1. On the Eozoic and Palaeozoic rocks of the Atlantic Coast of Canada.

1888

[*From the* Quarterly Journal *of the* Geological Society *for November* 1888.]

On the Eozoic *and* Palæozoic Rocks *of the* Atlantic Coast *of* Canada, *in* Comparison *with those of* Western Europe *and of the* Interior *of* America.

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Since the year 1845 the author has contributed from time to time to the Journal of this Society more than forty papers on the geology of Nova Scotia, New Brunswick, and Prince Edward Island, in which frequent comparisons were made between the rocks and fossils of the Atlantic coast-region and those of the inland plateau of the North-American continent on the one hand, and those of Europe on the other *. Many additional details bearing on the more uncertain parts of these subjects have been accumulated in unpublished notes in recent years, while large additions to our information have resulted from the extension of the Geological Survey of Canada, under Logan and Selwyn and their assistants, to those provinces, and from the Geological Survey of Newfoundland under Murray and Howley †, while new facts have been accumulating with reference to the continuation of the Atlantic rocks southward on the coast of the United States, and also with regard to the intermediate or "inner marginal" series observed on the Lower St. Lawrence and thence southward. The time seems thus to have arrived when some further and useful comparisons may be made, as well as corrections and amplifications of previous statements; and these seem to be the more necessary, inasmuch as it is evidently difficult for geologists who have not personally studied these districts to correlate with accuracy the geological features of the marginal belts of the two sides of the Atlantic.

The subject is, however, so extensive that within the limits of this paper it will be necessary to confine attention to the most salient points, and to state these as briefly as possible. I shall also confine the descriptive part to the rocks of the Atlantic border of North America, especially of Canada, and shall merely mention the parallel formations of other districts.

It may be useful to explain that I shall use the term "System" for the larger divisions of the great geological ages, and "Series" for their most important subdivisions, and the term "Group" in its ordinary sense as indicating a number of associated beds without reference to precise classificatory value.

* I find that, of forty-three papers on the Geology of Canada which I have contributed to the Society's Journal, ten are on subjects connected with the Eozoic and older Palæozoic rocks, twenty-nine relate to the Devonian and Carboniferous, and four to the Mesozoic and Modern.

† Though Newfoundland is not, politically, a portion of Canada, it is necessary to include its geology in any general survey of that of the Canadian coast.

I. The Laurentian System.

It is, I think, becoming more and more evident that in every part of the world the oldest rocks exposed are of the nature of orthoclase-gneisses associated with various kinds of crystalline schists, and locally with quartzites and limestones. This statement applies with equal force to the Acadian Provinces of Canada and to western Europe. In these districts, however, the old Laurentian substratum is represented, not by great continuous areas, as in the interior of North America, but by rugged islets and ridges of crystalline rock, in most places so imperfectly exposed that their subdivisions can scarcely be made out, and that geologists may even be excused for doubting the stratified character of their rocks. It is only by comparing them with the magnificent series exposed in the country north of the St. Lawrence, and worked out so ably by Logan, that the more limited exposures of the Atlantic margins can be understood.

In the Journal of this Society for February 1865 will be found a summary statement by Logan of the structure of this formation, which still holds good*. He there divides the Laurentian into two series, the lower and the upper, the former largely composed of othoclase-gneiss, but with beds of limestone, quartzite, and micaceous and hornblendic schists in its upper parts; the latter composed of similar gneisses and limestones, but with beds of gneissose anorthosite and labradorite, and great masses of coarsely cleavable labradorite and hypersthene.

It is perhaps unfortunate that these last masses, many of them, no doubt, accidental and intrusive, so forcibly attracted the attention of Logan that he characterized the upper Laurentian as a labradorite series, whereas the true aqueous rocks of this series would afford better terms of comparison with other districts than merely igneous masses or beds. A similar objection, I think, applies in some degree to the name Norian, as more recently given by Hunt; and I have no doubt, from my own observations in the typical districts, that Logan's division must stand, though perhaps it would be well to separate the lower gneiss from the remainder of his Lower Laurentian and to recognize a Lower, Middle, and Upper group, all of which are distinctly crystalline rocks†. The upper member, as developed in the west, should, I think, include some of the crystalline rocks which have been classed as Huronian, and which seem to fill part of the gap between the latter and the Lower Laurentian in the regions further east ‡. This view will in

* "On the Eozoic and Palæozoic Rocks."

† The two principal members have been named respectively the Ottawa and Grenville series. The third, or upper member, in Logan's typical district has been separated as the Norian series by Hunt; and by Selwyn (Reports Geol. Survey of Canada, 1879–80) is regarded as mainly composed of igneous rocks. In the maritime Provinces, as we shall see, only two members have been recognized.

‡ Dr. Bigsby, "On Lake of the Woods," Journal of Geol. Society, 1851–2; Dr. G. M. Dawson, Report on 49th Parallel, 1875; Mr. Lawson, Reports Geol. Survey of Canada, 1885. The latter has proposed the name "Keewatin" for some of these rocks in the west.

any case afford better means of comparison with the Laurentian of other districts, and the occurrence of masses of binary granite and syenite in the Lower group and of labradorite in the Upper need not interfere with such comparisons, though it is to be observed that in the Upper member plagioclase felspars are much more abundant than in the Lower. Prof. Bonney has some very judicious remarks on this in his Anniversary Address before this Society in 1886.

Whatever views may be entertained as to the origin of these old rocks, no one who has studied the typical districts of the Ottawa River can doubt for a moment that they are regularly bedded deposits, and that in the middle Laurentian those conditions which in later periods have produced beds of limestone, sandstone, iron-ore, and even of coal, were already in operation on a gigantic scale *. At the same time it may be admitted that some areas of the lower gneiss may be cooled portions of an original igneous mass, and that many of the schistose rocks may be really bedded igneous materials.

Turning now to the Atlantic coast, the greatest area of Laurentian rocks is that forming the nucleus of the Island of Newfoundland. In the northern part of that island the absence of the great crystalline limestones would seem to indicate that the lower member of the series alone is represented. The same remark applies to the continuation of the formation in the south of the island, with the exception that indications of graphitic limestone and of magnetic iron-ore have been found in two places †.

It is to be noted here that the great uplift in Pre-Cambrian times of the Laurentian nucleus of Newfoundland seems to have acted as an outwork to the formations to the westward, protecting the area of the Gulf of St. Lawrence from those thrusts from the eastward which have piled up in gigantic earth-waves the older formations of other parts of Eastern Canada and the Appalachian region. In consequence of this the area of the Gulf of St. Lawrence has throughout Palæozoic time remained undisturbed, and has conformed in its conditions of deposit rather to the internal plateau than to the maritime districts.

