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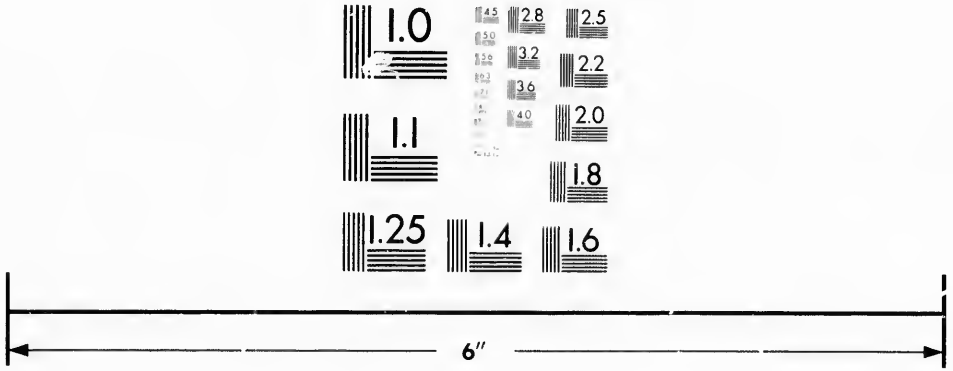

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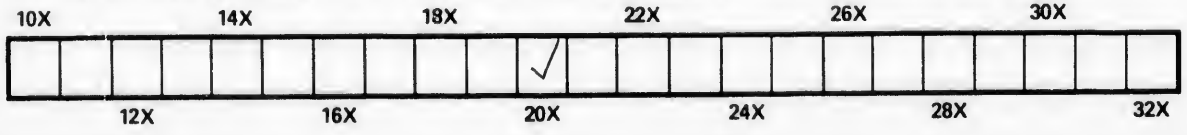

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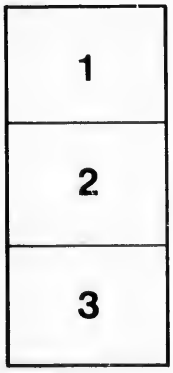

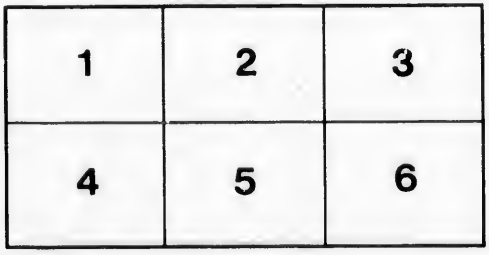

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HISTORY OF THE NAMES

CAMBRIAN AND SILURIAN

IN

GEOLOGY.

With Chas. Hoffmann's compliments.

By T. STERRY HUNT, LL.D., F.R.S.

From the CANADIAN NATURALIST *for April and July*, 1872.

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1737

HISTORY OF THE NAMES CAMBRIAN AND SILURIAN IN GEOLOGY.

By T. Sterry Hunt, LL.D, F.R.S.

It is proposed in the following pages to give a concise account of the progress of investigation of the lower paleozoic rocks during the last forty years. The subject may naturally be divided into three parts: 1. The history of Silurian and Upper Cambrian in Great Britain from 1831 to 1854; 2. That of the still more ancient paleozoic rocks in Scandinavia, Bohemia, and Great Britain up to the present time, including the recognition by Barrande of the so-called primordial paleozoic fauna; 3. The history of the lower paleozoic rocks of North America.

I. Silurian and Upper Cambrian in Great Britain.

Less than forty years since, the various unerystalline sedimentary rocks beneath the coal-formation in Great Britain and in continental Europe were classed together under the common name of graywacke or grauwacké, a term adopted by geologists from German miners, and originally applied to sandstones and other coarse sedimentary deposits, but extended so as to include associated argillites and limestones. Some progress had been made in the study of this great Graywacke formation, as it was called, and organic remains had been described from various parts of it; but to two British geologists was reserved the honor of bringing order out of this hitherto confused group of strata, and establishing on stratigraphical and paleontological grounds a succession and a geological nomenclature. The work of these two investigators was begun independently and simultaneously in different parts of Great Britain. In 1831 and 1832, Sedgwick made a careful section of the rocks of North Wales from the Menai Strait across the range of Snowdon to the Berwyn hills, thus traversing in a south-eastern direction Caernarvon, Denbigh and Merionethshire. Already, he tells us, he had in 1831, made out the relations of the Bangor group, (including the Llanberris slates and the overlying Harlech grits,) and showed that the fossiliferous strata of Snowdon occupy a synclinal, and are stratigraphically several thousand feet above the horizon of the

