," || by the author.¶

I. Professor How's paper announces the discovery, in the great bed of gypsum quarried at Windsor, of a rare boracic-acid mineral hitherto found only in Peru.** Its formula, according to Professor How, is—

$$Na\,O\;2\,BO_3 + 2\,Ca\,O,\;3\,BO_3 + 15\,HO.$$

* American Journal of Science, Sept. 1857.

† Proceedings of American Association, 1857.

‡ Proceedings of Geological Society of London, 1858.

§ Ibid. 1859. || Ibid. 1860.

¶ Professor How and Mr Poole have also published papers on the "Oil Coals," or earthy bitumen, of Nova Scotia.

** Professor How has still more recently discovered a second boracic-acid mineral in the gypsum. It consists of borate and sulphate of lime, soda, and magnesia, and Professor H. proposes to name it Cryptomorphite.

With respect to the geological conditions of its occurrence, Professor How quotes from Professor Anderson of Glasgow the statement that, at Tarapaca in Peru, the mineral is found in a district supposed to be volcanic, and imbedded in the nitrate of soda deposits. He then remarks that, with a very few exceptions, boracic acid is found "either in directly volcanic regions, most abundantly as such, or as borax: and a well-marked case of actual sublimation of the acid from a volcano in the island of Vulcano, near Sicily, has been studied by Warrington; or in smaller amount, in minerals the products of recent or extinct volcanoes, as Humboldtite from ejected blocks of Vesuvius, and zeolites and datholite from trap of Salisbury Crags, New Jersey, and other places; or in minerals of purely plutonic or metamorphic rocks, as tourmaline, the rhodozite of Roze, and axinite—the species which contain it at all being few in number. It may be noticed also, that traces of this acid have lately been met with in the Kochbrunnen of Wiesbaden and in the waters of Aachen.

"If we may reason from the character of the majority of its situations, we may almost consider the volcanic or at least igneous origin of boracic acid so well established as to lead us, by its occurrence in the gypsiferous strata, to seek for some volcanic agency as the cause of their production. Such an origin has I find already been assigned to the gypsum of Nova Scotia by Mr Dawson. This formation has been shown to be a member of the Lower Carboniferous series, and is assumed to have arisen from the action of rivers of sulphuric acid more or less dilute, such as are known to exist in various parts of the world, issuing from then active volcanoes and flowing over the calcareous reefs and bed of the sea."

This is an interesting confirmation of the views formerly expressed as to the origin of the gypsum; and though Professor Hunt has ably shown, in his recent papers on Chemical Geology,* that gypsum may be produced in stratified masses in aqueous deposits by other processes, I am still inclined, in consequence of the great thickness and local character of the deposits, and the apparent absence of magnesian limestone, as well as the presence of boracic acid, to adhere to the view above stated, in so far as the great gypsum beds of Nova Scotia are concerned.

The other papers referred to above relate principally to the fossils of the Carboniferous system in Nova Scotia, and may be noticed under the following heads:—

II. *Sternbergia.*—The fossils known by this name are cylindrical or flattened stems, marked with transverse wrinkles, common in some parts of the Coal formation, but until recently of quite uncertain affinities, being among the most anomalous of those vegetable puzzles which the coal-fields have furnished to the botanists.

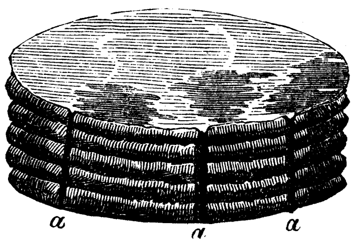
In a paper communicated to the Geological Society of London in 1846, to which Professor Williamson, in his able memoir in the Manchester Transactions (vol. ix., 1851), assigns the credit of first suggesting that connexion between these curious fossils and the conifers which he has so successfully worked out, I stated my belief that those specimens of Sternbergiæ which occur with only thin smooth coatings of coal might have belonged to rush-like endogens; while those to which fragments of fossil wood were attached presented structures resembling

* Report of Canadian Survey for 1858; Canadian Naturalist; Silliman's Journal; &c.

those of conifers. These last were not, however, so well preserved as to justify me in speaking very positively as to their coniferous affinities. They were also comparatively rare; and I was unable to understand how casts of the pith of conifers could assume the appearance of the naked or thinly-coated Sternbergiæ. Additional specimens, affording well-preserved coniferous tissue, have removed these doubts, and, in connexion with others in a less perfect state of preservation, have enabled me more fully to comprehend the homologies of this curious structure, and the manner in which specimens of it have been preserved independently of the wood.

My most perfect specimen is one from the coal-field of Pictou* (Fig. 36). It is cylindrical, but somewhat

Fig. 36.—*Portion of Sternbergia* (*nat. size*).



(*a*) Remains of woody fibre.

flattened, being one inch and two-tenths in its least diameter, and one inch and seven-tenths in its greatest. The diaphragms, or transverse partitions, appear to have been continuous, though now somewhat broken. They are rather less than one-tenth of an inch apart, and are more regular than is usual in these fossils. The outer surface of the pith, except where covered by the remains

* Presented to me by Mr Hogg of Pictou Island.

of the wood, is marked by strong wrinkles, corresponding to the diaphragms. The little transverse ridges are in part coated with a smooth tissue similar to that of the diaphragms, and of nearly the same thickness.

When traced around the circumference or toward the centre the partitions sometimes coalesce and become double, and there is a tendency to the alternation of wider and narrower wrinkles on the surface. In these characters and in its general external aspect, the specimen perfectly resembles many of the ordinary naked Sternbergiæ.

On microscopic examination the partitions are found to consist of condensed pith, which, from the compression of the cells, must have been of a firm bark-like texture in the recent plant (Figs. 37 and 38). The wood attached to the surface, which consists of merely a few small splinters, is distinctly coniferous, with two and

Fig. 37.

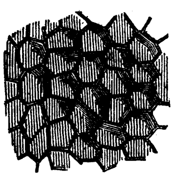


Fig. 38.

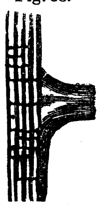
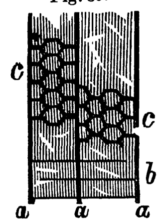


Fig. 39.



Figs. 37 and 38—Transverse and longitudinal section of diaphragm.
Fig. 39—Section of wood.

three rows of discs on the cell walls (Fig. 39). It is not distinguishable from that of *Pinites* (*Dadoxylon*) *Brandlingi* of Witham, or from that of the specimens figured by Professor Williamson. The wood and transverse partitions are perfectly silicified, and of a dark brown colour. The partitions are coated with small colourless crystals of quartz and a little iron pyrites, and the remaining spaces are filled with crystalline laminæ of sulphate of barytes.

Unfortunately this fine specimen does not possess enough of its woody tissue to show the dimensions or age of the trunk or branch which contained this enormous pith. It proves, however, that the pith itself has not been merely dried and cracked transversely by the elongation of the stem, as appears to be the case in the Butternut (*Juglans cinerea*), and some other modern trees, but that it has been condensed into a firm epidermis-like coating and partitions, apparently less destructible than the woody tissue which invested them. In this specimen the process of condensation has been carried much farther than in that described by Professor Williamson, in which a portion of the unaltered pith remained between the Sternbergia cast and the wood. It thus more fully explains the possibility of the preservation of such hollow chambered piths after the disappearance of the wood. It also shows that the coaly coating investing such detached pith casts is not the medullary sheath, properly so called, but the outer part of the condensed pith itself.

The examination of this specimen having convinced me that the structure of Sternbergiæ implies something more than the transverse cracking observed in Juglandaceæ, I proceeded to compare it with other piths, and especially with that of *Cecropia peltata*, a West Indian tree, of the natural family Artocarpaceæ, a specimen of which was kindly presented to me by Professor Balfour of Edinburgh, and which I believe has been noticed by Dr Fleming, in a paper to which I have not had access. This recent stem is two inches in diameter. Its medullary cylinder is three-quarters of an inch in diameter, and is lined throughout by a coating of dense whitish pith tissue, one-twentieth of an inch in thickness. This condensed pith is of a firm corky texture, and forms a sort of internal bark lining the medullary cavity. Within this the stem is hollow, but is crossed by arched partitions, convex upward, and distant from each other from three-quarters to one and a quarter inch. These partitions are of the same white corky tissue with the pith lining the cavity; and on their surfaces, as well as on that of the latter, are small patches of brownish large-celled pith, being the remains of that which has disappeared from the intervening spaces. Each partition corresponds with the upper margin of one of the large triangular leaf scars, arranged in quincuncial order on the surface of the stem.

Inferring from these appearances that this plant contains two distinct kinds of pith tissue, differing in duration and probably in function, I obtained, for comparison, specimens of living plants of this and allied families. In some of these, and especially in a species labelled "*Ficus imperialis*," from Jamaica, I found the same structure; and in the young branches, before the central part of the pith was broken up, it was evident that the tissue was of two distinct kinds: one forming the outer coating and transverse partitions opposite the insertions of the leaves, and retaining its vitality for several years at least; the other occupying the intervening spaces or internodes, of looser texture, speedily drying up, and ultimately disappearing.

The trunks above noticed are of rapid growth, and have large leaves; and it is probable that the more permanent pith tissue of the medullary lining and partitions serves to equalize the distribution of the juices of the stem, which might otherwise be endangered by the tearing of the ordinary pith in the rapid elongation of the internodes. A similar structure has evidently existed in the Coal-formation conifers of the genus Dadoxylon, and possibly they also were of rapid growth and furnished with very large or abundant leaves.

Applying the facts above stated to the different varieties or species of Sternbergia, we must in the first place connect with these fossils such plants as the *Pinites medullaris* of Witham. I have not seen a longitudinal section of this fossil, but should expect it to present a transverse structure of the Sternbergia type. The first specimen described by Professor Williamson represents a second variety, in which the transverse structure is developed in the central part of the pith, but not at the sides. In my Pictou specimen the pith has wholly disappeared, with the exception of the denser outer coating and transverse plates. All these are distinctly coniferous, and the differences that appear may be due merely to age, or more or less rapid growth.

Other specimens of Sternbergia want the internal partitions, which may, however, have been removed by decay; and these often retain very imperfect traces, or none, of the investing wood. In the case of those which retain any portion of the wood sufficient to render probable their coniferous character, the surface markings are similar in character to those of my Pictou specimen, but often vary greatly in their dimensions, some having fine transverse wrinkles, others having these wide and coarse. Of those specimens which retain no wood, but only a thin coaly investment representing the outer pith, many cannot be distinguished by their superficial markings from those that are known to be coniferous, and they occasionally afford evidence that we must not attach too much importance to the character of their markings. A very instructive specimen of this kind from Ohio, with which I have been favoured by Professor Newberry, has in a portion of its thicker end very fine transverse wrinkles, and in the remainder of the specimen much coarser wrinkles. This difference marks, perhaps, the various rates of growth in successive seasons, or the change of the character of the pith in older portions of the stem.