In Cape Breton the isolated mass of St. Ann's Mountain seems to be a representative of the Lower Laurentian of Newfoundland, and Mr. Fletcher's observations render it probable that rocks of this kind exist in the northern extremity of the island. In Nova Scotia proper I have not been able to recognize any true Laurentian, the rocks attributed by some other observers to this age being, in my judgment, intrusive granite masses of much later date associated with altered rocks ‡.

In southern New Brunswick, however, the Laurentian reappears. As seen near St. John, the lower part consists of red and grey gneiss with chloritic gneiss and diorite. The occurrence of hydrated silicates

* Q. J. G. S. vols. xxiii., xxv., xxxii., xxxv. In these papers I have set forth not merely the evidence for the organic character of *Eozoon*, but for that of the Laurentian limestones and graphites and phosphates in general.

† Murray's 'Geol. Survey of Newfoundland,' 1881.

‡ Supplement to Acadian Geology, 1878, p. 89.

in some parts of these old gneisses may be attributed to changes subsequent to their original formation. The upper member contains much limestone, with graphite and serpentine *, grey quartzites and diorite. This last series, which I hold to be really Laurentian, as it certainly underlies, and probably unconformably, the Huronian system, must belong to the upper member of the series. There is, indeed, nothing in its mineral character to exclude it from the Upper Laurentian as developed further west except the absence of certain igneous rocks.

The resemblance of this interrupted belt of Laurentian along the Atlantic coast of America to that which extends southward from Scandinavia along the west of Europe is patent to every observer. The relation to the next succeeding formations is also identical, and on both sides of the Atlantic those great foldings which have bent and crumpled the old crystalline rocks seem to have occurred at the close of the Laurentian and before the next succeeding formation. It is to be observed here, however, that in the case of the Laurentian these foldings pervaded the whole of what are now the Continental areas, as well as those marginal lines which were alone affected by the succeeding movements. This general disturbance of the Laurentian over the whole breadth of our continents, and this before any of the succeeding beds were deposited, impresses us with the conviction that the earth-movements immediately following the Laurentian were more extensive than those of any subsequent period, that they form a sufficient explanation of the very different character of the next succeeding formations, and that they produced wide areas of elevated rock which formed the nuclei of all later depositions and movements.

In comparing the Upper Laurentian of New Brunswick with the rocks which elsewhere, as in New Hampshire †, the district of St. Jerome, the Madoc district in Ontario, and the country west of Lake Superior, rest on the older Laurentian gneisses or on rocks regarded by some as primitive granites, one is obliged to admit either that this formation is of a somewhat protean character, or that, as Hunt maintains, there are several different formations of post-Laurentian crystalline rocks occurring in these different localities.

In the Lewisian gneiss of Murchison we have in Britain an adequate representative of the Lower Laurentian, and in the two members of the Dimetian of Hicks a sufficient parallel to the middle and upper members of this great series ‡, which undoubtedly also appear in the isolated mass of the Malverns, and have been recognized by Barrois and Bonney in the ancient crystalline rocks of Brittany §.

* In this limestone there occur fragments of *Eozoon*, and the graphite shows obscure fibrous structures.

† Hitchcock's Report. The beds called Montalban by Hitchcock occupy this position.

‡ Hicks's "Classification of Eozoic and Lower Palæozoic Rocks," Popular Science Review, 1881.

§ Bonney, Quart. Journ. Geol. Soc. vol. xliii.

II. The Huronian System.

In the typical area of Lake Huron, as originally described by Logan and Murray *, this system rests unconformably on the Lower and Middle Laurentian, and presents a great contrast in point of mineral character to these formations. It is comparatively little disturbed, and is clastic rather than crystalline in character. This point has been well insisted upon by Dr. Bonney and by Mr. Irving in recent papers †. Further, its conglomerates contain pebbles of Laurentian rock in the same crystalline state in which these rocks are found at present. It consists chiefly of quartzites, conglomerates of different kinds, limestone, and slates, sometimes chloritic, with interbedded diorite. Without discussing those more or less crystalline rocks west of Lake Superior and in the Appalachian region which have been by Logan himself and later authors identified with the Huronian, and which may, in part, belong to the interval between the Huronian and Laurentian or to the upper beds of the latter, or may even be later sediments in an altered state, we may attend at once to the beds which on the Atlantic coast suceeed the Laurentian. We may remark, however, that, associated with the Huronian at the west of Lake Superior and extending thence northwards to Hudson's Bay and the Arctic sea, are the dark slates, sandstones, &c. constituting the Ainimiké series of Hunt. Whether these constitute an upper member of the Huronian or a distinct formation does not certainly appear. It is, however, certain that this formation is very widely distributed, especially in the north ‡. It is also to be observed that many of the bedded rocks of the Huronian are really of volcanic origin, being bedded volcanic ashes or muds in an altered state §.

In Newfoundland the older slate-series of Jukes ||, which Murray originally called the intermediate series, but afterwards mapped as Huronian, consists, in ascending order, of quartzites with diorites and jaspery bands, slate-conglomerate, green, purple, and red slates, and dark-brown or blackish slates. In the upper part of this or the lower part of the next group are the worm-burrows known as *Arenicolites spiralis* and the uncertain fossils described by Billings as *Aspidella*. The lithological correspondence here between Newfoundland and Lake Huron is very close, and is increased by the fact that a series of red sandstones and conglomerates, the Kewenian of the West and the upper Huronian or Signal-Hill beds of Jukes and Murray, overlie the typical Huronian in both districts ¶.

* Geology of Canada, 1863.

† Anniversary Address, 1886. Amer. Journ. of Science, 1887.

‡ G. M. Dawson, "Notes on northern part of Dominion of Canada," Geol. Survey, 1887, p. 8; Dr. R. Ball, "Report on Hudson Bay, 1877 to 1885," Geol. Survey of Canada.

§ Dawson, 'Canadian Naturalist,' 1857; Nicholson, Quart. Journ. Geol. Soc. 1873; G. M. Dawson, Geol. Mag. 1875.

|| Report on Newfoundland, 1843.

¶ Geology of Newfoundland, 1881.

Passing from Newfoundland to the coast of southern New Brunswick, we find in the "Coldbrook" and "Coastal" series of Bailey a group corresponding essentially to that in Newfoundland, except perhaps in the fact that felsitic rocks occur to a larger extent in the lower part, and that the upper part presents not only conglomerates, ash-rocks, and amygdaloids, but also chloritic and hydro-mica schists. This upper part, distinguished as the "Coastal Series," is regarded by Prof. Bailey as distinct from the Huronian proper, and as either an upper member of that system or perhaps of later age, though pre-Cambrian *.