A Synclinal

B anticlinal

latter. Following up this investigation in 1832, he established the great Merioneth anticlinal, which brings up the lower rocks on the south-east side of Snowdon, and is the key to the structure of North Wales. From these, as a base, he constructed a section along the line already indicated, over Great Arenig to the Bala limestone, the whole forming an ascending series of enormous thickness. This limestone in the Berwyn hills is overlaid by many thousand feet of strata as we proceed eastward along the line of section, until at length the eastern dip of the strata is exchanged for a westward one, thus giving to the Berwyn chain, like that of Snowdon, a synclinal structure. As a consequence of this, the limestone of Bala re-appears on the eastern side of the Berwyns, underlaid as before by a descending series of slates and porphyries. These results, with sections, were brought before the British Association for the Advancement of Science at its meeting at Oxford, in 1832, but only a brief and imperfect account of the communication of Sedgwick on this occasion appears in the Proceedings of the Association. He did not at this time give any distinctive name to the series of rocks in question. [L. E. & D. Philos. Mag. [1854] IV, viii, 495.]

Meanwhile, in the same year, 1831, Murchison began the examination of the rocks on the river Wye, along the southern border of Radnorshire. In the next four years he extended his researches through this and the adjoining counties of Hereford and Salop, distinguishing in this region four separate geological formations, each characterized by peculiar fossils. These formations were moreover traced by him to the south-westward across the counties of Brecon and Caermarthen; thus forming a belt of fossiliferous rocks stretching from near Shrewsbury to the mouth of the river Towey, a distance of about 100 miles along the north-west border of the great Old Red sandstone formation, as it was then called, of the west of England.

The results of his labors among the rocks of this region for the first three years were set forth by Murchison in two papers presented by him to the Geological Society of London in January, 1834. [Proc. Geol. Soc. II., 11.] The formations were then named as follows in descending order: 1. Ludlow, 2. Wenlock, constituting together an upper group; 3. Caradoc, 4. Llandeilo (or Builth) forming a lower group. The Llandeilo formation, according to him, was underlaid by what he called the Longmynd and Gwastaden rocks. The non-fossiliferous strata of the Long-

mynd hills in Shropshire were described as rising up to the east from beneath the Llandeilo rocks; and as appearing again in South Wales, at the same geological horizon, at Gwastaden in Breconshire, and to the west of Llandovery in Caermarthenshire; constituting an underlying series of contorted slaty rocks many thousand feet in thickness, and destitute of organic remains. The position of these rocks in South Wales was, however, to the north-west, while the strata of the Longmynd, as we have seen, appear to the east of the fossiliferous formations.

In the *Philosophical Magazine* for July, 1835, Murchison gave to the four formations above named the designation of Silurian, in allusion, as is well known, to the ancient British tribe of the Silures. It now became desirable to find a suitable name for the great inferior series, which, according to Murchison, rose from beneath his lowest Silurian formations to the north-west, and appeared to be widely spread in Wales. Knowing that Sedgwick had long been engaged in the study of these rocks, Murchison, as he tells us, urged him to give them a British geographical name. Sedgwick accordingly proposed for this great series of Welsh rocks, the appropriate designation of Cambrian, which was at once adopted by Murchison for the strata supposed by him to underlie his Silurian system. [Murchison, Anniv. Address, 1842; Proc. Geol. Soc. III., 641.] This was almost simultaneous with the giving of the name of Silurian, for in August, 1835, Sedgwick and Murchison made communications to the British Association at Dublin on Cambrian and Silurian Rocks. These, in the volume of Proceedings (pp. 59, 60) appear as a joint paper, though from the text they would seem to have been separate. Sedgwick then described the Cambrian rocks of North Wales as including three divisions: 1. The Upper Cambrian which occupies the greater part of the chain of the Berwyns, where, according to him, it was connected with the Llandeilo formation of the Silurian. To the next lower division, Sedgwick gave the name of Middle Cambrian, making up all the higher mountains of Caernarvon and Merionethshire, and including the roofing-slates and flagstones of this region. This middle group, according to him, afforded a few organic remains, as at the top of Snowdon. The inferior division, designated as Lower Cambrian, included the crystalline rocks of the south-west coast of Caernarvon and a considerable portion of Anglesea, and consisted of chloritic and micaceous schists, with slaty quartzites and

chloritic schist = green slate

subordinate beds of serpentine and granular limestone; the whole without organic remains.