The state of preservation of the Sternbergia casts, in reference to the woody matter which surrounded them, presents, in a geological point of view, many interesting features. Professor Williamson's specimen I suppose to be unique in its showing all the tissues of the branch or trunk in a good state of preservation. More frequently, only fragments of the wood remain, in such a condition as to evidence an advanced state of decay, while the bark-like medullary lining remains. In other specimens, the coaly coating investing the cast sends forth flat expansions on either side, as if the Sternbergia had been the mid-rib of a long thick leaf. This appearance, at one time very perplexing to me, I suppose to result from the entire removal of the wood by decay, and the flattening of the bark, so that a perfectly flattened specimen may be all that remains of a coniferous branch nearly two inches in diameter. A still greater amount of decay of woody tissue is evidenced by those Sternbergia casts which are thinly coated with structureless coal. These must, in many cases, represent trunks and branches which have lost their bark and wood by decay; while the tough cork-like chambered pith drifted away to be imbedded in a separate state. This might readily happen with the pith of Cecropia; and perhaps that of these coniferous trees may have been more durable; while the wood, like the sap-wood of many modern pines, may have been susceptible of rapid decay, and liable, when exposed to alternate moisture and dryness, to break up into those rectangular blocks which are seen in the decaying trunks of modern conifers, and are so abundantly scattered over the surfaces of coal and its associated beds in the form of mineral charcoal.

Some specimens of Sternbergia appear to show that they have existed in the interior of trunks of considerable size. I have observed one at the South Joggins, which appears to show the remains of a tree a foot in diameter, now flattened and converted into coal, but retaining a distinct cast of a wrinkled Sternbergia pith.

Are we to infer from these facts that the wood of the trees of the genus Dadoxylon was necessarily of a lax and perishable texture. Its structure, and the occurrence of the heart-wood of huge trunks of similar character in a perfectly mineralized condition, would lead to a different conclusion; and I suspect that we should rather regard the mode of occurrence of Sternbergia as a caution against the too general inference, from the state of preservation of trees of the Coal formation, that their tissues were very destructible, and that the beds of coal must consist of such perishable materials. The coniferous character of the Sternbergiæ, in connexion with their state of preservation, seems to strengthen a conclusion at which I have been arriving from miscroscopic and field examinations of the coal and carbonaceous shales, that the thickest beds of coal, at least in eastern America, consist in great part of the flattened bark of coniferous, sigillaroid, and lepidodendroid trees, the wood of which has perished by slow decay, or appears only in the state of fragments and films of mineral charcoal. This subject, however, will be introduced in the next section of this chapter. In the researches in coal structures next to be noticed, I have also ascertained that some Sternbergiæ are pith cylinders of Sigillariæ. (Fig. 41, *b.*)

The most abundant locality of Sternbergia with which I am acquainted occurs in the neighbourhood of the town of Pictou, immediately below the bed of erect calamites described in the Journal of the Geological Society (vol. vii., p. 194). The fossils are found in interrupted beds of very coarse sandstone, with calcareous concretions, imbedded in a thick reddish brown sandstone. These gray patches are full of well preserved calamites, which have either grown upon them, or have been drifted in clumps with their roots entire. The appearances suggest the idea of patches of gray sand rising from a bottom of red mud, with clumps of growing calamites which arrested quantities of drift plants, consisting principally of Sternbergia and fragments of much decayed wood and bark, now in the state of coaly matter, too much penetrated by iron pyrites to show its structure distinctly. We thus probably have the fresh growing calamites entombed along with the debris of the old decaying conifers of some neighbouring shore; furnishing an illustration of the truth, that the most ephemeral and perishable forms may be fossilized and preserved contemporaneously with the decay of the most durable tissues. The rush of a single summer may be preserved with its minutest striæ unharmed, when the giant pine of centuries has crumbled into mould. It is so now, and it was so equally in the Carboniferous period.

III. *Vegetable Structures in Coal.*—This is a subject which had often engaged my attention in Nova Scotia, but it was not until after my removal to Canada that I had time fully to work it out. The objects in view and the results attained are thus stated in the paper above mentioned, to which I beg to refer for details, and for an elaborate series of figures of the structures observed.

Accepting as established conclusions the vegetable origin of coal and the accumulation of its materials by growth *in situ*, rather than by driftage, there still remain some questions regarding its production, to which as yet no very satisfactory answers have been given. One of these relates to the precise genera and species of plants which have contributed the vegetable matter required; another to the causes (whether differences in the plants themselves or in the manner of their preservation) which have produced the different qualities of coaly matter observable in the different parts of the same bed, or in different beds in the same coal-field.

The observation of the beds associated with the coal, and of their contained fossils, has already furnished data which, inferentially at least, might dispose of these questions. A fundamental fact is the almost constant occurrence of Stigmaria in the underclays, first ascertained by Sir W. E. Logan, especially when taken in connexion with the further observations of Mr Binney and Mr Brown,* that Stigmaria is the root of Sigillaria. The sifting, by Sir Charles Lyell, of the comparative merits of the "estuary" and "peat" theories, and their

* See also papers by the author, Quar. Jour. Geol. Soc. 1846 and 1853.

final union, as together affording the required explanation of the observed facts,—the elaborate investigations of Goeppert in the coal-fields of Silesia,—those of Rogers, Newberry, and Lesquereux in those of the United States,—and the exploration of the wonderful coast-sections of the South Joggins and Sydney by Sir Wm. Logan, Sir C. Lyell, Mr Brown, and the author, —have all contributed facts and conclusions tending inevitably to certain results respecting the materials of coal, which, however, it appears to me, those geologists not immediately engaged in the study of the Carboniferous system have been slow to perceive.

The direct investigation of the tissues preserved in the coal itself has also been pursued to some extent by Witham, Hutton, Goeppert, Brongniart, Bailey, Hooker, Quekett, Harkness, and others. Two difficulties, however, have impeded this investigation, and have in some degree prevented the attainment of reliable results. One of these is the intractable character of the material as a microscopic object, the other the want of sufficient information in regard to the structures of the plants known by impressions of their external forms in the beds of the Coal formation. Perplexed by the uncertain and contradictory statements arising from these difficulties, and impressed with the conviction that the coal itself might be made more fully to reveal its own origin, I have for some time been engaged in experiments and observations with this object, and believe that I can now offer definite and certain results in so far as relates to the particular coals examined, and, I have no doubt, with some slight modifications, to all the ordinary coals of the true coal measures.

In ordinary bituminous coal we recognise by the unassisted eye laminæ of a compact and more or less lustrous appearance, separated by uneven films and layers of fibrous anthracite or of mineral charcoal, and these two kinds of coal demand a separate consideration.

The substance known by the very appropriate name of 'mineral charcoal' consists of fragments of prosenchymatous and vasiform tissues in a carbonized state, somewhat flattened by pressure, and more or less impregnated with bituminous and mineral matters derived from the surrounding mass. We cannot suppose that this substance has escaped complete bituminization on account of its original constitution; for we have abundant evidence that this change has passed upon similar material in various geological periods. A substance so intimately intermixed with the ordinary coal cannot be accounted for by the supposition of forest conflagrations or the action of subterranean heat. The only satisfactory explanation of its occurrence is that afforded by the chemical changes experienced by woody matter in decay in the presence of air, in the manner so well illustrated by Liebig. In such circumstances, wood parts with its hydrogen and oxygen, and a portion of its carbon, in the forms of water and carbonic acid; and, as the ultimate result, a skeleton of nearly pure charcoal, retaining the form and structure of the wood, remains. In the putrefaction of wood under water, or imbedded in aqueous deposits, a very different change occurs, in which the principal loss consists of carbon and oxygen; and the resulting coaly product contains proportionally more hydrogen than the original wood. This is the condition of the compact bituminous coal. This last may, by the action of heat, or by long exposure to air and water, lose its hydrogen in the form of hydro-carbons, and be converted into anthracite. In all the ordinary coals we have the products, more or less, of all these processes. The mineral charcoal results from subaërial decay, the compact coal from subaqueous putrefaction, more or less modified by heat and exposure to air. As Dr Newberry has very well shown, in coals, like cannel-coal, which have been formed wholly under subaqueous conditions, the mineral charcoal is deficient.*

A consideration of the decay of vegetable matter in modern swamps and forests shows that all kinds of tissues are not under ordinary circumstances susceptible of the sort of carbonization which we find in the mineral charcoal. Succulent and lax parenchymatous tissues decay too rapidly and completely. The bark of trees very long resists decay, and, where any deposition is proceeding, is likely to be imbedded unchanged. It is the woody structure, and especially the harder and more durable wood, that, becoming carbonized and splitting along the medullary rays and lines of growth, affords such fragments as those which we find scattered over the surfaces of the coal.† These facts would lead us to infer that mineral charcoal represents the woody debris of trees subjected to subaërial decay, and that the bark of these trees should appear as compact coal along with such woody or herbaceous matters as might be imbedded or submerged before decay had time to take place.

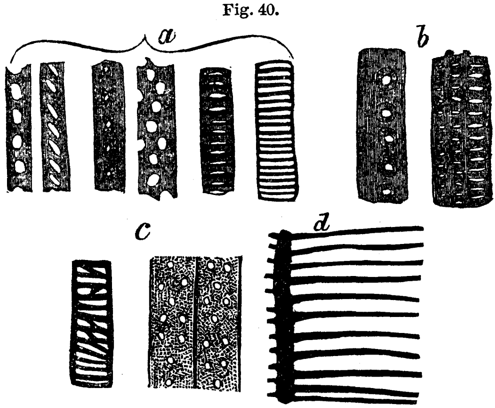
The method of preparing the mineral charcoal for ex-

* American Journal of Science. See also Goeppert, "Abhandlung über Steinkohlen;" also a paper by the author, "On Fossils from Nova Scotia," Quart. Journ. Geol. Soc. 1846.

† See paper of 1846, previously cited.

amination was an improvement on the "nitric-acid" process of previous observers, and the results gave very perfect examples of the disc-bearing tissue restricted in the modern world to conifers and cycads, but which existed also in the Sigillariæ of the coal period. With this were scalariform vessels, like those of ferns and club mosses, and several other kinds of woody tissue. On careful comparison it was found that all these tissues might be referred to the following genera of plants common in the coal measures: Sigillaria, including Stigmaria, Calamites, Dadoxylon, and other conifers, Lepidodendron, Ulodendron, ferns, and possibly some other less known plants. The perfect state of preservation of these tissues may be inferred from the following figures, selected from those prepared for my paper:—

Fig. 40.



(*a*) Tissues of Axis of Sigillaria. (*b*) Tissues of Calamites.
(*c*) Tissues of Ferns. (*d*) Scalariform Vessel of Lepidodendron.

Another form of tissue observed was a large spiral vessel, possibly belonging to some endogenous plant.

The structures preserved in the layers of shining compact coal are more obscure, and I therefore present a somewhat more full summary of the facts known in respect to them :—

The compact coal, constituting a far larger proportion of the mass than the "mineral charcoal" does, consists either of lustrous conchoidal *cherry* or *pitch coal*,—of less lustrous *slate coal*, with flat fracture,—or of coarse coal, containing much earthy matter. All of these are arranged in thin interrupted laminæ. They consist of vegetable matter which has not been altered by subaërial decay, but which has undergone the bituminous putrefaction, and has thereby been resolved into a nearly homogeneous mass, which still, however, retains traces of structure and of the forms of the individual flattened plants composing it. As these last are sometimes more distinct than the minute structures, and are necessary for their comprehension, I shall, under the following heads, notice both as I have observed them in the coals in question.