As in Newfoundland, the typical Huronian of New Brunswick is overlain by reddish and purple conglomerates, sandstones, and shales, which are, however, here regarded as the base of the Cambrian †. Matthew has recently found in them not only worm-burrows and fucoids, but a Linguloid shell. They appear, however, to underlie unconformably the lowest division of the *Paradoxides*-beds.

With these rocks, whether of Lake Huron, Newfoundland, or New Brunswick, I have no hesitation in comparing the Pebidian of Wales, as well as certain portions of the older Malvern rocks and those of Charnwood Forest. Some of these groups I have seen on the ground, others are well known to me by suites of specimens. Similar rocks also succeed the Laurentian in Scandinavia and in other parts of Europe as well as in Africa and portions of Asia. Thus the Huronian type is very widely distributed, even if we take it in the restricted sense as originally used by Logan and, later, by Irving ‡, and leave out doubtful deposits which have been connected with it.

The Huronian marks a period of igneous disturbance and coarse mechanical deposition succeeding to the Laurentian foldings. It is essentially a coastal or marginal deposit, and indicates that at the close of the Laurentian considerable areas of land had been elevated in the northern hemisphere. It was along the margins of this old Laurentian land that the Huronian was deposited, and its outcrops mark these margins, which in America before the rise of the Appalachians extended westward from the Atlantic coast along the southern shores of the Laurentian land. The conditions of deposit in Wales at the same period were evidently in general similar, though with local peculiarities.

Two important questions arise from the above statements. The first relates to possible deep-sea deposits of this age, differing from the coarse marginal detritus and volcanic accumulations. These must have existed; but to what an extent are they known to us? The limestones associated with the Huronian probably belong to their margins; but they have so far afforded no fossils except obscure indications of sponge-spicules in the chert-nodules which they

* Bailey, "Geology of New Brunswick," Geol. Survey Report 1877–8; Ells, 'History of New-Brunswick Geology,' 1887.

† Geological Survey Reports, 1878.

‡ Amer. Journal of Science, 1887.

contain *. I confess, however, that I am inclined to suspect that some of the beds known as Ainimiké and Taconian may prove to be of this character, as well as some of the disputed Huronian of the Appalachian region †.

The second question relates to the extent to which conditions similar to those of the Huronian may have been repeated in subsequent periods; and here it is evident that wherever on continental margins coarse aqueous rocks were being accumulated, in the vicinity of igneous foci and mixed with their detritus, rocks lithologically resembling the Huronian may have been deposited. This consideration imposes much caution as to the possible correlation of such deposits with the true Huronian on the ground of mineral character alone. In Nova Scotia and New Brunswick as well as in Great Britian there are rocks having in many respects the aspect of the Huronian which belong to Palæozoic times, and there is reason to believe that on the Pacific coast there are certain rocks of this kind of much later date. These, as has been shown by Dr. Selwyn and Dr. G. M. Dawson, are in great part bedded volcanic ash-rocks in an altered condition ‡.

An important new light has recently been thrown on the supposed upper Huronian of Newfoundland by Mr. Matthew, who has found that in New Brunswick the conglomerate and red sandstone underlying the *Paradoxides*-beds are, as before stated, unconformable to these, and that, like the Basal or Caerfai beds of Hicks in Wales, which somewhat resemble them in mineral character, they contain worm-tracks and a Linguloid shell as well as remains of Algæ. He therefore regards these as basal Cambrian beds. This may also prove to be the position of the Newfoundland Signal-Hill rocks, and of the Kewenian series of the west. This basal series of New Brunswick is estimated at 1200 feet in thickness. If it be reckoned as the equivalent of the Caerfai, the lower members of the St. John group proper will be the equivalent of the Solva group, and the upper members will represent the Menevian §. In a letter recently received from Mr. Irving, of the U. S. Geological Survey, he informs me that "an obscure Linguloid shell" has been found in the quartzite of south-western Minnesota, a formation which he regards as probably below the Kewenian, and possibly even Huronian. These facts render it possible that an upper Huronian series containing precursors of the Cambrian fauna may yet be recognized, or probably a new intermediate system to be designated by some other name ‖. It will also be observed that, like the typical Huronian, such series, whether

* I find such indications in the chert of the limestones on Georgian Bay. They are apparently simple acerate siliceous spicules, resembling those of some Cambrian sponges.

† See, however, Dr. Sterry Hunt, "Elements of Primary Geology," Geol. Mag., Nov. 1887, for his classification of the western rocks of these groups.

‡ Report Geol. Survey of Canada, 1871–1885.

§ Matthew, 'Canadian Record of Science,' 1887.

‖ Irving has proposed to call all the formations between the Laurentian and the base of the Cambrian "Agnotozoic;" but the term Huronian seems sufficient at present for this purpose.

Huronian or Kewenian or intermediate, will be common to the coastal and interior regions, thus differing from the true *Paradoxides*-zone.

III. The Cambrian System.

For a long time the base of the Palæozoic, in the eyes of the geologists of America, was the Potsdam Sandstone, which over great areas of Canada and the United States rests unconformably and directly on the Laurentian.

The marginal areas of the continent have since afforded a great series parallel to the Cambrian of Wales and of Scandinavia.

In southern Newfoundland the Huronian rocks, or the Signal-Hill red sandstones and conglomerates overlying them, are succeeded, according to Jukes and Murray, by a thick formation of sandstones and slates with a little limestone and conglomerate, and near the base of this the great *Paradoxides Bennetii* and other forms of like age are found. These are Lower Cambrian and obviously parallel with the beds holding the rich fauna of this age in New Brunswick, originally described by the late Prof. Hartt*, and more recently and more fully by Mr. Matthew †. The strata holding these fossils in Newfoundland have conglomerate, slate, and limestone below, and a great thickness of variously coloured slates above, overlain by sandstones and slate. Very similar beds constitute the lower Cambrian series of St. John, New Brunswick.

I have already stated that there exists in southern New Brunswick a series of red, purple, and grey conglomerates and sandstones not unlike the Signal-Hill series, unconformable to the Huronian below and the *Paradoxides*-beds above, and holding not only worm-tracks, but Linguloid shells. These are regarded as a basal Cambrian series, perhaps equivalent to the Caerfai group of Hicks, while above this are the equivalents of the Solva and Menevian groups of the same geologist, corresponding in mineral character and fossils so closely as to indicate portions of the same sea-bottom ‡. The Braintree slates in Massachusetts with their underlying conglomerates may be considered a continuation of the New Brunswick beds §.

Above these in Newfoundland is a slender representation of the lower part of the Upper Cambrian, now called Middle Cambrian by some, and consisting of sandstones and flags, often micaceous, with *Lingulæ*. Similar beds cap the Lower Cambrian in southern New Brunswick. Mr. Fletcher, of the Canadian Survey, has found fossils indicating what is probably the same horizon in the slaty districts of southern Cape Breton. Mr. Matthew regards these series as covering the whole succession from the Caerfai group of Hicks to the *Lingula*-flags, and the two great zones A and B of Angelin in Sweden.