These crystalline rocks were, however, soon afterwards excluded by him from the Cambrian series, for in 1838 [Proc. Geol. Soc. II, 679] Sedgwick describes further the section from the Menai Strait to the Berwyns, and assigns to the chloritic and micaceous schists of Anglesea and Caernarvon a position inferior to the Cambrian, which he divides into two parts; viz., Lower Cambrian, comprehending the old slate series, up to the Bala limestone beds; and Upper Cambrian, including the Bala beds and the strata above them in the Berwyn chain, to which he gave the name of the Bala group. The dividing line between the two portions was subsequently extended downwards by Sedgwick to the summit of the Arenig slates and porphyries. The lower division was afterwards subdivided by him into the Bangor group, (to which the name of Lower Cambrian was henceforth to be restricted,) including the Llanberris roofing-slates and the Harlech grits or Barmouth sandstones; and the Festiniog group, which included the Lingula-flags and the succeeding Tremadoc slates.

In the communication of Murchison to the same Dublin meeting, in August, 1835, he repeated the description of the four formations to which he had just given the name of Silurian; which were, in descending order, Ludlow and Wenlock (Upper Silurian), and Caradoc and Llandeilo (Lower Silurian). The latter formation was then declared by Murchison to constitute the base of the Silurian system, and to offer in many places in South Wales distinct passages to the underlying slaty rocks, which were, according to him, the Upper Cambrian of Sedgwick.

Meanwhile, to go back to 1834, we find that after Murchison had, in his communication to the Geological Society, defined the relation of his Llandeilo formation to the underlying slaty series, but before the names of Silurian and Cambrian had been given to these respectively, Sedgwick and Murchison visited together the principal sections of these rocks from Caermarthenshire to Denbighshire. The greater part of this region was then unknown to Sedgwick, but had been already studied by Murchison, who interpreted the sections to his companion in conformity with the scheme already given; according to which the beds of the Llandeilo were underlaid by the slaty rocks which appear along their north-western border. When, however, they entered the region which had already been examined by Sedgwick, and reached the

section on the east side of the Berwyns, the fossiliferous beds of Meifod were at once pronounced by Murchison to be typical Caradoc, while others in the vicinity were regarded as Llandeilo. The beds of Meifod had, on paleontological grounds, been by Sedgwick identified with those of Glyn Ceirog, which are seen to be immediately overlaid by Wenlock rocks. These determinations of Murchison were, as Sedgwick tells us, accepted by him with great reluctance, inasmuch as they involved the upper part of his Cambrian section in most perplexing difficulties. When however, they crossed together the Berwyn chain to Bala, the limestones in this locality were found to contain fossils nearly agreeing with those of the so-called Caradoc of Meifod. The examination of the section here presented showed, however, that these limestones are overlaid by a series of several thousand feet of strata bearing no resemblance either in fossils or in physical characters to the Wenlock formation which overlies the Caradoc beds of Glyn Ceirog. This series was, therefore, by Murchison supposed to be identical with the rocks which, in South Wales, he had placed beneath the Llandeilo, and he expressly declared that the Bala group could not be brought within the limits of his Silurian system. It may here be added that in 1842 Sedgwick re-examined this region, accompanied by that skilled palæontologist, Salter, confirming the accuracy of his former sections, and showing moreover by the evidence of fossils that the beds of Meifod, Glyn Ceirog and Bala are very nearly on one parallel. Yet, with the evidence of the fossils before him, Murchison, in 1834, placed the first two in his Silurian system, and the last deep down in the Upper Cambrian; and consequently was aware that on paleontological grounds it was impossible to separate the lower portion of his Silurian system from the Upper Cambrian of Sedgwick. (These names are here used for convenience, although we are speaking of a time when they had not been applied to designate the rocks in question.)

This fact was repeatedly insisted upon by Sedgwick, who, in the Syllabus of his Cambridge lectures, published very early in 1837, enumerated the principal genera and species of Upper Cambrian fossils, many of which were by him declared to be the same with those of the Lower Silurian rocks of Murchison. Again, in enumerating in the same Syllabus the characteristic species of the Bala limestone, it is added by Sedgwick: "all of which are common to the Lower Silurian system." This was again insisted

upon by him in 1838 and 1841. [Proc. Geol. Soc. II, 679; III, 548.] It was not until 1840 that Bowman announced the same conclusion, which was reiterated by Sharpe in 1842. [Ramsay, Mem. Geol. Sur. III, part 2, page 6.]

In 1839, Murchison published his *Silurian System*, dedicated to Sedgwick, a magnificent work in two volumes quarto, with a separate map, numerous sections and figures of fossils. The succession of the Silurian rocks, as there given, was precisely that already set forth by the author in 1834, and again in 1835; being, in descending order, Ludlow and Wenlock, constituting the Upper Silurian, and Caradoc and Llandeilo (including the Lower Llandeilo beds or Stiper-stones), the Lower Silurian. These are underlaid by the Cambrian rocks, into which the Llandeilo was said to offer a transition marked by beds of passage. Murchison, in fact, declared that it was impossible to draw any line of separation either lithological, zoological or stratigraphical between the base of the Silurian beds (Llandeilo) and the upper portion of the Cambrian,—the whole forming, according to him, in Caermarthenshire, one continuous and conformable series from the Cambrian to the Ludlow. [Silurian System, pages 256, 358.] By Cambrian in this connection we are to understand only the Upper Cambrian or Bala group of Sedgwick, as appears from the express statement of Murchison, who alludes to the Cambrian of Sedgwick as including all the older slaty rocks of Wales, and as divided into three groups, but proceeds to say that in his present work (the Silurian System) he shall notice only the highest of these three.