1. The laminæ of pitch or cherry coal, when carefully traced over the surfaces of accumulation, are found to present the outline of flattened trunks. This is also true, to a certain extent, of the finer varieties of slate coal; but the coarse coal appears to consist of extensive laminæ of disintegrated vegetable matter mixed with mud.

2. When the coal (especially the more shaly varieties) is held obliquely under a strong light, in the manner recommended by Goeppert, the surfaces of the laminæ present the forms of many well-known coal-plants, as Sigillaria, Stigmaria, Poacites or Cordaites, Lepidodendron, Ulodendron, and rough bark, perhaps of conifers.

3. When the coal is traced upward into the roof-shales,

we often find the laminæ of compact coal represented by flattened coaly trunks and leaves, now rendered distinct by being separated by clay.

4. In these flattened trunks it is the outer cortical layer that alone constitutes the coal. This is very manifest when the upper and under bark are separated by a film of clay or of mineral charcoal, occupying the place of the wood. In this condition the bark of a large Sigillaria gives only one or two lines in thickness of coal; Stigmaria, Lepidodendron, and Ulodendron give still less. In the shales these flattened trunks are often so crushed together that it is difficult to separate them. In the coal they are, so to speak, fused into a homogeneous mass.

5. The phenomena of erect forests explain, to some extent, the manner in which layers of compact coal and mineral charcoal may result from the accumulation of trunks of trees *in situ*. In the sections at the South Joggins, the usual state of preservation of erect Sigillariæ is that of casts in sandstone, enclosed by a thin layer of bark converted into compact, caking, bituminous coal, while the remains of the woody matter may be found in the bottom of the cast in the state of mineral charcoal. In other cases the bark has fallen in, and all that remains to indicate the place of a tree is a little pile of mineral charcoal, with strips of bark converted into compact coal. Lastly, a series of such remains of stumps, with flattened bark of prostrate trunks, may constitute a rudimentary bed of coal, many of which exist in the Joggins section. In short, a single trunk of Sigillaria in an erect forest presents an epitome of a coal-seam. Its roots represent the Stigmaria underclay; its bark the compact coal; its woody axis the mineral charcoal;

its fallen leaves, with remains of herbaceous plants growing in its shade, mixed with a little earthy matter, the layers of coarse coal. The condition of the durable outer bark of erect trees concurs with the chemical theory of coal, in showing the especial suitableness of this kind of tissue for the production of the purer compact coals. It is also probable that the comparative impermeability of bark to mineral infiltration is of importance in this respect, enabling this material to remain unaffected by causes which have filled those layers consisting of herbaceous materials and decayed wood, with earthy matter, pyrites, &c.

6. The microscopic structure of the purer varieties of compact coal accords with that of the bark of Sigillaria. The compact coals are capable of affording very little true structure. Their cell-walls have been pressed close together; and pseudo-cellular structures have arisen from molecular action and the segregation of bituminous matter. Most of the structures which have been figured by microscopists are of this last character, or at the utmost are cell-structures masked by concretionary action, pressure, and decay. Hutton, however, appears to have ascertained a truly cellular tissue in this kind of coal. Goeppert also has figured parenchymatous and perhaps bast-tissues obtained from its incineration. By acting on it with nitric acid, I have found that the structures remaining both in the lustrous compact coals and in the bark of Sigillariæ are parenchymatous cells and fibrous cells, probably bast-fibres.

7. I by no means desire to maintain that all portions of the coal-seams not in the state of mineral charcoal consist of cortical tissues. Quantities of herbaceous plants, leaves, &c. are also present, especially in the

coarser coals; and some small seams appear to consist entirely of such material,—for instance, of the leaves of Cordaites or Poacites. I would also observe that, though in the roof-shales and other associated beds it is usually only the cortical layer of trees that appears as compact bituminous coal, yet I have found specimens which show that in the coal-seams themselves true woody tissues have sometimes been imbedded unchanged, and converted into structureless coal, forming, like the coniferous trees converted into jet in more modern formations, thin bands of very pure bituminous material. The proportion of woody matter in this state differs in different coals, and is probably greatest in those which show the least mineral charcoal; but the alteration which it has undergone renders it almost impossible to distinguish it from the flattened bark, which in all ordinary cases is much more abundant.

The following are the general conclusions arrived at in respect to the origin and materials of the coal:—

"1. With respect to the plants which have contributed the vegetable matter of the coal, these are principally the Sigillariæ and Calamiteæ, but especially the former. With these, however, are intermixed remains of most of the other plants of the period, contributing, though in an inferior degree, to the accumulation of the mass. This conclusion is confirmed by facts derived from the associated beds,—as, for instance, the prevalence of Stigmaria in the underclays, and of Sigillariæ and Calamites in the roof-shales and erect forests.

"2. The woody matter of the axes of Sigillariæ and Calamiteæ and of coniferous trunks, as well as the scalariform tissues of the axes of the Lepidodendreæ and Ulodendreæ, and the woody and vascular bundles of ferns, appear principally in the state of mineral charcoal. The outer cortical envelop of these plants, together with such portions of their wood and of herbaceous plants and foliage as were submerged without subaërial decay, occur as compact coal of various degrees of purity: the cortical matter, owing to its greater resistance to aqueous infiltration, affording the purest coal. The relative amounts of all these substances found in the states of mineral charcoal and compact coal depend principally upon the greater or less prevalence of subaërial decay, occasioned by greater or less dryness of the swampy flats on which the coal accumulated.

"3. The structure of the coal accords with the view that its materials were accumulated by growth, without any driftage of materials. The Sigillariæ and Calamiteæ, tall and branchless, and clothed only with rigid linear leaves, formed dense groves and jungles, in which the stumps and fallen trunks of dead trees became resolved by decay into shells of bark and loose fragments of rotten wood, which currents would necessarily have swept away, but which the most gentle inundations or even heavy rains could scatter in layers over the surface, where they gradually became imbedded in a mass of roots, fallen leaves, and herbaceous plants.

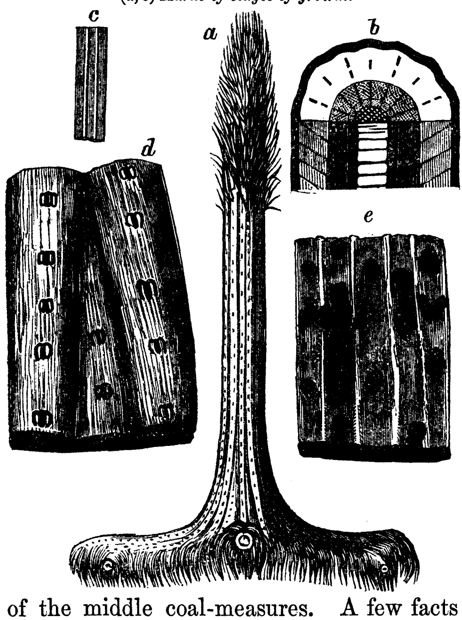
"4. The rate of accumulation of coal was very slow. The climate of the period, in the northern temperate zone, was of such a character that the true conifers show rings of growth not larger nor much less distinct than those of many of their modern congeners.* The Sigillariæ and Calamites were not, as often supposed, composed wholly, or even principally, of lax and soft

* Paper on Fossils from Nova Scotia, Quart. Journ. Geol. Soc. 1847.

tissues, or necessarily short-lived. The former had, it is true, a very thick cellular inner bark; but their dense woody axes, their thick and nearly imperishable outer bark, and their scanty and rigid foliage, would indicate no very rapid growth or decay. In the case of Sigillariæ, the variations in the leaf-scars in different parts of the trunk, the intercalation of new ridges at the surface representing that of new woody wedges in the axis (Fig. 41, *d*), the transverse marks left by the stages of upward growth (Fig. 41, *c*)—all indicate that several years must have been required for the growth of stems of moderate size. As the best means of illustrating these features of the growth of Sigillaria, I have given, in Fig. 41, a restoration of a plant of this genus, with figures illustrative of its mode of growth, from specimens in my own possession. The enormous roots of these trees, and the conditions of the coal-swamps, must have exempted them from the danger of being overthrown by violence. They probably fell, in successive generations, from natural decay; and, making every allowance for other materials, we may safely assert that every foot of thickness of pure bituminous coal implies the quiet growth and fall of at least fifty generations of Sigillariæ, and therefore an undisturbed condition of forest-growth enduring through many centuries. Further, there is evidence that an immense amount of loose parenchymatous tissue, and even of wood, perished by decay; and we do not know to what extent even the most durable tissues may have disappeared in this way; so that in many coal-seams we may have only a very small part of the vegetable matter produced.

"*Lastly*, the results stated in this paper refer to coal-

Fig. 41.—(*a*) *Restoration of Sigillaria;* (*b*) *Section of stem, showing pith, woody axis, and inner and outer bark;* (*c*) *Portion of leaf;* (*d, e*) *Marks of stages of growth.*



beds of the middle coal-measures. A few facts which I have observed lead me to believe that, in the thin seams of the lower coal measures, remains of Cordaites and Lepidodendron are more abundant than in those of the middle coal-measures. In the upper coal-measures similar modifications may be expected."

IV. *New Reptiles, &c.*—In revisiting the Joggins in the summer of 1859, chiefly with the view of examining more carefully than I had been able previously to do, the upper and lower portions of that section, and of collecting material for the further prosecution of my researches on coal, I was so fortunate as to discover, with the assistance of Mr Boggs, the superintendent of the Joggins mines, a fossil stump similar to that described at p. 161, "Acadian Geology," and abounding in remains of terrestrial animals. It occurred in the same bed with that formerly discovered—namely, No. XV. of the detailed section of the South Joggins coal-measures—and was even more interesting and curious than that found in 1851.

The reptiliferous tree of 1851 had fallen from the cliff before it was observed; and though, by putting together the fragments, it was possible to form a pretty correct idea of their original arrangement, this could not be ascertained with positive certainty. In the present specimen, the arrangement of the materials filling the stump could be distinctly seen, and corresponded perfectly with that inferred in 1851. The trunk was indistinctly ribbed in the manner of Sigillaria on its outer surface. It was rooted in arenaceous shale or fine argillaceous sandstone, immediately over a six-inch coal, and had extended upward into the overlying sandstone, but the upper part had been removed by the sea. The bottom of the trunk was floored as usual with a thin layer of carbonized bark. On this rested a bed of fragments of mineral charcoal, about an inch in thickness, being probably the fallen remains of the woody axis of the trunk. On microscopic examination this charcoal displays elongated wood-cells, some of them with pores or discs in several rows, as in many sigillaroid trees. Imbedded in the upper part of the layer of mineral charcoal were a few reptilian bones. Above the charcoal the trunk was filled to a height of about six inches with a hard, black, laminated material, consisting of sand and carbonized vegetable matter, cemented by carbonate of lime. In this occurred the greater part of the animal remains, along with many fragments of plants, principally leaves of Cordaites, Carpolites, bark of Lepidodendron, Calamites, and abundance of mineral charcoal showing the structures of Stigmaria, Lepidodendron, and the leaf-stalks of ferns. In the lower part of the mass was a cast in sandstone of a Sternbergia pith, perhaps that of the tree itself. The animal remains were so arranged as to show that they must have been introduced at intervals in the process of the filling of the hollow stump; and the scattered condition of the bones indicated that the soft parts had time to decay at the surface before new additions were made to the mass. The upper part of the carbonaceous matter, above described, alternated with thin layers of gray sandstone, with which the remainder of the trunk had been filled in the usual manner.