* Acadian Geology, 1868.
† Trans. Royal Society of Canada, 1885 to 1888.
‡ Matthew, 'Canadian Record of Science,' 1888.
§ Crosby, 'Boston Society of Nat. History,' 1884.

There is, however, no certain evidence that any of these beds reach so high as the horizon of the Potsdam *.

These rocks of Newfoundland and the Acadian Provinces, constituting what I formerly named the "Acadian group" †, are in their lithological characters and fossil remains precise equivalents of the Longmynd, Menevian, and Lower Lingula-flag groups of England.

In this connexion an important group of rocks is the Atlantic coast series, or gold series of Nova Scotia, described by me in this Society's Journal as far back as 1850 ‡, and subsequently in 'Acadian Geology' and supplements thereto §. This great series, extending for more than 200 miles along the Atlantic coast of Nova Scotia, consists of dark-coloured quartzite and slate in massive bands, the former predominating below and the latter above, and the whole attaining to a thickness of perhaps 10,000 feet. In its western extension it appears to rest on rocks of Huronian aspect, and where it is invaded by granitic masses and veins (Devonian in age) it assumes the condition of mica-schist and imperfect gneiss, being then similar in mineral character to the rocks elsewhere known as Montalban. It has unfortunately afforded no well-characterized fossils. The markings called Eophyton || and certain radiating bodies (Astropolithon) ¶ found in it are, however, similar to those occurring elsewhere in Lower Cambrian rocks. Murray was disposed to regard this formation as corresponding to his Huronian in Newfoundland; but it does not agree with this either in mineral character or in fossils, and is perhaps rather to be regarded as a great development of the lowest member of the Cambrian, an exaggerated equivalent of the Harlech Grits and Llanberris Slates. In this case, however, it may be expected that it will yet afford true Cambrian fossils.

In Western Europe, as Hicks has shown, great movements of depression must have occurred in this period, and we have evidence of a similar character in America. If we roughly divide the Cambrian system into three great series, characterized respectively by the prevalence of the large Trilobites of the genera *Paradoxides*, *Olenellus*, and *Dikelocephalus*, we shall find that the former, the true Lower Cambrian, is unknown over all the great continental plateau of America **. It is strictly a marginal deposit formed at a time when there was probably a great continent west of the then infant Appalachians. But the second, or *Olenellus*-group, slenderly represented on the coast, appears in force immediately within the great Laurentian axis of Newfoundland ††. It is known in the valley of the St. Lawrence by the great masses of limestone full of fragments of

* Fletcher, 'Report Geol. Survey of Canada'; Matthew, Trans. Roy. Soc. Can. 1886; Canadian Record of Science, 1887.

† Acadian Geology, 1868.

‡ Quart. Journ. Geol. Soc. vol. vi. § 1868 and 1878.

|| Selwyn, Report Geol. Survey.

¶ Acadian Geology, Supplement, p. 82.

** Walcott apparently places the lower portion of the Wahsatch section in Utah in the Lower Cambrian; but this may belong to a western marginal area.

†† Murray's 'Newfoundland'; Billings's 'Palæozoic Fossils.'

Olenellus, *Solenopleura*, *Hyolithes* &c. in the conglomerates of the Quebec group*, and it also appears in the Georgia series of Vermont †, nd, according to Walcott, as far west as Nevada and Utah ‡. On the other hand the upper members of the Cambrian, the *Dikelocephalus*-group or Potsdam Sandstone, is apparently altogether absent n the Acadian provinces, which at that time must have been under ocean-depths in which deposits of a very different kind would be produced, or elevated into land, perhaps the border of an Atlantic island now mostly submerged. It seems doubtful if any good equivalent of the Potsdam exists in England or Wales.

It is otherwise, however, with the next succeeding formation, that passage-series between the Cambrian and Ordovician known in Wales as the Tremadoc. This, in America, takes a more inland position, and becomes an interior or submarginal formation connected with the Quebec group to be mentioned in the sequel. At Matane and Cape Rosier, as noted by me in 1883 §, and as Lapworth has more fully proved in 1886 ‖, we have a true Tremadoc filled with *Dictyonema sociale* and containing also fragments of characteristic Trilobites. Further inland, on the main American plateau, these beds are not found, but are represented by the peculiar "Calciferous" formation, a dolomite formed apparently in an inland sea and having a characteristic fauna of its own.

A very remarkable and exceptional feature in British geology is the appearance in the sandstone and limestone of the Durness series of Scotland of a group of fossils long ago recognized by Salter as of the interior American type ¶. In other words there existed in Scotland, within the shelter of the old Laurentian and Huronian ridges, an area which sustained a fauna similar to that of the internal plateau of America, and which, so far as known, did not exist in Wales or on the American coast. This curious case of apparent isolation we might better understand did we know the exact geographical arrangements of the period. One consideration bearing on it is the probability that the Trilobitic and Graptolitic faunas of the coast mainly belonged to cold northern currents, while the Plateau-faunas, richer in Cephalopods, Gasteropods, and Corals, belonged to the superficial warm currents passing over shallow plateaus, or to the tepid waters accumulated in closed basins. This is, I think, quite manifestly the case with the very dissimilar marginal and continental faunas to be noticed under the next heading. Salter seemed to suppose that the occurrence of these fossils in Scotland, and not to the south, indicated a climatal difference. In this he was justified; but the character of the climate was probably different from that which he imagined.

* At Metis, St. Simon, &c.

† Emmons's 'American Geology;' Billings's 'Palæozoic Fossils.'

‡ Bulletin U. S. Survey.

§ Report Peter Redpath Museum, No. ii. Richardson's observations at Matane.

‖ Transactions Royal Society of Canada.

¶ Quart. Journ. Geol. Soc. vol. xv. These rocks are also recognized by Geikie in Skye (Quart. Journ. Geol. Soc., Feb. 1888).

Before leaving the Cambrian, it may be well to state that Mr. Matthew informs me that he hopes to make out in the St. John series the equivalents of all of the subdivisions of the *Paradoxides*-zone established by Linnarsson in Sweden, so that there would seem to be a correspondence even in the minor details of the deposits on the opposite sides of the Atlantic *. This, as we shall see, also appears to Prof. Lapworth to hold in the case of the Graptolitic fauna of the Upper Cambrian and Ordovician on the two Atlantic margins.

IV. The Ordovician System.

With the incoming of this new age a more marked distinction occurs in America between the marginal and plateau-deposits. I have already referred to this in the Calciferous; but it is more distinct as between the marginal and submarginal areas and those inland, in the period on which we now enter.