Since January, 1834, when Murchison first announced the stratigraphical relations of the lower division of what he afterwards called the Silurian system, the aspect of the case had materially changed. This division was no longer underlaid, both to the east in Shropshire and to the west in Wales, by a great unfossiliferous series. His observations in the vicinity of the Berwyn hills with Sedgwick in 1834, and the subsequently published statements of the latter had shown, that this supposed older series was not without fossils; but on the contrary, in North Wales, at least, held a fauna identical with that characterising the Lower Silurian. Hence the assertion of Murchison in his *Silurian System*, in 1839, that it was not possible to draw any line of demarcation between them. The position was very embarrassing to the author of the *Silurian System*, and for the mo-

ment, not less so to the discoverer of the Upper Cambrian series. Meanwhile, the latter, as we have seen, in 1842 re-examined with Salter his Upper Cambrian sections in North Wales, and satisfied himself of the correctness, both structurally and paleontologically, of his former determinations. Murchison, in his anniversary address as President of the Geological Society in 1842, after recounting, as we have already done, the history of the naming by Sedgwick in 1835, of the Cambrian series, which Murchison supposed to underlie his Silurian system, proceeded as follows: "Nothing precise was then known of the organic contents of this lower or Cambrian system except that some of the fossils contained in its upper members in certain prominent localities were published Lower Silurian species. Meanwhile, by adopting the word Cambrian, my friend and myself were certain that whatever might prove to be its zoological distinctions, this great system of slaty rocks being evidently inferior to those zones which had been worked out as Silurian types, no ambiguity could hereafter arise. * * * In regard, however, to a descending zoological order it still remained to be proved whether there was any type of fossils in the mass of the Cambrian rocks different from those of the Lower Silurian series. If the appeal to nature should be answered in the negative, then it was clear that the Lower Silurian type must be considered the true base of what I had named the protozoic rocks; but if characteristic new forms were discovered, then would the Cambrian rocks, whose place was so well established in the descending series, have also their own fauna, and the paleozoic base would necessarily be removed to a lower horizon." If the first of these alternatives should be established, or in other words, if the fauna of the Cambrian rocks was found to be identical with that of the Lower Silurian, then, in the author's language, "the term Cambrian must cease to be used in zoological classification, it being, in that sense, synonymous with Lower Silurian." That such was the result of paleontological inquiry, Murchison proceeded to show by repeating the announcements already made by Sedgwick in 1837 and 1838, that the collections made by the latter from the great series of fossiliferous strata in the Berwyns, from Bala, from Snowdon and other Cambrian tracts, were identical with the Lower Silurian forms. These strata, it was said, contain throughout "the same forms of Orthis which typify the Lower Silurian rocks." It was farther declared by Murchison in this

address, that researches in Germany, Belgium and Russia led to the conclusion that the "fossiliferous strata characterized by Lower Silurian Orthidæ are the oldest beds in which organic life has been detected." [Proc. Geol. Soc. III, 641, et seq.] The Orthids here referred to are, according to Salter, *Orthis calligramma*, Dalm, and its varieties. [Mem. Geol. Survey III, part 2, 335–337.]

Meanwhile Sedgwick's views and position began to be misrepresented. In 1842, Mr. Sharpe, after calling attention to the fact that the fossils of the Bala limestone were, as Sedgwick had long before shown, identical with those of Murchison's Lower Silurian, declared that Sedgwick had placed the Upper Cambrian, in which the Bala beds were included, beneath the Silurian, and that this determination had been adopted by Murchison on Sedgwick's authority. [Proc. Geol. Soc. IV, 10.] This statement Murchison suffered to pass uncorrected in a complimentary review of Sharpe's paper in his next annual address (1843). In his *Siluria*, 1st edition, page 25, (1854) he speaks of the term Cambrian as applied (in 1835) by Sedgwick and himself "to a vast succession of *fossiliferous* strata containing undescribed fossils, the whole of which were supposed to rise up from beneath well-known Silurian rocks. The Government geologists have shown that this *supposed* order of superposition was erroneous," &c. The italics are the author's. Such language, coupled with Mr. Sharpe's assertion noticed above, helped to fix upon Sedgwick the responsibility of Murchison's error. Although the historical sketch, which precedes, clearly shows the real position of Sedgwick in the matter, we may quote farther his own words: "I have often spoken of the great Upper Cambrian group of North Wales as inferior to the Silurian system, * * * * * on the sole authority of the Lower Silurian sections, and the author's many times repeated explanations of them before they were published. So great was my confidence in his work that I received it as perfectly established truth that his order of superposition was unassailable. * * * * I asserted again and again that the Bala limestone was near the base of the so-called Upper Cambrian group. Murchison asserted and illustrated by sections the unvarying fact that his Llandeilo flag was superior to the Upper Cambrian group. There was no difference between us until his Llandeilo sections were proved to be wrong." [Philos. Mag. IV, viii, 506.] That there must be a great mistake either in Sedg-