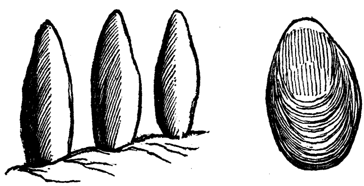
This tree must, as usual with erect Sigillariæ in this section, have become hollow by decay and been filled from above, after being partially buried in sediment. The peculiarity to which it owes its abundance of animal remains is, that the hollow cylinder resulting from its decay remained open for some time in a swamp or forest, receiving merely soil and vegetable and animal matters, washed in by rains or falling from above, before—by submergence or some violent inundation—it was filled with sand. Such a combination of circumstances must have been rare; and hence the occurrence of reptilian remains hitherto in the trees of this bed alone. While existing as open pits, such hollow stumps may either have been places of shelter to the creatures found in them, or may have been too deep to permit their escape when they fell in by accident. Very probably they were places of residence for snails, myriapods, &c., and traps and tombs to the reptiles. The quantity of coprolitic matter in some of the layers may indicate that some of these last subsisted for a time in these underground prisons.

Descriptions and figures of the animal remains found in this singular repository were sent to the Geological Society of London, and are published in its proceedings. The following summary will give a general idea of their nature :—

*Hylonomus** *Lyelli* (N. Sp.)—This is a new carboniferous reptile, about six inches in length. It has smooth cranial bones, numerous conical teeth, about fifty-two in each jaw, well developed ribs, and remarkably large and strong hind limbs. The body was covered with bony scales.

Hylonomus aciedentatus (N. Sp.)—is a somewhat larger species, closely resembling the first in general form, but having the teeth flattened and expanded toward the summits, and about eighty in each jaw.

Fig. 44.



Teeth and Scale of *Hylonomus aciedentatus* (magnified).

Hylonomus Wymani (N. Sp.)—This is a very small species,

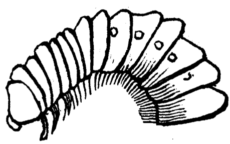
* "Forest-dweller," from its supposed habitat in the Sigillaria woods of the Coal period.

with more elongated vertebræ than the others, and about twenty-two obtusely conical teeth in each jaw. It is probably the species to which the small vertebræ found in the tree of 1851 belonged.

Dendrerpeton Acadianum (Owen).—Remains of two specimens of this animal were found, and they illustrated several points in its structure not exhibited by the specimen found in 1851. The cranium was sculptured after the manner of the Labyrinthodonts; the teeth were in two series, the outer simple and conical, the inner larger and furrowed with corrugated plates of dentine. The vertebræ were ossified, but biconcave; the ribs and limbs stout and short. The body was covered with thin ovate scales.

*Xylobius** *sigillariæ* (N. Sp.)—This is an articulated animal, of which a number of specimens were found in a flattened state. On careful examination they were found to present the characters of the gally-worms or millipedes, creatures not before found in the palæozoic rocks, but which must have had many congenial dwelling-places in the forests of the Coal period.

Fig. 45.



Portion of *Xylobius sigillariæ* (magnified).

* "Living in wood"—its supposed habitat being the interior of decaying trunks.

Pupa vetusta (N. Sp.)—This is the land-snail described and figured at page 160 ("Acad. Geol."), and still the only representative of the air-breathing snails in the palæozoic rocks. Numerous specimens were found, which enabled me completely to restore the form of this pretty little species, perhaps the first-born of its order, and to ascertain that it differed in no material respect from the modern genus Pupa.

The discovery of all these remains in the interior of a hollow stump about fifteen inches in diameter, indicates that these and perhaps other land animals abounded in the coal forests, and forcibly impresses us with the probable imperfection of our knowledge of the terrestrial fauna of that ancient period. If so many creatures could thus be entombed in one spot, how many others may there have been which, from size or mode of life, could not find access to such a repository—how many others in other districts, or on the hills and rising grounds which bounded the coal swamps. We have no doubt yet much to learn respecting palæozoic terrestrial life.

With respect to the grade of these creatures in our systems, the Pupa and Xylobius fill up for the coal period two gaps in the molluscs and the articulates. The Dendrerpeton and its allied, though larger, contemporary, the *Baphetes planiceps* * of the Pictou coal-field,

* The specific name *planiceps* is by no means happy, as the flattening is due to pressure, and there is no reason to believe that the creature had a flatter head than others of its order. Since the description of the species by Professor Owen, I have discovered a bone, probably of the scapular arch, which would seem to indicate limbs of considerable dimensions, and a rounded dermal scale, corrugated like the surface of the skull. The original specimen was the

appear to belong to that group of mailed batrachians peculiar to the palæozoic and mesozoic rocks, and of which the Labyrinthodon is the type. The genus Hylonomus would appear to have been more lizard-like in its affinities, and possibly belonged to the true reptiles rather than to the batrachians; in which case it will take a higher place in the zoological scale than any other generic form yet found in the Carboniferous system.

V. *Lower Carboniferous Coal Measures.*—The sandstones and shales containing fossil plants and remains of fishes, locally underlying the lower carboniferous limestone, and distinct from, though liable to be confounded with the true coal-measures, are of so great interest that I thought it desirable, on revisiting Nova Scotia in 1857, to re-examine the sections of these beds at Horton and Windsor, described in Chapter XI. I had the pleasure in this examination of the company and aid of Dr Harding and Professor How of Windsor, and Rev. Mr Rand of Hantsport. The results were embodied in the following table, which presents at one view the relations of the different members of the coal series in the localities of the most instructive exposures of the lower coal measures:—

first batrachian bone found in the Coal formation of America, having been discovered by the writer in 1850, and presented, with a note on its geological position, to the Geological Society of London, in that or the following year, but it was not described until 1854.

TABULAR VIEW OF THE LOWER COAL-MEASURES.

	Horton.	*Mill-Brook, Windsor.*	*Hillsborough, N. Brunswick.*	*Plaister Cove, C. Breton.*
Upper Coal-Measures.	Not seen.	Not seen.	Upper sandstones and shales of South Joggins.	Not seen.
Middle Coal-Measures.	Not seen.	Not seen.	Coal-measures of Joggins, and Millstone grit, or lower coal-measures of Dorchester, &c.	Coal-measures of Caribou Cove, River Inhabitants, and Ship Harbour. Sandstones of Strait of Canseau.
Lower Carboniferous Marine Limestones.	Limestone, marl, red sandstone, and gypsum of Half-way River and Windsor.	Same as last column.	Limestones, gypsum, and conglomerate of Dorchester and Petitcodiac R.	Limestone, gypsum, and marls of Plaister Cove.
Lower Coal-Measures.	Dark clay shale and calcareous shale, with laminated limestone, dark micaceous flags, gray and white sandstone, and in the lower part some red sandstone. Plants, fishes, entomostraca, worm tracks, ripple and rain marks, sun cracks, reptilian footprints, erect trees. Lower Horton, Wolfville, Horton Bluff, Half-way River. (Paper by Sir C. Lyell, Geol. Proc. iv. p. 184. Paper by the author, Geol. Journ., vol. iv. p. 59. Obs. by the author in 1857.)	Thick white sandstone (debris of white granite), in places with quartz pebbles, fragments of plants. Dark micaceous flags and shales, obscure footprints, carbonaceous impressions, an underclay, a thin ironstone, gray coarse sandstone and conglomerate, white sandstone, carbonaceous shale, and black underclay. Near the bottom irregular and shore-like layers of coarse sandstone, shale, Lepidodendra. (Paper by Sir C. Lyell, *l. c.* Obs. by the author, 1857.)	Fine calcareous and highly bituminous shales, with thin beds of sandstone. Abundance of remains of fishes, seen at Petitcodiac River, above Dorchester, Albert Mine, and other localities westward of that place. (Paper by the author, Geol. Journ., vol. ix. p. 107.)	Hard sandstones and shales of gray and black colours, with obscure fragments of plants, resting on coarse gray conglomerate of great thickness. (Paper by author, Geol. Journ., vol. v. p. 335.)
Underlying Rocks.	Upper silurian slates—unconformable.	Hard thick-bedded rock, resembling an indurated volcanic ash—no fossils; age uncertain.	Metamorphic rocks of uncertain age, in coast range of New Brunswick.	Slates, &c., of Cape Porcupine, &c., probably Upper Silurian.

With respect to their general arrangement, the lower coal-measures skirt the margin of the carboniferous region, from Horton and Windsor, by Rawdon and the Shubenacadie, as far as Stewiacke. They reappear along an anticlinal line parallel to the former, at Walton, Noel, and other places on the shore of the Bay of Fundy. The intervening trough is filled with the gypsiferous or lower carboniferous series, with the exception of a limited space near the Kennetcook and Five-Mile Rivers, occupied by beds which perhaps represent the middle coal-measures, though they may be a local upheaval of the beds now under consideration. The two lines above mentioned run in a N.E. and S.W. direction, and are distant ten to fifteen miles from each other. Northward of this, these beds are not seen again until they are thrown up in a disturbed condition along the base of the Cobequid mountains, where they are associated with great beds of conglomerate, and, owing to the slender development of the marine limestones, appear in some places to pass upward into the true coal-measures. On the northern side of the Cobequids I have observed no definite development of these beds, and their next appearance is in the remarkable bituminous shales near Dorchester, and in Albert county, New Brunswick. Details on these subjects will be found in the paper above referred to; and I may here give a summary of the characteristic fossils of the lower coal-measures, beginning with the plants:—

Lepidodendron.—This genus is very characteristic of these beds, as distinguished from the middle coal series. *L. elegans*, *L. Sternbergi*, and a new species, *L. corrugatum*, are the most abundant forms.

There are also at Horton immense quantities of spherical or flattened carbonaceous bodies, resembling small shot, which I at one time supposed to be spawn of fishes, but Dr Hooker regards them as the spore-cases of Lepidodendra.

Sigillaria.—A narrow-ribbed species, like *S. angusta*, Brongt.

Stigmaria—of the forms known as *ficoides* and *stellata.*

Filices.—A very fine fern, closely resembling the *Sphenopteris* (*Cyclopteris*) *adiantoides* of Lindley and Hutton, is very abundant at Horton. With this there is another species, which in my paper I called *Schizopteris;* but farther specimens, obtained from Mr Hart of Wolfville, show that it differs materially from anything hitherto described. It presents magnificent fronds which must sometimes have been five feet in length. The leaf-stalks are finely striated and dichotomous, the pinnules terminal and cuneate, with the venation of *Noeggerathia;* and the fructification was borne on the divisions of the petiole, near their divergence from the main stem, as in the modern *Anemia tomentosa* of Brazil. I hope to describe this plant more fully elsewhere.

Cordaites.—To the genus thus named must, I believe, be referred the long parallel-sided and parallel-veined leaves common in the lower and middle coal-measures, and which I have elsewhere in this volume named *Poacites.* Their botanical affinities are still doubtful.

Calamites—so common in the middle and upper coal-measures—occur in these beds very rarely.

Animal Remains.—As early as 1841, Sir W. E. Logan discovered footprints, apparently of a small quadruped, at Horton Bluff. Some years later, Dr Harding found similar impressions in beds of the same age at Parrsborough. Though discredited at the time, the discovery of Sir W. E. Logan was real, as I have convinced myself by comparing the specimen in his collection with those found at the Joggins and elsewhere, and was consequently the earliest evidence of the occurrence of reptiles in the coal rocks of America.