In Newfoundland, Murray and Howley have described large areas of Quebec-group rocks in the west and north of the island which seem to be continuations of the submarginal area of the Lower St. Lawrence. There is also one limited exposure of Trenton Limestone on the west coast, and belonging to the area of the Gulf of St. Lawrence, the peculiar conditions of which I have already mentioned. In Nova Scotia we have as yet no representatives of the Ordovician system except slates associated with igneous rocks, resembling in mineral character the Borrowdale series of the North of England, and destitute of fossils. In northern New Brunswick we find a belt of slaty beds representing the Quebec group of Logan, which is the characteristic form of the submarginal development of this system occupying the St. Lawrence valley. This group, resembling in many respects the Arenig of England, and consisting principally of slates, sandstones, and conglomerates, constitutes the eastern representative of the great Upper Calciferous and Chazy Limestones widely spread over the internal plateau, and probably of part of the Trenton as well.

The origin of this formation and its true relations to the interior plateau-deposits were early defined by Logan, who regarded the Quebec group as an Atlantic deposit thrown down in the open sea along the margin of the old Laurentian plateau, while thinner and differently constituted beds were being formed in the shallower and warmer waters of the plateau itself. It was further found and illustrated by Logan that in the great earth-movements which closed the Ordovician period these marginal and submarginal deposits had been crushed and folded against the old Laurentian border, and even, in places, pushed over the inland formations by reversed faults, while the latter remained comparatively undisturbed. These peculiar arrangements, which extend southward along the Appalachian ranges, led to much discussion among the geologists of the New York Survey, and to that "Taconic" controversy which is still scarcely terminated.

So far as our present subject is concerned, it is sufficient to

* Amer. Journ. of Science, May 1887.

observe that the Quebec group is not strictly an outer marginal formation, but rather submarginal, and belongs to a period when the principal area of coastal deposition of sediment from the north was inland of the Acadian provinces, or between them and the main American plateau, and separated from the outer ocean by a belt of active volcanos. Its conditions of deposit and characteristic fossils may fairly be compared with those of the Skiddaw and Arenig of England *. The Ordovician series of Shropshire extending upward from the Stiper Stones to the Caradoc is also a counterpart of the Quebec group †.

Perhaps no term of comparison for these beds is more satisfactory than that of the Graptolitic fauna ‡. This has been studied in the case of the Canadian series with great care by Hall, whose monograph on the Graptolites of Canada is a classical work, and subsequent observations have ascertained several divisions between the Matane series of the Lower St. Lawrence and the Utica §. The whole subject has, however, recently been reviewed by Lapworth ‖, in connexion with material placed in his hands by the Director of the Geological Survey of Canada, and his results are of the greatest interest as indicating the precise correspondence in those truly pelagic forms on the two sides of the Atlantic. They may be summed up as follows, in ascending order:—

Quebec Group of Lower St. Lawrence.

1. *Matane Beds* ¶.—Grey, red and black shales, sandstones and limestone, equivalent to Lower Calciferous of inland America and Tremadoc of England. Characterized by *Dictyonema sociale*, *Bryograptus*, *Clonograptus*, &c.

2. *Levis Beds.*—Dark shales, with sandstones and limestone-conglomerates. Limestone-bands and dolomite. Characterized by *Phyllograptus*, *Tetragraptus*, *Didymograptus*, &c. Remains of siliceous sponges also occur in some places **. This corresponds to the Chazy of inland America and the Arenig or Skiddaw of England.

3. *Marsouin Beds.*—Shales, limestones, dolomites, and sandstone, with *Cœnograptus*, *Diplograptus*, &c. Equivalent to the Trenton formation of interior America, including the Normanskill Shales of Hall, and to the Llandeilo formation of England.

4. *Utica Series.*—Soft shales, often highly bituminous or carbonaceous, with *Leptograptus*, *Diplograptus*, &c. This is the Utica-Slate formation of inland America, and corresponds to the Hartfell and Caradoc group of England.

* Hicks, 'Classification of Lower Palæozoic Rocks,' 1881.

† Lapworth, Geol. Magazine, 1887.

‡ Mr. A. M. Ami, F.G.S., of the Geological Survey of Canada, has devoted much labour to these fossils.

§ Report Redpath Museum, 1882. Paper by Mr. H. M. Ami, 'Ottawa Field Club,' &c.

‖ Transactions Royal Society of Canada, 1886.

¶ Cape Rosier Zone of Lapworth.

** Dawson and Hinde, Canadian Record of Science, 1888; also "Redpath Museum Notes," 1888.

It will be observed here that the Graptolitic faunas referred to by Lapworth extend from the Tremadoc to the Caradoc inclusive; but the Quebec group proper may be regarded as limited by these groups above and below.

It is also to be observed that the Quebec group conditions of shale- and sandstone-deposit with cold-water animal species seem, in the later Trenton and Utica periods, to have become prevalent over the interior plateau as well as the marginal area.

This appears not only from the wide extension of the Graptolitic fauna over all the plateau west of the Appalachians in this later Ordovician time, but from the occurrence of these fossils in the extreme west. Graptolites of this age are reported by White in Nevada *, and have recently been found by McConnell and identified by Lapworth in the Wapta Pass in the Rocky Mountains of Canada †. Thus, what we have regarded as marginal and submarginal conditions may in the later Ordovician have prevailed from the Atlantic to the Pacific. This was undoubtedly a consequence of the gradual subsidence going on in the Ordovician age. It was naturally followed by the settlement of the ocean-bed, which raised again the continental area and folded the marginal and submarginal Ordovician rocks on both sides of the Atlantic.

I may add that the above views correspond closely with those I have held for many years, as the result of much study of these rocks in my summer vacations on the Lower St. Lawrence, and which are thus expressed in a paper published in 1883 ‡:—

"There seems reason to believe from Mr. Richardson's recent observations that Graptolitic zones reaching from the Lower Tremadoc to the Upper Llandeilo may be discriminated in the great mass of sediments known as the 'Quebec Group,' which the writer has long believed, on the evidence of the fossils he has himself observed, to represent a lapse of geological time extending from the base of the Potsdam to the Chazy limestone." Prof. Lapworth's recent memoir extends the range of this comparison as far upward as the Trenton and even the Utica.

One feature of the Quebec Series is especially characteristic and American; this is the great limestone-conglomerates, which form conspicuous features in its middle portion. These conglomerates, which are very irregular in their distribution, and swell out rapidly to great thickness, degenerating as rapidly to mere sandstones, are remarkable for the quantity of boulders and pebbles of limestone which they contain, and which often afford Cambrian fossils, though in other cases they appear to belong to the limestone of the lower part of the Quebec group itself. The only means of explaining these conglomerates seems to be the action of the coast ice, which at this period appears to have been as energetic on the American shores as at the present day, and seems to have had great reefs of limestone, probably in the area of the Gulf of St. Lawrence, to act

* Report on the 100th Meridian, vol. iv.

