# SUPPLEMENTARY CHAPTER

TO

# "ACADIAN GEOLOGY."


By J. W. DAWSON, LL.D., F.G.S.,

PRINCIPAL OF MACGILL COLLEGE, MONTREAL;

Author of "Archaia," &c.



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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.

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## 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—

$$Na\,O\ 2\,B\,O_3 + 2\,Ca\,O,\ 3\,B\,O_3 + 15\,H\,O.$$

* 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.

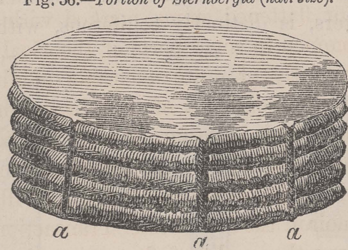
In a paper communicated to the Geological Society of London in 1846, to which Professor Williamson, in his able memoir in the Manchester Transactions (vol. ix., 1851), assigns the credit of first suggesting that connexion between these curious fossils and the conifers which he has so successfully worked 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.

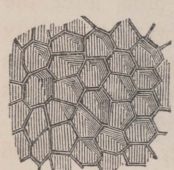


Fig. 38.

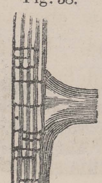
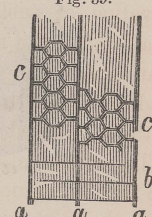


Fig. 39.




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.

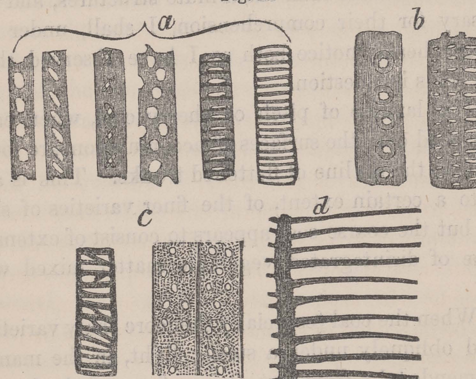
The method of preparing the mineral charcoal for ex-

* 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.

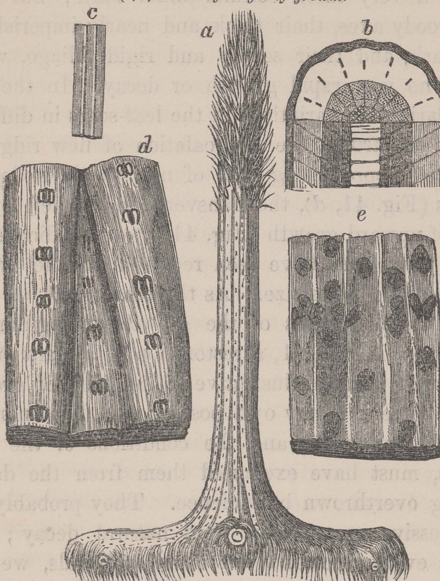
"4. The rate of accumulation of coal was very slow. The climate of the period, in the northern temperate zone, was of such a character that the true conifers show rings of growth not larger nor much less distinct than those of many of their modern congeners.* The Sigillariæ and Calamites were not, as 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.

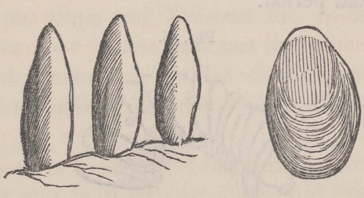
This tree must, as usual with erect Sigillariæ in this section, have become hollow by decay and been filled from above, after being partially buried in sediment. The peculiarity to which it owes its abundance of animal remains is, that the hollow cylinder resulting from its decay remained open for some 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,

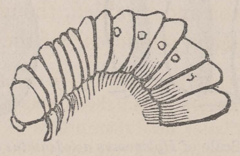
* "Forest-dweller," from its supposed habitat in the Sigillaria woods of the Coal period.

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.<br>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.<br>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.<br>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:

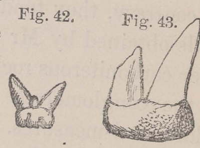
"There are numerous small faults running across the measures in the Fraser Mine, which are uniformly downthrows to the west; and I may here mention that I observed, some years ago, in the Deep seam, several faults from four to ten feet each, which could not be found in the main coal workings above (the 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. They diverge at an angle of 35° to 40°, and the central denticle is small and conical. The base is broad and

Fig. 42. Fig. 43.



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.

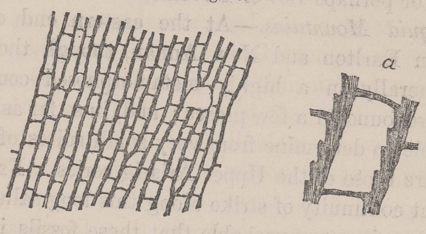
Clinton series (the Surgent of Rogers), in New York and Canada; and, as we shall find in the sequel, in a much higher position in the western part of Nova Scotia. On the whole, I regard the beds seen at the East River of Pictou as belonging to the same line of outcrop with the Arisaig series, but as 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 rugœcosta* (?) 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.

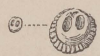


Fig. 48.

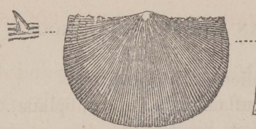


Fig. 49.

Fig. 50.

Fig. 51.

Fig. 52.

Fig. 53.

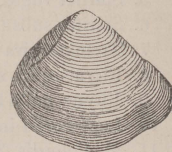


Fig. 54.

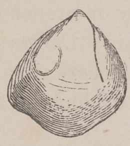


Fig. 55.

Fig. 56.

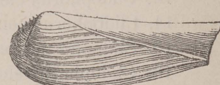


Fig. 57.

Fig. 58.

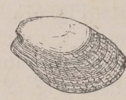


Fig. 59.

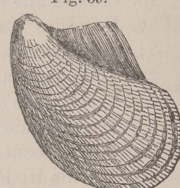


Fig. 60.

Fig. 61.

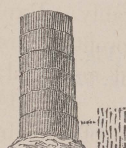


Fig. 62.

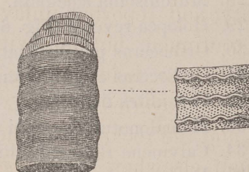
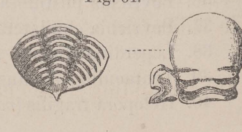


Fig. 63.

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.

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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.