Remains of fishes are very abundant, especially at Horton and Albert Mine. Most of them are of small species, allied to Palæoniscus, and probably inhabitants of fresh water; but there are others of the genera Rhizodus, Gyrolepis, Ctenacanthus, &c., which were large and predaceous.

Minute Entomostraca, allied to, though apparently not specifically identical with, the cyprids of the coal-measures, are abundant at Horton, as are trails of annelids, some of the most curious of which I have figured in the paper already referred to.

VI. *Miscellaneous Carboniferous Fossils.*—A great number of new or undetermined species of fossils from the Carboniferous system of Nova Scotia still remain in my collection; and I may add here some remarks respecting such of these as I have had time to examine.

In the section of the South Joggins a number of animal remains are mentioned merely by their generic names. They occur principally in the layers of bituminous limestone and calcareous shale believed to have been deposited in lagunes or estuaries existing in or near the coal swamps, and filled with either fresh or brackish water. Similar beds occur in the Sydney and Pictou coal-fields under similar relations. These fossils have as yet received little attention, and I am scarcely now prepared to do more than contribute a few notes toward their determination.

The Spirorbis, so often mentioned as occurring attached to fragments of plants, appears to be perfectly identical with the *S. carbonarius*, or, as it was formerly called, *Microconchus carbonarius* of the British coal-fields. I can distinguish no other specific form among the countless specimens to be found in the Joggins section; and it seems to have continued throughout the whole period of the Middle and Upper Coal formation. I have not yet seen it in the Lower Coal formation.

The so-called Modiolæ of the coal-measures are still uncertain as to their affinities. They do not come within the characters of the genera Cardinia, Anthracosia, &c., to which fossils occurring in similar situations in the British coal-fields have been referred. They are all thin shells, marked with growth lines, but destitute of other ornamentation, and, so far as can be observed, without teeth. In so far as external form is concerned they may all be referred to the genera Modiola and Anodon. But mere form may be a very fallacious guide, and I shall notice what seem to me to be the distinct specific forms under the provisional name Naiadites, intending thereby to express my belief that they are probably allied to the Unionidæ. They are certainly distinct from any of the fossils of the marine carboniferous limestones, and are never associated with marine fossils. It is possible that their nearest living analogues are the species of *Bysso-anodonta* of D'Orbigny, found in the River Parana.

(1.) *Naiadites carbonarius* (N. Sp.) — Hinge-line nearly straight, more than one half the length of the shell; beak acute, in the anterior fourth of hinge-line; anterior margin abruptly rounded; ventral margin nearly straight; posterior margin broad and regularly rounded; shell thin, with distinct growth lines. When recent the shell was probably somewhat tumid, but is usually flattened, and often much distorted by pressure. Length of adult, about one inch. This is the most abundant species in the coal-measures of the Joggins: beds of some thickness being often almost entirely made up of the valves. Fig. 10, p. 148 ("Acad. Geol."), represents a somewhat distorted specimen. See also Fig. 22, in my paper on the South Joggins, in the Journal of Geological Society, vol. x. p. 39. This shell may possibly be the *Modiola Wyomingensis* of Lea (Journ. Ac. Nat. Science, 2d series, vol. ii.); but his specimen is imperfect.

(2.) *Naiadites elongata* (N. Sp.)—Smaller than the preceding, and more elongated laterally; the beaks obtuse and more anterior; the hinge-line nearly straight and less than half the length; ventral margin slightly compressed; length about half an inch; common at the Joggins and Sydney, in the middle coal-measures. See Fig. 23, in paper above cited.

(3.) *Naiadites laevis* (N. Sp.)—Broad ovate, extremely thin; beak about one-third of distance from anterior end. This species is smaller, more rounded, thinner, and with the beaks more central than No. 1. It occurs in a bed of shale at the base of the middle coal series at the Joggins.

(4.) *Naiadites arenaceus.*—Elliptical; twice as long as wide; beaks prominent, one-fourth from anterior end, which is compressed and rounded. In arenaceous shale at Pictou.

(5.) *Naiadites ovalis.*—Similar in general form to No. 4, but much broader in proportion. See paper above cited, Fig. 24. It occurs in bituminous limestone, with cyprids, in the lower part of the Joggins coal-measures.

(6.) *Naiadites angulata.*—Similar in general form and proportions to No. 4, but with more prominent beaks, a straight hinge-line and an undefined ridge running backward from the umbo, and causing the posterior extremity to present an angular outline. Lower Coal formation at Parrsborough.

Remains of *fishes* are frequently noticed as occurring in the beds containing the remains above mentioned. For the greater part these are scales of small lepidoids, which were probably inhabitants of fresh water, and provided with the lung-like air-bladder which enables the Lepidosteus and Amia to subsist in water deprived of its free oxygen by decomposing vegetable matter, as must have been the case with the lagunes of the coal swamps. With these are, however, some remains of larger ganoids, especially of the genus Rhizodus, of which there are scales and teeth that must have belonged to more than one species.

I have also in my collection a tooth of a *Ctenoptychius*, differing from any species of which I have seen a description. It is two lines in length, with fourteen sharp denticles, much compressed, and with a narrow base. Another very fine tooth found in these beds belongs to the genus *Conchodus*. It has seven strong angular ridges, with a slightly granulated and obliquely wrinkled surface, and is an inch and a half in length, and about seven lines wide in the middle. The anterior edge is slightly and regularly rounded, and the posterior edge forms an obtuse angle rounded at the apex.

Many scales and other remains of fishes occur in the bed in the Albion coal seam which afforded the *Baphetes planiceps*, and which is evidently in the manner of its formation of the same general character with the Modiola and Cypris shales of the Joggins. Most of these belong to the genus Rhizodus, and to a species not distinguishable from *R. lancifer* (Newberry) of the coal-field of Ohio. There is also a fine species of Diplodus, which appears to be new, and which I would name *D. acinaces*. Its lateral denticles are compressed and sharp-edged, but scarcely crenulated, and both bent in the same direction. Middle cone obsolete; base large and broad. One denticle is usually much larger than the other. The greatest diameter of the larger denticle is to its length as one to three. A tooth of ordinary size measures six lines from the lower side of the base to the point of the longest denticle, and the base is four lines broad (Fig. 43). I regard as probably belonging to this fish certain cylindrical spines found in the same bed. They are about half an inch in diameter, with nearly central canal two lines in diameter, and marked externally by parallel longitudinal striæ.

Since 1855 I have recognised a considerable number of species of plants in the Coal formation, not included in the lists appended to this work. I have also obtained several additional species of marine shells from the Lower Carboniferous limestone; but there is nothing especially remarkable in these remains, and mere lists of them would be uninteresting to the general reader.

VII. I am indebted to H. Poole, Esq., Superintendent of the Fraser Mine, Pictou, for a very valuable communication* on the recent discoveries in the Pictou coal-field, of which I present the following summary:—

The Fraser Mine is worked in a bed about 528 feet in vertical thickness below the "Deep seam" of the Albion Mines. Part of this thickness appears to be composed of barren sandstones and shales similar to those separating the more productive portions of the coal-measures at the Joggins. In the lower part are soft shales, with bands of ironstone, and containing Stigmara, Sigillaria, and fern leaves. Below these is a bed of coal, fourteen inches in thickness, and, I presume, the same referred to in "Acadian Geology," p. 263. Only the lower four inches are of good quality, the remainder being soft and impure. Below this bed lies the "oil coal" of the Fraser Mine, which is a substance of shaly aspect, laminated, and slickensided, and the laminæ much twisted, causing it to be distinguished as "curly" oil coal. This bed varies from two to twenty inches in thickness. Under it is a bed called "oil shale," about two feet thick, and containing ganoid scales, Lepidodendron and Cordaites. Below this are argillaceous shales abounding in Cypris and Spirorbis.

The crop of a small seam of coal, which must underlie the Fraser Mine about thirty feet, is seen in the vicinity; and on the property of Robert Culton, nearly a mile distant to the S.W., a bed of oil coal, in many respects resembling that of the Fraser Mine, appears with a similar N.E. dip, and probably underlies the latter.

The texture, the slickensided character, and the

* Published in the Canadian Naturalist and Geologist.

associations of the "oil coal" prove that it is of the nature of a highly bituminous underclay,—in short, a water-soaked vegetable soil, completely bitumenized, and twisted and slickensided owing to the giving way under pressure of the roots and trunks with which it was interlaced.* It is a very valuable material: the curly variety affording, in the ordinary "D retort," 63 gallons of crude oil per ton, and the shale below 45 gallons per ton.

At the Fraser Mine the dip is N. 42° E., at an angle of 18°, which corresponds with that of the Albion Mines coal-measures. But west of the Fraser Mine there seems to be a dislocation, beyond which the measures dip N. 67° W., at an angle of 13°. At this place the oil coal appears with its usual thickness, and of even better quality than at the Fraser Mine. Various trials on and near the M'Culloch Brook, about midway between the East and Middle Rivers, show that the whole of the measures are here bent to the northward with various minor fractures, and present a general northerly dip; but further towards the Middle River they appear to recover their N.E. dip.

From Mr Poole's observations, in connection with what I have myself noted, it appears that to the N.E. of the Albion Mines the beds are thrown into an abrupt synclinal fold, dipping to the southward on the East River, about half a mile above New Glasgow, and along a line extending thence to the S.E. Beyond this there is an anticlinal which corresponds in some degree, though not perfectly, with the outcrop of the great New Glasgow

* This I believe to be the true origin of most of the "earthy bitumens" and "oil coals," which have excited so much controversy.

conglomerate, to the north of which the dips are northerly as far as Pictou Harbour.

To the S.E. of the Albion Mines, about three miles distant, and nearly on the same line of outcrop, there are coal-measures on M'Lellan's Brook containing small seams of coal, and a bed of earthy bitumen which is now worked. These beds are probably near the bottom of the coal-measures, and are succeeded in descending order by lower carboniferous rocks, and in ascending order are met by coal-measures dipping S. 15° E. This place appears, in short, to be nearly at the running out of the synclinal above referred to.

In the country north of the great conglomerate, small beds of coal and bituminous shale, with remains of fishes, have been met with in several places, but have not hitherto proved workable. A small collection of the fish remains from these beds, and those previously mentioned, has been forwarded by Mr Poole, and will be noticed in the sequel.

The facts above stated in no respect shake the conclusion that the New Glasgow conglomerate is contemporary with the Albion coal-measures, and the remains of a great accumulation of shingle separating these from the more open space without. On the contrary, they tend to confirm it; and none of the fossils obtained by Mr Poole indicate any recurrence of lower carboniferous rocks in the anticlinal, which throws up the conglomerate in association with beds of the middle coal-measures. A very remarkable fact stated by Mr Poole is perhaps a proof of the contemporaneous disturbances and changes of level connected with the original formation of this conglomerate. He says:

"There are numerous small faults running across the measures in the Fraser Mine, which are uniformly downthrows to the west; and I may here mention that I observed, some years ago, in the Deep seam, several faults from four to ten feet each, which could not be found in the main coal workings above (the distance between the two seams is 157½ feet), which shows that the disturbances must have taken place previous to the formation of the Main coal seam."