† "Report on Rocky Mountains," Geol. Surv. of Canada, 1887.

‡ Report on Peter Redpath Museum.

upon and to remove in large slabs and boulders, piling these up on banks, to constitute masses of conglomerate. This would bespeak a cold ice-laden sea as that in which the Graptolites lived, and it may account for the survival in these areas of old Trilobitic genera which were not represented in the warmer waters of the continental plateau. This circumstance has perhaps some connexion with the greater apparent survival of these in America as compared with Europe, though I suspect that the observed appearances depend in part upon collectors attributing species belonging to fragments of older limestones to the Quebec group itself.

The importance of the Quebec group of Logan is thus vindicated, as representing widely spread local conditions and great lapse of geological time; and the prescient view which he entertained of it may be indicated by the following extract from a note appended by him to Murray's Report on Newfoundland in 1865:—

"The sediments which in the first part of the Silurian period were deposited in the ocean surrounding the Laurentian and Huronian nucleus of the present American continent, appear to have differed considerably in different areas. Oscillations in this ancient land permitted to be spread over its surface, when at times submerged, that series of apparently conformable deposits which constitute the New York system, ranging from the Potsdam to the Hudson River formation. But between the Potsdam and Chazy periods, a sudden continental elevation, and subsequent gradual subsidence, allowed the accumulation of a great series of intermediate deposits, which are displayed in the Green Mountains on one side of the ancient nucleus, and in the metalliferous rocks of Lake Superior on the other, but which are necessarily absent in the intermediate region of New York and central Canada.

"At an early date in the Silurian period, a great dislocation commenced along the south-eastern line of the ancient gneissic continent, which gave rise to the division that now forms the western and eastern basins. The western basin includes those strata which extended over the surface of the submerged continent, together with the Pre-Chazy rocks of Lake Superior, while the Lower Silurian rocks of the eastern basin present only the Pre-Chazy formations, unconformably overlaid, in parts, by Upper Silurian and Devonian rocks. The group between the Potsdam and Chazy, in the eastern basin, has been separated into three divisions, but these subdivisions have not yet been defined in the western basin. In the western basin the measures are comparatively flat and undisturbed; while in the eastern they are thrown into innumerable undulations, a vast majority of which present anticlinal forms overturned on the north-western side. The general sinuous north-east and south-west axis of these undulations is parallel with the great dislocation of the St. Lawrence, and the undulations themselves are a part of those belonging to the Appalachain chain of mountains. It is in the western basin that we must look for the more regular succession of the Silurian rocks, from the time of the Chazy, and in the eastern, including Newfoundland, for that of those anterior to it."

Of Ordovician rocks other than the Quebec group and nearer to the Atlantic margin, perhaps the best example is that of the area in Central and Western New Brunswick described by Prof. Bailey*. This consists, in ascending order, of (1) gneiss and mica-schist with chloritic and hornblendic schists, (2) grey and purplish micaceous sandstones and slates with limestone and conglomerate and felspathic slates, (3) black graphitic and pyritous slates, (4) schistose felspathic rocks and conglomerates, (5) amygdaloid and felsite with sandstone and slate, (6) felsites capped with sandstones and slates, often chloritic. These remarkable rocks, which are of great thickness and have evidently experienced much metamorphism, have been found at one locality to contain fossils of Trenton age equivalent to Bala and Llandeilo. Similar rocks come out from beneath Silurian beds in various parts of the hilly districts of Nova Scotia†. They resemble the Cumberland Ordovician more nearly than other British developments of these rocks. In the continuation of these beds in Northern New Brunswick Graptolites were discovered some years ago by Mr. Robb and Dr. Ells, of the Canadian Geological Survey, and are believed to be of Upper Ordovician age.

V. The Silurian System.

In the inland plateau of North America this period begins with shallow-water conditions passing into the great and long-continued depression marked by the Niagara Limestone. There is then a second elevation, that of the Salina, succeeded by the very widely distributed Helderberg Limestones. There are thus two depressions separated by an intervening elevation.

In Newfoundland the Silurian rocks occur in a narrow trough extending through the centre of the island, and, so far as can be ascertained from the Reports of the Survey of Newfoundland, are not dissimilar from the exposures in Nova Scotia.

In the latter province the great limestones are absent or represented by comparatively insignificant and impure bands. Shales with some sandy beds (Lower Arisaig beds of previous papers) represent the Clinton and contain *Graptolithus clintonensis*; coarse impure limestone and shale (New Canaan beds of previous papers) correspond to the Niagara, holding characteristic corals of this age, and shaly beds with thin layers of limestone (Upper Arisaig of previous papers) represent the Helderberg. In Nova Scotia these occur in the New Canaan, Arisaig, and Pictou districts, and their characters correspond to those seen in Newfoundland, New Brunswick, and Maine. In the Cobequid Mountains of Nova Scotia, however, and in New Brunswick, these beds, especially in their upper part, show great contemporaneous emissions of igneous rock. These are partly felsitic and partly doleritic and amygdaloidal. They correspond in age with those isolated igneous masses of the

* Report Geological Survey of Canada, 1884–5.

† Quart. Journ. Geol. Soc. 1850. 'Acadian Geology' and Supplement.

plain of the St. Lawrence to which the Montreal and Belœil Mountains belong.

In proceeding to the west and north the Helderberg Limestones appear in great force at Cape Bon Ami in Northern New Brunswick, where they are rich in fossils and associated with beds of trap. Both limestones are largely developed in Bonaventure and Gaspé, and the lower member in the Island of Anticosti, so that here as in previous periods the area of the Gulf of St. Lawrence corresponds with the interior plateau rather than with the coastal region. In some respects, indeed, this area presents an exaggeration of the interior conditions, since in Anticosti there is apparently a gradual passage from the limestones of the Hudson-river group to those of the Clinton, without the intervention of sandstones similar to the Oneida and Medina of New York and Ontario. In so far as I am aware there is also an absence of beds representing that condition of deserts and salt lagoons represented by the Salina or Onondago salt-group. In this last respect, as in so many others, the conditions of the eastern districts of America conform to those of Europe, and not to those of the interior plateau of America.

In America as in England the Silurian of the maritime districts is unconformable to the Ordovician, though this does not hold in Anticosti or in the inland region.

Lithologically the English Silurian is more perfect than that of the East Coast of America, as containing, in the Wenlock Limestone, a better representative of the Niagara formation. The unequal character of this limestone, however, and its thinning out toward the south-west, bring the series into harmony with that in Nova Scotia. The Ludlow rocks are perfect representatives of the Upper Arisaig series of Nova Scotia, and the fossils are remarkably similar, much more so than in the case of the Arisaig and the inland Helderberg in any locality known to me*.