wick's or in Murchison's sections was evident, and the Government surveyors, while sustaining the correctness of those of Sedgwick, have shown the sections of Murchison to have been completely erroneous.

The first step towards an exposure of the errors of the Silurian sections is, however, due to Sedgwick and McCoy. In order better to understand the present aspect of the question it will be necessary to state in a few words some of the results which have been arrived at by the Government surveyors in their studies of the rocks in question, as set forth by Ramsay in the Memoirs of the Geological Survey. In the section of the Berwyns, the thin bed of about twenty feet of Bala limestone, which, (as originally described by Sedgwick) they have found outcropping on both sides of the synclinal chain, is shown to be intercalated in a vast thickness of Caradoc rocks; being overlaid by about 3,300 and underlaid by 4,500 feet of strata belonging to this formation. Beneath these are 4,500 feet additional of beds described as Llandeilo, which rest unconformably upon the Lingula-flags just to the west of Bala; thus making a thickness of over 12,000 feet of strata belonging to the Bala group of Sedgwick. A small portion of rocks referred to the Wenlock formation occupies the synclinal above mentioned. [Memoirs, III, part 2, 214, 222.] The second member, in ascending order, of the Silurian system, to which the name of Caradoc was given by him in 1839, was originally described by Murchison under the names of the Horderley and May Hill sandstone. The higher portions of the Caradoc were subsequently distinguished by the Government surveyors as the Lower and Upper Llandovery rocks; the latter (constituting the May Hill sandstone, and known also as the Pentamerus beds, being by them regarded as the summit of the Caradoc formation. In 1852, however, Sedgwick and McCoy showed from its fauna that the May Hill sandstone belongs rather to the overlying Wenlock than to the Caradoc formation, and marks a distinct paleontological horizon.

This discovery led the geological surveyors to re-examine the Silurian sections, when it was found by Aveline that there exists in Shropshire a complete and visible want of conformity between the underlying formations and the May Hill sandstone; the latter in some places resting upon the nearly vertical Longmynd rocks, and in others upon the Llandeilo flags, the Caradoc proper or Bala group, and the Lower Llandovery beds. Again, in

South Wales, near Builth, the May Hill sandstone or Upper Llandovery rests upon Lower Llandeilo beds; while at Noeth Grug the overlying formation is traced transgressively from the Lower Llandovery across the Caradoc to the Llandeilo. These important results were soon confirmed by Ramsay and by Sedgwick. [Ibid, 4, 236.] The May Hill sandstone often includes, near its base, conglomerate beds made up of the ruins of the older formation. To the north-east, in the typical Silurian country, it is of great thickness and continuity, but gradually thins out to the south-west.

There exists, moreover, another region where not less curious discoveries were made. About forty miles to the eastward of the typical region in South Wales appear some important areas of Silurian rocks. These are the Woolhope beds, appearing through the Old Red sandstone, and the deposits of Abberley, the Malverns and May Hill, rising along its eastern border, and covered along their eastern base by the newer Mesozoic sandstone. The rocks of these localities were by Murchison in his *Silurian System* described as offering the complete sequence. When however it was found that his Caradoc included two unconformable series, examination showed that there was no representative of the older Caradoc or Bala group in these eastern regions, but that the so-called Caradoc was nothing but the Upper Llandovery or May Hill sandstone. The immediately underlying strata, which Murchison had regarded as Llandeilo, or rather as the beds of passage from Llandeilo to Cambrian, and had compared with the north-west parts of the Caermarthenshire sections, (Sil. Sys. 416.) have since been found to be much more ancient deposits, of Middle Cambrian age, which rest upon the crystalline hypozoic rocks of the Malverns, and are unconformably overlaid by the May Hill sandstone. We shall again revert to this region, which has been carefully studied and described by Prof. John Phillips. [Mem. Geol. Sur. II., part 1.]