The observations thus made by Mr Poole bear mainly on the following points:—(1.) The character of the coal-measures below the Deep seam, previously very little known. (2.) The sudden bending of the outcrops of the measures so as to strike nearly east and west, at a short distance westward of the Albion Mines. (3.) The better definition of the various folds and fractures of the measures between the Albion Mines and Pictou Harbour. (4.) The occurrence of several bituminous shales and small coals, with remains of fishes, &c., north of the New Glasgow conglomerate.

Among the fossils forwarded to me by Mr Poole, the most interesting are the following:—

(1.) A new Diplodus (*D. penetrans*), Fig. 42. This is smaller than *D. acinaces* of the Main coal (Fig. 43). Its height is about two and a half lines, and the breadth nearly the same. The lateral points are half as broad as long, and flattened; rhombic in cross section at the base; serrated, especially at the outer and lower margins.

Fig. 42.

Fig. 43.

They diverge at an angle of 35° to 40°, and the central denticle is small and conical. The base is broad and strongly lobed. These teeth occur in the roof of beds of coal near to, and above the New Glasgow conglomerate, and therefore in the upper part of the middle coal measures, and perhaps also in the upper coal measures.

(2.) *Ctenoptychius.* A small tooth with eight denticles; —the specimen is an imperfect impression.

(3.) Remains of several ganoid fishes. One of these is a conical curved tooth, half an inch long, smooth on the convex side, and marked on the concave side with five spiral ridges. It probably belongs to the genus Rhizodus. With it are scales, possibly of the same fish, which have the punctures and striæ of the genus Osteoplax of M'Coy. There are also two remarkable flattened sabre-shaped spines, one inch and a half in length, and resembling in general form the Devonian Machæracanthus. Several rounded scales have the characters of those of Rhizodus, and there are numerous scales and other remains referable to Palæoniscus and allied genera. These last in the Albion measures, as at the Joggins, abound in the bituminous shales and thin coals.

In the lower part of the measures at M'Lellan's Brook is found a *Naiadites* (*N. obtusa*, N. Sp.) as large as *N. carbonarius*, but remarkable for the broad and truncated form of its anterior end, giving it an approach to a quadrangular form. It is thin, and much marked by growth lines.

SILURIAN AND DEVONIAN ROCKS.

The notices of these rocks in the previous pages of this volume are confessedly very imperfect, owing to the limited opportunities for their study which I had enjoyed, to the difficulties of the formations themselves, the deficiency or bad state of preservation of the fossils, and the absence of sufficient suites of these for comparison. With the view of remedying these deficiencies, I have embraced such opportunities as have occurred to me, since the publication of "Acadian Geology," to study these rocks in those parts of the country which appeared to promise the most satisfactory results. My collections of fossils have also been increased by contributions received from Dr Webster of Kentville, who has long directed his attention to the New Canaan and Nictaux districts, which I have had the advantage of exploring under his guidance; from the Rev. D. Honeyman, who has carefully collected the fossils of the Arisaig section; and from Mr C. F. Hart of Wolfville. Prof. Hall of Albany has also kindly consented to apply his unrivalled knowledge of the palæozoic fauna of America to the determination of the fossils, and has enabled me to publish with these notes his descriptions of the more important new species.

With these aids, though aware that the complete solution of all the difficulties of these deposits must await a systematic and detailed survey, I hope now to fix with certainty the geological position of several important series of beds, and thus to afford some data for comparison with the formations of similar age in other countries.

1. Lower Silurian.—The Atlantic coast series described in Chapter XV., which I regard as probably of this age, has afforded little that is new since my former publication on the subject. It extends continuously, with prevailing east and west strike and northerly dip, from Cape Canso to the middle of the peninsula at Halifax Harbour. Thence it continues with prevailing north-east and south-west strike to the western extremity of the province. Its most abundant rocks are coarse clay slate and quartzite in thick beds. In some districts the slates are represented by mica-schist and gneiss, and interrupted by considerable masses and transverse bands of intrusive granite. It has afforded no fossils; but it appears to be the continuation of the older slate series of Mr Jukes* in Newfoundland, which has afforded trilobites of the genus Paradoxides.† These fossils would indicate a position in the lower part of the Lower Silurian series, possibly on the horizon of the Potsdam sandstone or Lingula flags. If so, the Lower Silurian limestones are either absent or buried by the unconformable superposition of the next series, or of the carboniferous beds which in some places immediately adjoin these older rocks.

It is, however, proper to state that on a comparison of these rocks with the series of altered deposits from eastern Canada, collected by the Canadian Survey, and elaborately examined by Mr Sterry Hunt, they appear more nearly to resemble those of the Hudson River group than any other of the series. It seems also that chiastolite and staurotide, which occur abundantly in some parts of the Nova Scotia coast series, as, for

* Survey of Newfoundland.

† Salter, Proceedings of the Geological Society of London, 1859.

example, at Cape Canseau and in Shelburne, are characteristic in Canada and New England of altered Upper Silurian and Devonian rocks. It is possible that this last fact may be accounted for by the local occurrence of some beds newer than the others; and the characters of the Silurian and Devonian series, as seen elsewhere in Nova Scotia, seem at least to exclude the mass of these coast rocks from any formation newer than the Middle Silurian.

2. Middle and Upper Silurian.—The inland group of metamorphic rocks, described in Chapter XIV., is more variable in its character, presenting many varieties of shales and slates, sometimes talcose and chloritic, often coarse and arenaceous, and associated with beds of sandstone and quartzite, and with calcareous layers. In some districts there are also extensive beds which have the appearance of interstratified igneous products both of hornblendic and felspathic composition. The associated igneous rocks are granite (which appears to be continuous with that of the coast series and intrusive), syenite, diorite, porphyry, and compact felspars. The more highly altered portions are penetrated by numerous veins of peroxide and carbonate of iron, with copper and iron pyrites.

These beds, as well as the overlying Devonian series, have been thrown into folds, varying in direction from east and west to north-east and south-west, and have been at the same time much altered and disturbed by plutonic rocks. They afterwards suffered extensive denudation, forming both anticlinal and synclinal valleys, in which were deposited beds of the carboniferous system, and of the New Red Sandstone, a deposit still of uncertain age. This denudation has apparently been so complete as to remove from view nearly all the softer and least altered beds, the remains of which appear principally at the margins of the valleys now filled by the carboniferous series. Even in these exceptional spots they have in some instances been farther obscured by trappean eruptions of carboniferous or later date. The following are the principal localities in which I have been able to obtain determinable fossils. The geographical position of these points will be found in the map.

Arisaig.—Near this place, at the extreme northern limit of the Silurian system, on the eastern coast of Nova Scotia, is one of the most instructive sections of these rocks in the province. At the eastern end of the section, where they are unconformably overlaid by lower carboniferous conglomerate and interstratified trap,* the Silurian rocks consist of gray and reddish sandy shales and coarse limestone bands dipping south at an angle of 44°. The direction of the coast is nearly east and west, and in proceeding to the eastward, the dip of the beds turns to south 30° west, dipping 45°, so that the series, though with some faults and flextures, is on the whole descending, and exhibits, in succession to the rocks just mentioned, gray and dark shales, with bands and lenticular patches of coarse limestone, some of which appear to consist principally of brachiopodous shells *in situ*, while others present a confused mass of drifted fossils. Below these the beds become more argillaceous, and in places have assumed a slaty structure, and occasionally a red colour. The thickness of the whole series to this point was estimated at 500 feet.

* See papers by the author in Proceedings Geol. Soc. 1843-44.

The dip then returns to the south, and the beds run nearly in the strike of the shore for some distance, when they become discoloured and ochraceous, and then red and hardened; and, finally, at Arisaig pier, are changed into a coarse reddish banded jasper, where they come into contact with a great dyke of augitic trap of carboniferous date. Beyond this place they are much disturbed, and, so far as I could ascertain, destitute of fossils. The alteration of the beds extends to a distance of 300 yards from the trap, and beyond this in some places slaty cleavage and reddish colours have been produced, the latter change appearing to be connected with vertical fissures traversing the beds.

In the lower or shaly portion of the Arisaig series, the characteristic fossils are Graptolithus, not distinguishable from *G. Clintonensis*, *Leptocœlia* (*Atrypa*) *intermedia* (Hall), a new species closely allied to *L. hemispherica* of the Clinton group of New York, *Atrypa emacerata*, *Orthis testudinaria*, *Strophomena profunda*, *S. rugosa*, *Rhynconella equiradiata*, *Avicula emacerata*, Tentaculites, allied to or identical with *T. distans*, Helopora, allied to *H. fragilis*. There are also abundant joints and stems of crinoids, and a Palæaster, the only one as yet found in Nova Scotia, which was presented to me by Mr Honeyman, and has been described by Mr Billings in the Canadian Naturalist, under the name of *P. parviusculus*. These and other fossils associated with them, in the opinion of Professor Hall, fix the geological position of these rocks as that of the Clinton group, the Upper Llandovery of Murchison, at the base of the Upper Silurian or top of the Middle Silurian.

In the upper and more calcareous part of the series, fossils are very abundant, and include species of Calymene, Dalmania, Homalonotus, Orthoceras, Murchisonia, Clidophorus, Tellinomya, and several brachiopods, among which are *Discina tenuilamellata*, *Lingula oblonga*, *Rhynconella quadricosta*, *R. Saffordi* (Hall) allied to *R. Wilsoni*, *R. neglecta*, *Atrypa reticularis*,* all found in the upper part of the Middle Silurian or in the Upper Silurian elsewhere in America. Most of the other forms are new species, descriptions of which will be found in Professor Hall's list appended to these notes. The general assemblage is on the whole like that of the Clinton, but is of such a character as to warrant the belief that we may have in these beds a series somewhat higher in position, and probably of Upper Silurian age. The new species *Chonetes Nova-Scotica* is very characteristic of the upper member.

On the whole we must regard the Arisaig series as representing the upper part of the Middle Silurian, probably with a part of the Upper Silurian,—a position much lower than that assigned to it in my "Acadian Geology," which was, however, at the time, based on the opinions of the best palæontologists who had examined specimens from these rocks. Unfortunately the Arisaig series stands alone, wedged between carboniferous and plutonic rocks, so that no opportunity occurs on the coast of verifying these conclusions derived from fossils, by the evidence of stratigraphical connexion with newer or older Silurian deposits, and I have been unable to devote sufficient time to this object to attempt to trace the beds in their succession or continuation inland.†

* Also *Strophomena corrugata.*

† Since writing the above, I have received from Rev. Mr Honeyman a number of additional fossils from the Arisaig rocks. They include the head of *Homolonotus Dawsoni* (Hall), which is of very

East River of Pictou.—The next example of fossiliferous Silurian rocks known to me is on the east branch of the East River of Pictou and its vicinity, where these deposits rise from beneath the Lower Carboniferous series, forming the high ground on the eastern side of the river. The beds are here much altered and penetrated by igneous dykes, and are vertical, with very high southerly dips and N. E. and S. W. strike. They consist of coarse slates and calcareous bands resembling those of the upper Arisaig series in mineral character, and holding many of the same species, especially *Chonetes Nova Scotica;* but we have here in addition a great bed of fossiliferous peroxide of iron, in some parts forty feet in thickness, and with oolitic structure; but passing into a ferruginous sandstone, associated with slate and quartz rock. The age of these rocks relatively to the Arisaig series it is not easy to determine. The stratigraphical evidence, though obscure, would place them in a higher position. The fossils are in a bad state of preservation; but in so far as they give any information, it coincides with the apparent relation of the beds. Similar ferruginous beds occur in the

characteristic form, having the glabella descending abruptly in front, nearly in a line with the anterior parts of the eyes, which are large and prominent. The front margin rises with equal abruptness, forming a deep groove along the front of the glabella. There are also fragments of two additional trilobites, apparently of the genus Phacops, an Orthoceras, apparently new, a *Theca*, scarcely if at all distinguishable from *T. Forbesii* (Sharpe), or *T. triangularis* (Hall), two or three species of Bellerophon allied to *B. carinata* and *expansa*, and a Pentamerus or Stricklandia. These and other fossils, collected by Mr Honeyman, will probably form the subject of a separate paper at some future time. I mention them now principally as evidence of the richness of the Arisaig beds in the remains of the inhabitants of ancient seas, and of the success which attends Mr H.'s careful explorations.