In England the trees which I have named *Nematodendreæ* appear first in the Denbighshire Sandstone at the base of the Silurian†. In America they appear in the Helderberg series. Placoganoid fishes have recently been recognized in the Silurian in New Brunswick‡.

The eurite and tufaceous rocks of the Silurian of the West of Ireland appear to be the principal British representatives of the abundant rocks of volcanic origin associated with the Upper Silurian in Nova Scotia and New Brunswick §.

In summing up the Eozoic and older Palæozoic rocks of the Maritime Provinces I may reproduce here, with some slight additions, the table given in the Supplement to 'Acadian Geology,' 1878.

* Acadian Geology and Supplements.
† Hicks, Quart. Journ. Geol. Soc. vols. xxxvii. and xxxviii.; Dawson, *ibid.*
‡ Matthew, 'Canadian Record of Science,' 1886.
§ Murchison, 'Siluria.'

England, &c.	Nova Scotia and New Brunswick.
Silurian.	
Ludlow, Wenlock and Llandovery, or Mayhill.	Upper Arisaig Series, Nova Scotia; Mascarene Series, New Brunswick; Lower Arisaig, New Canaan and Wentworth beds of Nova Scotia; and Restigouche series, New Brunswick.
Ordovician.	
Caradoc and Bala, with Snowdon felsites and ash-beds, Coniston and Knock Series.	Upper Cobequid Series, slates, felsites, quartzites, and greenstones. Ordovician of Western and Central New Brunswick.
Great felsite and trap-ash Series of Borrowdale (Ward).	Lower Cobequid Series, felsites, porphyrites, agglomerates, and massive syenite of Cobequids, Pictou, and Cape Breton ? *
Lower Llandeilo flags and shales, Arenig Series, Skiddaw slates, &c.	Middle Graptolitic or Levis Series of Quebec and North New Brunswick, part of Cape Breton Series ?
Cambrian.	
Tremadoc slates and Lingula-flags.	Matane or Cape Rosier Graptoltic beds. Miré and St. Andrew's Channel Series in Cape Breton ?
Menevian and Longmynd Series, Harlech grits, and Llanberis slates.	Acadian Series of St. John, New Brunswick. Quartzite and slate of Atlantic coast of Nova Scotia.
Caerfai Group of Hicks.	Basal Cambrian of Southern New Brunswick.
Huronian.	
Pebidian Series (Hicks), containing felsite, chlorite-schist, and serpentine.	Huronian felsites, chloritic and epidotic rocks of Southern New Brunswick, Yarmouth, and of Cape Breton in part.
Laurentian.	
Older gneisses of Scotland and of Scandinavia, Dimetian ?	Gneiss, quartzite and limestone of St. John, Portland Group, gneiss of St. Anne's Mountain.

VI. The Erian, or Devonian System.

This formation, most largely and completely represented in the great "Erie Division" of the Geological Survey of New York, which occupies an immense area in the district around the lake from which it is named, and attains therein its maximum thickness and development, appears on the eastern coast entirely in the form of sandstones and shales, which may be compared with those of the Old Red Sandstone of Scotland and England. They differ entirely in mineral character from the great limestone- and shale-deposits of the interior of America, where, in the Province of Ontario, the Corniferous Lime-

* It seems impossible at present to separate these perfectly from the Huronian, in some localites at least.

stone is perhaps the richest of all the palæozoic limestones in fossil corals, and indicates a long continuance of truly marine conditions. These beds abound in fossil plants and, locally, in remains of fishes, and both the fishes and the plants are generically similar to those of Britain, and divisible into two series, representing the lower and the upper members respectively. The beds do not appear, however, to be lake-deposits but, rather, estuarine and littoral. They have been fully described in the papers referred to below *.

In the Baie de Chaleur, for example, the lowest series is characterized by *Psilophyton* and *Nematophyton*, and by fishes of the genera *Cephalaspis*, *Coccosteus*, *Ctenacanthus*, and *Homacanthus*†. The upper division is characterized by ferns of the genera *Archæopteris* and *Platyphyllum*, and by fishes of the genera *Pterichthys*, *Diplacanthus*, *Phaneropleuron*, *Glyptolepis*, *Cheirolepis*, and a new genus named by Whiteaves *Eusthenopteron*‡.

The only truly marine portion of the system in the Maritime Province is the lower part, corresponding to the Oriskany of the interior, and this may perhaps be regarded as an equivalent of the Downton Sandstones of England.

The greatest granitic intrusions of Nova Scotia belong to the close of the Devonian, as do many granitic masses in New Brunswick and Quebec. These are the equivalents of the Devonian and Cornish granites, though perhaps a little earlier in date, and are also represented by the felsites of the Scottish Devonian.

The remarkably rich flora of the Erian of the east of Canada was first made known in the Journal of this Society, and still holds its position as probably the most copious known in this age, though I have been obliged to withdraw two of its species, *Selaginites formosus* and *Equisetites Wrightianus*, as probably Crustacean, and the genus *Dictyophyton* as certainly belonging to sponges and not vegetable §.

VII. The Carboniferous System, &c.

The Carboniferous formations of Nova Scotia have been described by the writer in a number of papers in the Journal of this Society‖. Like the Carboniferous of Britain, these rocks present many local diversities. Their subdivisions are :—

1. A lower series corresponding to the Tuedian of the North of England and Calciferous of Scotland both in mineral character and fossils (the *Horton Series* of my later papers) ¶.

2. A Carboniferous Limestone, associated, however, with gypsum, and marly and red sandstones, but having fossil remains for the most

* Quart. Journ. Geol. Soc. vols. xv. and xviii.

† Dawson's Report on Erian Plants. Whiteaves, Trans. Roy. Soc. Can. vol. iv. "On Devonian Fishes."

‡ *Ibid.*

§ Quart. Journ. Geol. Soc. vols. xv., xviii., xxvii., xxix., xxxvi., xxxviii. The Devonian Flora of Scotland and that of Belgium, as described by Crépsin, and exhibited in the Brussels Museum, are closely allied to that of Eastern Canada.

‖ Quart. Journ. Geol. Soc. vols. i., ii., v., ix., x., xi., xv., xix., xxii., xxix., xxx.

¶ Acadian Geology, 3rd edition.

part specifically identical with those of England (*Windsor Series* of recent papers).

3. A Millstone-grit series consisting of coarse sandstones and shales with conglomerate, mostly of red colours.

4. The Main or Productive Coal-measures, precisely similar in character to those of Britain. Of 135 species of fossil plants which I have catalogued from these beds more than one half are specifically identical with those of England. The animal fossils of these beds, Batrachians, Fishes, Crustaceans, and Mollusks, are also akin to those of England. In the class of Batrachians a still more close approximation appears in those obtained by Fritzsch in the Upper Carboniferous of Bohemia.