What then was the value and the significance of the Silurian sections of Murchison, when examined in the light of the results of the Government surveyors? The Llandeilo rocks, having throughout the characteristic Orthis so much insisted upon by Murchison, were shown to be the base of a great conformable series, and to the eastward, in Shropshire, to rest on the upturned edges of the Longmynd rocks; while westward, near Bala, they overlie unconformably the Lingula-flags, and in the island of

Anglesea repose directly upon the ancient crystalline schists. According to the author of the *Silurian System*, there existed beneath the base of the Llandeilo formation a great conformable series of slaty rocks into which this formation passed, and from which it could not be distinguished either zoologically, stratigraphically or lithologically. The sequence, determined from what were considered typical sections in the valley of the Towey in Caermarthenshire, as given by Murchison, for several years both before and after the publication of his work, was as follows: 1. Cambrian; 2. Llandeilo flags; 3. Caradoc sandstone; 4. Wenlock and Ludlow beds; 5. Old Red sandstone; the order being from north-west to south-east. What then were these fossiliferous Cambrian beds underlying the Llandeilo and indistinguishable from it? Sedgwick, with the aid of the Government surveyors, has answered the question in a manner which is well illustrated in his ideal section across the valley of the Towey. The whole of the Bala or Caradoc group rises in undulations to the north-west, while the Llandeilo flags at its base appear on an anticlinal in the valley, and are succeeded to the south-east by a portion of the Bala. The great mass of this group on the south-east side of the anticlinal is however concealed by the overlapping May Hill sandstone,—the base of the unconformable upper series which includes the Wenlock and Ludlow beds. [Philos. Mag. IV, viii, 488.] The section to the south-east, commencing from the Llandeilo flags on the anticlinal, was made by Murchison the Silurian system, while the great mass of strata on the north-west side of the Llandeilo, (which is the complete representative of the Caradoc or Bala beds, partially concealed on the south-west side,) was supposed by him to lie beneath the Llandeilo, and was called Cambrian; (the Upper Cambrian of Sedgwick). These rocks, with the Llandeilo at their base, were in fact identical with the Bala group studied by the latter in North Wales, and are now clearly traced through all the intermediate distance. This is admitted by Murchison, who says: "The first rectification of this erroneous view was made in 1842 by Prof. Ramsay, who observed that instead of being succeeded by lower rocks to the north and west, the Llandeilo flags folded over in those directions, and passed under superior strata, charged with fossils which Mr. Salter recognized as well-known types of the Caradoc or Bala beds." [Siluria, 4th ed., p. 57, foot-note.]

The true order of succession in South Wales was in fact: 1,

Llandeilo; 2, Cambrian (= Caradoc or Bala); 3, Wenlock and Ludlow; 4, Old Red sandstone; the Caradoc or Bala beds being repeated on the two sides of the anticlinal, but in great part concealed on the south-east side by the overlapping May Hill or Upper Llandovery rocks. These latter, as has been shown, form the true base of the upper series which, in the Silurian sections, was represented by the Wenlock and Ludlow. Murchison had, by a strange oversight, completely inverted the order of his lower series, and turned the inferior members upside down. In fact, the Llandeilo flags, instead of being, as he had maintained, superior to the Cambrian (Caradoc or Bala) beds, were really inferior to them, and were only made Silurian by a great mistake. The Caradoc, under different names, was thus made to do duty at two horizons in the Silurian system, both below and above the Llandeilo flags. Nor was this all, for by another error, as we have seen, the Caradoc in the latter position was made to include the Pentamerus beds of the unconformably overlying series. Thus it clearly appears that with the exception of the relations of the Wenlock and Ludlow beds to each other and to the overlying Old Red sandstone, which were correctly determined, the Silurian system of Murchison was altogether incorrect, and was moreover based upon a series of stratigraphical mistakes, which are scarcely paralleled in the history of geological investigation.

It was thus that the Lower Silurian was imposed on the scientific world; and we may well ask with Sedgwick, whether geologists "would have accepted the Lower Silurian classification and nomenclature had they known that the physical or sectional evidence upon which it was based had been, from the first, positively misunderstood." Feeling that his own sections were, as has since been fully established, free from error, Sedgwick naturally thought his name of Upper Cambrian should prevail for the great Bala group. Hence the long and embittered discussion that followed, in which Murchison, in many respects, occupied a position of vantage as against the Cambridge professor, and finally saw his name of Lower Silurian supplant almost entirely that of Upper Cambrian given by Sedgwick, who had first rightly defined and interpreted the geological relations of the group.