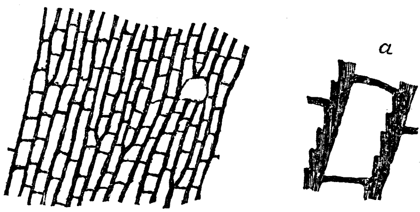
Clinton series (the Surgent of Rogers), in New York and Canada; and, as we shall find in the sequel, in a much higher position in the western part of Nova Scotia. On the whole, I regard the beds seen at the East River of Pictou as belonging to the same line of outcrop with the Arisaig series, but as containing, in addition to the upper member of that series, beds higher in the Silurian system, or perhaps Lower Devonian.

Cobequid Mountains.—At the eastern end of this chain, in Earlton and New Annan, though the rocks are generally in a highly metamorphosed condition, fossils are found in a few places; and, in so far as I have been able to determine from very small suites of specimens, are those of the Upper Arisaig series. From the apparent continuity of strike along this long salient line of outcrop, it seems probable that these fossils indicate the true age of the greater part of the sedimentary rocks of the Cobequid hills,—a conclusion confirmed by their similarity in mineral character to the altered equivalents of the Arisaig and East River series as seen elsewhere.

New Canaan.—Between the East River of Pictou and New Canaan in King's county, 100 miles distant, I know no Silurian beds with fossils; and in the central part of the province these rocks disappear under the carboniferous deposits. In the hills of Horton and New Canaan they reappear, and constitute the northern margin of a broad belt of metamorphic and plutonic country, occupying here nearly the whole breadth of the peninsula. The oldest fossiliferous beds seen are the fine fawn-coloured and gray clay slates of Beech Hill, in which Dr Webster, many years since, found a beautiful Dictyonema, the only fossil they have hitherto afforded. It is a new species, closely allied to *D. reti-*

formis and *D. gracilis* of Hall, and will be described by that palæontologist under the name of *D. Websteri*, in honour of its discoverer. In the meantime I may merely state that it is most readily characterized by the form of the cellules, which are very distinctly marked in the manner of Graptolithus. A portion of a frond is represented in Fig. 46.

Fig. 46.



Part of frond of *Dictyonema Websteri*, Hall.—*a*, portion magnified.

The Dictyonema slates of Beech Hill are of great thickness, but have in their upper part some hard and coarse beds. They are succeeded to the south by a great series of dark-coloured coarse slates, often micaceous, and in some places constituting a slate conglomerate, containing small fragments of older slates, and occasionally pebbles of a gray vesicular rock, apparently a trachyte. In some parts of this series there are bands of a coarse laminated magnesian and ferruginous limestone, containing fossils which, though much distorted, are in parts still distinguishable. They consist of joints of crinoids, casts of brachiopodous shells, trilobites, and corals. Among the latter are two species of Astrocerium, not distinguishable from *A. pyriforme* and *venustum* of the Niagara group, and a Heliolites allied to *H. elegans*, if not a variety of this species. On the evidence of these fossils and the more obscure remains associated with them, Professor Hall regards these beds as equivalents of the Niagara formation of the New York geologists, the Wenlock of Murchison. Their general strike is N. E. and S. W.; and to the southward, or in the probable direction of the dip, they are succeeded, about six miles from Beech Hill, by granite. They have in general a slaty structure coinciding with the strike but not with the dip of the beds, and this condition is very prevalent throughout this inland metamorphic district, where also the principal mineral veins usually run with the strike. The beds just described run with S. W. strike for a considerable distance, and are succeeded in ascending order by those next to be described.

3. DEVONIAN.—It is probable that Devonian rocks in a metamorphosed state are extensively distributed throughout the districts now under consideration; but the only localities in which they have been clearly recognised are along a line of outcrop on the northern margin of the hilly region westward of New Canaan. The first and most important of these exposures is at

Nictaux.—At this place, 20 miles westward of New Canaan, the first old rocks that are seen to emerge from beneath the New Red Sandstone of the low country are fine-grained slates, which I believe to be a continuation of the Dictyonema slates of Beech Hill. Their strike is N. 30° to 60° E., and their dip to the S. E. at an angle of 72°. Interstratified with these are hard and coarse beds, some of them having a trappean aspect.

In following these rocks to the S. E., or in ascending order, they assume the aspect of the New Canaan beds; but I could find no fossils except in loose pieces of coarse limestone, and these have the aspect rather of the Arisaig series than of that of New Canaan. In these, and in some specimens recently obtained by Mr Hart, I observe *Orthoceras elegantulum*, *Bucania trilobita*, *Cornulites flexuosus*, *Spirifer rugæcosta* (?) and apparently *Chonetes Nova Scotica*, with a large Orthoceras, and several other shells not as yet seen elsewhere. These fossils appear to indicate that there is in this region a continuance of some of the Upper Arisaig species nearly to the base of the Devonian rocks next to be noticed.

After a space of nearly a mile, which may represent a great thickness of unseen beds, we reach a band of highly fossiliferous peroxide of iron, with dark coloured coarse slates, dipping S. 30° E. at a very high angle. The iron ore is from 3 to 4½ feet in thickness, and resembles that of the East River of Pictou, except in containing less siliceous matter. The fossils of this ironstone and the accompanying beds, as far as they can be identified, are *Spirifer arenosus*,* *Strophodonta magnifica*, *Atrypa unguiformis*, *Strophomena depressa*, and species of Avicula, Bellerophon, Favosites, Zaphrentis, &c. These Professor Hall compares with the fauna of the Oriskany sandstone; and they seem to give in-

* There is in the iron ore and associated beds another and smaller *Spirifer*, as yet not identified with any described species, but eminently characteristic of the Nictaux deposits. It is usually seen only in the state of casts, and often strangely distorted by the slaty structure of the beds. The specimens least distorted may be described as follows: General form, semi-circular tending to semi-oval, convexity moderate; hinge line about equal to width of shell; a rounded mesial sinus and elevation with about ten subangular plications on each side; a few sharp growth ridges at the margin of the larger valves. Average diameter about one inch; mesial sinus equal in width to about three plications. I shall call this species, in the meantime, *S. Nictavensis*.

dubitable testimony that the Nictaux iron ore is of Lower Devonian age.

To the southward of the ore the country exhibits a succession of ridges of slate holding similar fossils, and probably representing a thick series of Devonian beds, though it is quite possible that some of them may be repeated by faults or folds. Farther to the south these slates are associated with bands of crystalline greenstone and quartz rock, and are then interrupted by a great mass of white granite, which extends far into the interior, and separates these beds from the similar, but non-fossiliferous rocks on the inner side of the metamorphic band of the Atlantic coast. The Devonian beds appear to dip into the granite, which is intrusive and alters the slates near the junction into gneissoid rock holding garnets. The granite sends veins into the slates, and near the junction contains numerous angular fragments of altered slate.

Westward of the Nictaux River, the granite abruptly crosses the line of strike of the slates, and extends quite to their northern border, cutting them off, in the manner of a huge dyke, from their continuation about ten miles further westward. The beds of slate, in running against this great dyke of granite, change in strike from southwest to west, near the junction, and become slightly contorted and altered into gneiss, and filled with granite veins; but in some places they retain traces of their fossils to within 200 yards of the granite. The intrusion of this great mass of granite, without material disturbance of the strike of the slates, conveys the impression that it has melted quietly through the stratified deposits, or that these have been locally crystallized into granite *in situ*.

Moose River.—At this place the iron ore and its associated beds recur on the western side of the granite before mentioned, but in a state of greater metamorphism than at Nictaux. The iron is here in the state of magnetic ore, but still holds fossil shells of the same species with those of Nictaux.

Bear River.—On this stream, near the bridge by which the main road crosses it, beds equivalent to those of Nictaux occur with a profusion of fossils. The iron ore is not seen, but there are highly fossiliferous slates and coarse arenaceous limestone, and a bed of gray sandstone with numerous indistinct impressions apparently of plants. In addition to several of the fossils found at Nictaux, these beds afford Tentaculites, an Atrypa, apparently identical with an undescribed species very characteristic of the Devonian sandstones of Gaspé, and a coral which Mr Billings identifies with the *Pleurodictyum problematicum* (Goldfuss),—a form which occurs in the Lower Devonian in England, and on the continent of Europe.

Westward of Bear River, rocks resembling in mineral character those previously described, extend with similar strike, but in an altered condition, and in so far as I have been able to ascertain, destitute of fossils, quite to the western extremity of the peninsula, where they turn more to the southward, and are, as I suppose, repeated by a sharp synclinal fold; after which, they are succeeded by the Atlantic coast series, consisting of quartzite and clay slate, with chlorite and hornblende slates at Yarmouth and its vicinity, and further to the S. E. of mica slate and gneiss.

General Remarks.—The above facts show that we can recognise among the partially metamorphosed subcarboniferous rocks of Nova Scotia, formations ranging from the Middle Silurian to the Lower Devonian inclusive; but of a more argillaceous and less calcareous character than the series occupying this position in the mainland of America. The principal masses of plutonic rock associated with these beds, and especially the granite, are of newer Devonian date; but there is evidence of igneous eruptions as far back as the beginning of the Upper Silurian, and of the continuance or recurrence of such action as late as the carboniferous period. In and near the non-calcareous Lower Silurian series, granite prevails, almost to the entire exclusion of other plutonic rocks. At a greater distance from these, the plutonic rocks penetrating the Upper Silurian and Devonian series, though apparently of nearly the same age with the granite, are principally syenite and greenstone.

With respect to the general arrangement of the formations, though I cannot venture to speak with confidence on this point, with reference to a district so much disturbed, and which I have been able only very imperfectly to explore, I may suggest, as at present the most probable arrangement, a series of sharp and irregular vertical folds. The coast series would thus belong to an anticlinal, bringing up Lower Silurian rocks. On these, in proceeding to the north-west, rest Middle and Upper Silurian and perhaps Devonian beds in a metamorphosed condition, which, along the northern margin of the metamorphic district, rise again with an opposite dip, at Arisaig, East River, New Canaan, &c., forming a trough, the middle of which, in the east, is divided by a secondary anticlinal and filled with carboniferous rocks, but in the west is occupied with a great mass of granite into which the beds appear to have sunk in the direction of their dip. Beyond the north-western edge of this trough, the Silurian beds probably again dip to the northward, but are hidden by carboniferous deposits, and reappear in another anticlinal with east and west strike in the Cobequid Mountains.