5. A Permo-Carboniferous series, perhaps corresponding in age to the Lower Permian of England, and consisting largely of Red Sandstones with species of plants characteristic in Europe of the Lower Permian, but including no limestones.

The conditions of the Carboniferous are on the whole similar throughout North America, except in the extreme West and locally in the Appalachian region; but in Nova Scotia, Newfoundland, and New Brunswick they are more nearly allied to the British type, except in the abundance of red marls and gypsum in the Lower part.

Interstratified trappean rocks, similar to those in Scotland and England, occur in Nova Scotia and New Brunswick, especially in the Lower Carboniferous.

The details of the Carboniferous and Permian of Nova Scotia and Prince Edward Island are so fully given in the papers referred to in the notes, that the above general mention will be sufficient here.

One fact of general application which is admirably illustrated in the Carboniferous of Nova Scotia is the extreme sensitiveness of the earth's crust to unequal pressure. The Coal-formation of the Cumberland district, 5000 feet in thickness, and consisting wholly of beds which must have been deposited almost exactly at the sea-level, shows that for every inch of sediment or of vegetable matter there must have been a corresponding depression of the crust. This accurate correspondence of sedimentation with subsidence has long appeared to me one of the most striking facts in geological dynamics.

The Triassic Red Sandstone of Nova Scotia and Prince Edward Island and the associated Traps closely resemble the same formations in England. Like them they contain no important marine limestones, and their fossils are limited thus far to a single Dinosaurian reptile and a few fossil plants. In these it is far inferior to deposits of the same age further to the south on the Atlantic coast of the United States. In America, as in Europe, the Triassic flora and land- and freshwater-faunas seem to have been of southern origin.

The maritime region of Eastern Canada is remarkable for its deficiency of Mesozoic rocks newer than the Trias. If there are such deposits, they must be, like the Cretaceous rocks believed to exist further south on George's Banks, still under the sea. It is only on Greenland and the Arctic Islands that we find beds ranging from

the Lias to the Eocene, and these belong rather to the Arctic basin than to that of the Atlantic *. In this respect the maritime region of Canada differs materially from that of Europe, though it is noteworthy that the extreme coastal region of Great Britain to the west is also somewhat deficient in such rocks.

The question of Palæozoic climates in the northern hemisphere has some bearings on the subjects discussed in this paper, and is well illustrated by a map of the Arctic districts of Canada recently issued by the Geological Survey †. From this it appears that there are no indications of a warm climate in the Arctic basin up to the close of the Cambrian. The later Ordovician and the Silurian were, however, signalized by the deposition in the Arctic seas of thick and extensive organic limestones, holding fossils comparable with those of the temperate regions at the same time. The Lower Erian may perhaps indicate a short relapse to cold; but in the Upper Erian and Lower Carboniferous we have warm seas tenanted by marine animals and a rich land-vegetation appearing both in the Arctic Islands of Canada and in Spitzbergen. The Upper Coal-formation and the Permian and Trias indicate a return of cold, and the temperature seems to increase in the Jurassic, attaining its maximum in the later Cretaceous and Eocene, and gradually diminishing to the glacial age, between which and the modern there seems to have been a warm period of short duration, evidenced in the deposition of mammoth bones, &c., on the Arctic coasts. The cycles of cold and warm climate thus indicated in the Arctic region have, I think, an important bearing on the succession of life further south, at least in Eastern America, and their correlation with the climatal changes in Europe would be a subject of much interest, on which, however, I do not feel in a position to speak positively; but I imagine that the warm and cold periods will be found to correspond with those of the Arctic basin and of America.

The general sketch above given is sufficient to show that in the rocks from the Laurentian to the Trias inclusive we have on the two sides of the Atlantic a continuous parallelism in the following points:—

1. In mineral character and order of succession of aqueous deposits.
2. In the occurrence of great earth-movements of elevation, depression, and plication, at corresponding times.
3. In the ejection of like kinds of igneous rocks in connexion with like members of the aqueous series.
4. In the order of introduction and extinction of animals and plants.
5. In the specific identity of animals and plants in corresponding formations.

All this, I think, points to an actual contemporaneity of the successive changes on the two sides of the Atlantic basin, and to a special correspondence of the formations of the respective marginal

* For references see 'Notes on Geological Map of Northern Canada' by Dr. G. M. Dawson.

† 'Geology of Northern Canada,' Dr. G. M. Dawson, 1887.

areas as contrasted with those of the continental plateaus. It also indicates a persistence, on the whole, of the oceanic character of the Atlantic depression.

Lastly it shows the necessity in any system of geological classification of distinguishing the continental plateaus, the lines of great foldings and of igneous action, and the ancient ocean-margins from each other, and of adapting our arrangements and nomenclature to their actual diversity. In order to do this, while adopting common designations for the great ages of geological time, and for those systems of formations which mark the successive submergences and emergences of the continental plateaus, separate classifications must exist for the different kinds of areas, in their details. It is also, I think, necessary that we should not tie ourselves down to hard-and-fast lines either as to the limits of systems or as to the relative values of their divisions in widely separated localities, as these differ in nature, and nothing is to be gained by conventional arrangements overlooking these differences.

Finally, I can imagine that many questions which have not occurred to me may present themselves to the minds of other geologists who may read or hear this paper. Should I possess any facts tending to the solution of such questions, and not stated in the above pages, they will be at the service of any one desirous to use them for the advancement of science.

Discussion.

The President, whilst recognizing the importance of the paper, doubted whether the question of correlation of the Pre-Cambrian rocks on either side of the Atlantic was ripe for discussion.

Dr. Hicks felt sure that the paper would be welcomed on this side of the Atlantic. He agreed with most of the conclusions of the Author, including the correlation of the Huronian with the Pebidian. This was borne out, not only by similarity of lithological characters, but by the exact correspondence of the succeeding beds in the two areas as shown by Mr. G. F. Matthew. The difficulty of correlation lay with the rocks below the Huronian. He noticed that fragments of granitoid rocks occurred in the Huronian as in the Pebidian. He also had called attention to the contrast between the Palæozoic rocks of the ocean borders and those of the interior of the continents, in papers read before the Society and elsewhere.

Dr. Scott referred to Mr. Walcott's work, and mentioned the occurrence of great deposits of Pre-Cambrian rock in Arizona. Where terrestrial species play an important part, difficulties of correlation were much increased.

Dr. Hinde noticed the difference between the coast-geology of America and that of the interior.

Mr. Marr stated that the paper referred very fully to the point noticed by the last speaker.