In a paper read before the Geological Society in June, 1843, [Proc. Geol Soc. IV, 212-223] when the perplexity in which the relations of the Upper Cambrian and Lower Silurian rocks were

involved had not been cleared up by the discovery of Murchison's errors in stratigraphy, Sedgwick proposed a compromise, according to which the strata from the Bala limestone to the base of the Wenlock were to take the name of Cambro-Silurian; while that of Silurian should be reserved for the Wenlock and Ludlow beds, and for those below the Bala the name of Cambrian should be retained. The Festiniog group (including what were subsequently named the Lingula-flags and the Tremadoc slates) would thus be Upper instead of Middle Cambrian, the original Upper Cambrian being henceforth Cambro-Silurian; it being understood that, wherever the dividing line might be drawn, all the groups above it should be called Cambro-Silurian, and all those below it Cambrian. This compromise was rejected by Murchison, who in the map accompanying the first edition of his *Silaria*, in 1854, extended the Lower Silurian color so as to include all but the lowest division of the Cambrian; viz., the Bangor group. When, however, the relations of Upper Cambrian and Silurian were made known by the discoveries of Sedgwick and the Government surveyors, this compromise was seen to be uncalled for, and was withdrawn in 1854 by Sedgwick, who re-claimed the name of Upper Cambrian for his Bala group.

In June, 1843, Sedgwick proposed that the whole of the fossiliferous rocks below the horizon of the Wenlock should be designated Protozoic, and on the 29th of November, 1843, presented to the Geological Society an elaborate paper on the Older Paleozoic (Protozoic) Rocks of North Wales, with a colored geological map. This paper, which embodied the results of the researches of Sedgwick and Salter, was not, however, published at length, but an abstract of it was prepared by Mr. Warburton, then president of the society, with a reduced copy of the map. [Proc. Geol. Soc. IV, 212 and 251-268; also Geol. Jour. I, 5-22.] In this map of Sedgwick's three divisions were established, viz., the hypozoic crystalline schists of Caernarvonshire, the "*Protozoic*," and the "*Silurian*." On the legend of the reduced map, as published by the Geological Society, these latter names were altered so as read "*Lower Silurian (Protozoic)*" and "*Upper Silurian*." These changes, in conformity with the nomenclature of Murchison, were, it is unnecessary to say, made without the knowledge of Sedgwick, who did not inspect the reduced and altered map until it was appealed to as an evidence that he had abandoned his former ground, and had recognized the equivalency

of the whole of his Cambrian with the Lower Silurian of Murchison. The reader will sympathize with the indignation with which Sedgwick declares that his map was "most unwarrantably tampered with," and will, moreover, learn with surprise, that an inspection of the proof-sheets of Warburton's abstract of Sedgwick's paper was refused him, notwithstanding his repeated solicitations. The story of all this, and finally of the refusal to print in the pages of the Geological Journal the reclamations of the venerable and aggrieved author, make altogether a painful chapter, which will be found in the Philos. Magazine, for 1854 [IV, viii, pp. 301-317, 359-370, and 483-506] and more fully in the Synopsis of British Paleozoic Rocks, which forms the introduction to McCoy's British Paleozoic Fossils.

In connection with this history it may be mentioned that in March, 1845, Sedgwick presented to the Geological Society a paper on the Comparative Classification of the Fossiliferous Rocks of North Wales and those of Cumberland, Westmoreland, and Lancashire; which appears also in abstract in the same volume of the Geological Journal that contains the abstract of the essay and the map just referred to. [I, 442.] That this abstract also is made by another than the author is evident from such an expression as "the author's opinion seems to be grounded on the following facts, etc.," (p. 448) and from the manner in which the terms Lower and Upper Silurian are applied to certain fossiliferous rocks in Cumberland. Yet the words of this abstract are quoted with emphasis in Siluria [1st ed., 147] as if they were Sedgwick's own language recognizing Murchison's Silurian nomenclature.

II.—Middle and Lower Cambrian.

Investigations in continental Europe were, meanwhile, preparing the way for a new chapter in the history of the lower paleozoic rocks. A series of sedimentary beds in Sweden and Norway had long been known to abound in singular petrifications, some of which had been examined by Linnaeus, who gave to them the name of *Entomolithi*. They were also studied and described by Wahlenberg and by Brongniart, the latter of whom, from two varieties of the *Entomolithus paradoxus*, Linn, established in 1822 two genera, *Paradoxides* and *Agnostus*. In 1826 appeared a memoir by Dalman on the Palæadæ or so-called Trilo-