Rocks similar in character and relations to those above described are extensively distributed in the Island of Cape Breton and also in New Brunswick, but I have no detailed knowledge of their distribution. The formations described in this paper, represent in age, and resemble in their state of alteration, many portions of the metamorphosed Silurian and Devonian rocks of New England and eastern Canada. In the latter, the relations of the intrusive granite and the middle and upper Silurian rocks as described by Sir William Logan, and as I have observed them in a few localities, strikingly resemble the phenomena observed in Nova Scotia.

I have no doubt that a detailed survey of these rocks in Nova Scotia and Cape Breton, would develop many curious and intricate disturbances, and might also ascertain the presence of members of the Silurian series, now supposed to be absent, but which may be only obscured by denudation. In the mean time local observers can do much to increase our knowledge of these rocks by carefully collecting the few fossils that remain unobliterated in the semi-metamorphic beds; and the above remarks may serve to guide such explorations, and to enable geologists to speak with more confidence than heretofore of the older palæozoic rocks of an important region of eastern America.

Professor Hall has described, in a paper published in the "Canadian Naturalist and Geologist," forty new species or characteristic varieties of fossils from the Arisaig series. I give here a list of these, referring to the paper itself for descriptions :—

1. Crania Acadiensis (Fig. 47).
2. Discina tenuilamellata (*var.* subplana).
3. Chonetes Nova-Scotica (Fig. 48).
4. Chonetes tenuistriata (Fig. 49).
5. Spirifer rugæcosta.
6. Spirifer subsulcatus.
7. Trematospira Acadiæ (Fig. 50).
8. Rhyncospira sinuata.
9. Rhynconella Saffordi.
10. Leptocoelia intermedia (Fig. 51).
11. Modiolopsis (?) rhomboidea (Fig. 52).
12. Modiolopsis (?) sub-nasutus.
13. Clidophorus cuneatus.
14. Clidophorus concentricus (Fig. 53).
15. Clidophorus erectus (Fig. 54).
16. Clidophorus elongatus (Fig. 55).
17. Clidophorus semiradiatus.
18. Clidophorus nuculiformis.
19. Clidophorus subovatus.
20. Nuculites (Orthonota) carinata (Fig. 56).
21. Tellinomya attenuata (Fig. 57).
22. Tellinomya angustata.
23. Leptodomus (Sanguinolites) aratus.
24. Megambonia cancellata (Fig. 58).
25. Megambonia striata.
26. Avicula Honeymani (Fig. 59).
27. Murchisonia Arisaigensis.
28. Murchisonia aciculata.
29. Holopea reversa (Fig. 60).
30. Orthoceras punctostriatum (Fig. 61).
31. Orthoceras elegantulum (Fig. 62).
32. Cornulites flexuosus.
33. Homalonotus Dawsoni (Fig. 63).
34. Calymene Blumenbachii (*var.*)
35. Dalmania Logani (Fig. 64).
36. Beyrichia pustulosa.
37. Beyrichia equilatera.
38. Leperditia sinuata.
39. Tentaculites distans.
40. Helopora fragilis (*var.* Acadiensis).

Fig. 47.

Fig. 48.

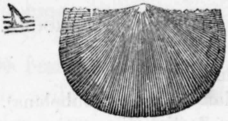


Fig. 49.

Fig. 50.

Fig. 51.

Fig. 52.

Fig. 53.

Fig. 54.

Fig. 55.

Fig. 56.

Fig. 59.

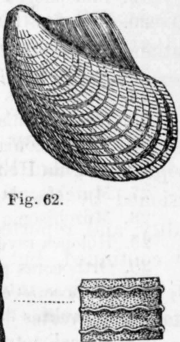


Fig. 57.

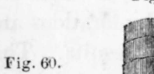


Fig. 58.

Fig. 61.

Fig. 62.

Fig. 60.

Fig. 63.

Fig. 64.

Of the above, Nos. 4, 10, 32, 39, and 40 appear to be characteristic of the dark and olive shales of the lower members of the Arisaig series, in which are also *Strophomena profunda*, *S. rugosa*, *Orthis testudinaria*, *Atrypa emacerata*, *Rhynconella equiradiata*, *Graptolithus Clintonensis*, and crinoidal columns; also a Modiolopsis allied to *M. subcarinatus*. The remaining species are in the coarse limestone and reddish shale of the upper member, in which are also *Strophomena corrugata*, *Atrypa reticularis*, *Rhynconella neglecta*, *Lingula oblonga*, *Bucania trilobita*, and a Chætetes or Stenopora similar to that of the Clinton formation. *Cornulites flexuosus* is almost the only species which occurs equally in both groups of beds. Some of the Clidophori are also found in both groups.

Note.—While these sheets were in the press, some excitement was produced in Nova Scotia by the discovery of small quantities of gold in loose quartz and slate on the Tangier River, in the Atlantic Coast Silurian district (Chap. xv., and Sup. p. 53). The Hon. Joseph Howe and Professor How of Windsor were commissioned by the Provincial Government to visit the locality, and reported unfavourably. Explorations are still continued, but not with profitable results. The fact, however, is interesting, and may lead to more important discoveries. Quartz veins abound in this district, and the rocks are of the age of those in which gold is found elsewhere. The great amount of denudation which they have suffered is perhaps the most unfavourable indication as to their probable productiveness.

In concluding this chapter, I may remark that an important change has taken place in the tenure of the useful minerals of Nova Scotia, which have now passed into the hands of the Provincial Government. This has given a new stimulus to mining enterprise. Many additional mines have been opened, especially of coal, and the bituminous shales now so much in demand for the manufacture of coal oil. It is to be hoped that ere long a systematic geological survey may be undertaken, both for the better exploration of the valuable minerals and of the theoretical geology of the province. In the meantime I beg to offer this additional contribution toward the natural history of my native province, in the confidence that, notwithstanding the inevitable errors and omissions in details, its general accuracy will be vindicated by succeeding explorers. In its preparation I have often been tempted to enter at length into the numerous interesting points of theoretical geology, suggested more especially by the remarkable fauna and flora of the coal period; but this would be out of place in a supplementary chapter, and I hope at some future time to discuss these topics in a separate work on the terrestrial life of the palæozoic period, as indicated by the rocks of British America.

INDEX.

THE END.

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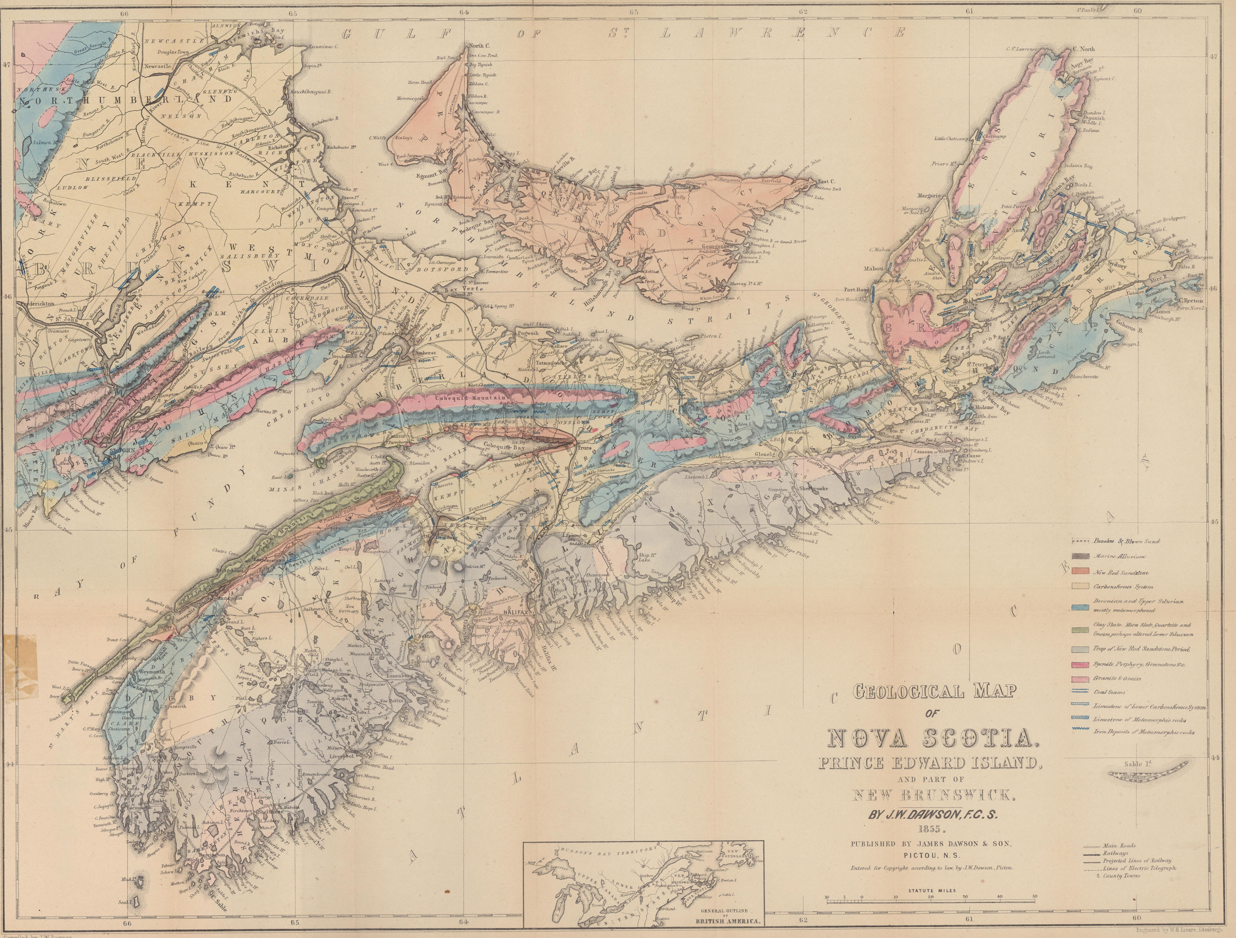
GEOLOGICAL MAP
OF
NOVA SCOTIA,
PRINCE EDWARD ISLAND,
AND PART OF
NEW BRUNSWICK.
BY J.W. DAWSON, F.C.S.
1855.
PUBLISHED BY JAMES DAWSON & SON,
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Beaches & Blown Sand
Marine Alluvium
New Red Sandstone
Carboniferous System
Devonian and Upper Silurian mostly metamorphosed
Clay Slate, Mica Slate, Quartzite and Gneiss, perhaps altered Lower Silurian
Trap of New Red Sandstone Period
Syenite Porphyry, Greenstone &c.
Granite & Gneiss
Coal Seams
Limestone of Lower Carboniferous System
Limestone of Metamorphic rocks
Iron Deposits of Metamorphic rocks
Main Roads
Railways
Projected Lines of Railway
Lines of Electric Telegraph
County Towns
STATUTE MILES
10 5 0 10 20 30 40 50
Sable Id
GULF OF ST LAWRENCE
NORTHUMBERLAND STRAITS
BAY OF FUNDY
ATLANTIC OCEAN
NEW BRUNSWICK
PRINCE EDWARD ISLAND
CAPE BRETON
HALIFAX
GENERAL OUTLINE OF BRITISH AMERICA
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