bites; which was followed, in 1828, by his classic work on the same subject. [Uber de Palaeaden oder so-genanten Trilobiten, 4to. with six plates, Leipsic.] In these works were described and figured, among many others, two genera—*Oleuus*, which included *Paradoxides*, Brongn. and *Battus*, including *Agnostus* of the same author. Meanwhile, Hisinger was carefully studying the strata in which these trilobites were found in Gothland, and in the same year (1828) published in his *Anteckningar*, or Notes on the Physical and Geognostical Structure of Norway and Sweden, a colored geological map and section of these rocks as they occur in the county of Skaraborg; where three small circumscribed areas of nearly horizontal fossiliferous strata are shown to rest upon a floor of old crystalline rocks, in some parts granitic and in others gneissic in character. The section and map, as given by Hisinger, show the succession in the principal area to be as follows, in ascending order: 1. granite or gneiss; 2. sandstone; 3. alum-slates; 5. orthoceratite-limestones; 4. clay-slates. By a curious oversight the colors on the legend are wrongly arranged and wrongly numbered, as above; for in the map and section it is made clear that the succession is that just given, and that the clay-slates (4), instead of being below, are above the orthoceratite-limestones (5).

In 1837, Hisinger published his great work on the organic remains of Sweden, entitled *Lethœa Suecica* [4to. with forty-two plates.] In this he gives a tabular view, in descending order, of the rock-formations, and of the various genera and species described. The rocks of the areas just noticed appear in his fourth or lowest division, under the head of *Formationes transitionis*, and are divided as follows:

a. Strata calcarea recentiora Gottlandiæ.
b. Strata schisti argillacei.
c. Strata schisti aluminaris.
d. Strata calcarea antiquiora.
e. Strata saxi arenacei.

The succession thus given was however erroneous, and probably, like the mistake in the legend of the same author's map just mentioned, the result of inadvertence, the true position of the alum-slates (*c*) being between the older limestone (*d*) and the basal sandstone (*e*). This is shewn both by Hisinger's map of 1828, and by the testimony of subsequent observors. In Murchison's work on the Geology of Russia in Europe, publish-

ed in 1845, there is given (page 15 et seq.) an account of his visit to this region in company with Prof. Loven, of Christiania; which, with figures of the sections, is reproduced in the different editions of Siluria. The hill of Kinnekulle on Lake Wener, is one of the three areas of transition rocks delineated on the map of Hisinger above referred to. Resting upon a flat region of nearly vertical gneissic strata, we have, according to Murchison: 1. a fucoidal sandstone; 2. alum-slates; 3. red orthoceratite limestone; 4. black graptolitic slates; the whole series being little over 1000 feet in thickness, and capped by erupted greenstone. Above these higher slates there are found in some parts of Gothland, other limestones with orthoceratites, trilobites and corals, the newer limestone strata (*a*) of Hisinger; the whole overlaid by thin sandstone beds. These higher limestones and sandstones contain the fauna of the Wenlock and Ludlow of England; while the lower limestones and graptolitic slates afford *Calymene Blumenbachii*, *Orthis calligramma*, and many other species common to the Bala group of North Wales. The alum-slates below these however, contained, according to Hisinger, none of the species then known in British rocks, but in their stead five species of *Olenus* and two of *Battus* (*Agnostus.*)

In 1854, Angelin published his *Palæontologica Scandinavica*, part I, *Crustacea formationis transitionis*, [4to. forty-one plates] in which he divided the series of transition rocks above described by Hisinger into eight parts designated by Roman numerals, counting from the base. Of these I was named *Regio Fucoidarum*, no organic remains other than fucoids being know therein; while the remaining seven were named from their characteristic genera of trilobites, which were as follows, in ascending order; certain letters being also used to designate the parts: II. (A) Olenus; III. (B) Conocoryphe; IV. (BC) Ceratopyge; V. (C) Asaphus; VI. (D) Trinucleus; VII. (DE) Harpes; VIII. (E) Cryptonymus. In the *Regio Olenorum* (II) was found also the allied genus *Paradoxides*. With regard to the characteristic genus of Regio III., the name of *Conocoryphe* was proposed for it by Corda in 1847, as synonymous with Zenker's name of *Conocephalus* (*Conocephalites*) already appropriated to a genus of insects.

Meanwhile, the similar crustaceans which abound in the transition rocks of Bohemia had been studied and described by Hawle, Corda and Beyrich, when Barrande began his admirable investigations of this ancient fauna and of its stratigraphical re-

lations. He soon found that beneath the horizon characterized by fossils of the Bala group (Llandeilo and Caradoc) there existed in Bohemia a series of strata distinguished by a remarkable fauna, entirely distinct from anything known in Great Britain, but closely allied to that of the alum-slates of Scandinavia, corresponding to Regiones II. and III. of Angelin. To this he gave the name of the first or primordial fauna, and to the rocks yielding it that of the Primordial Zone. Resting upon the old gneisses of Bohemia appears a series of crystalline schists designated by Barrande as *Etage A*, overlaid by a series of sandstones and conglomerates, *Etage B*, upon which repose the fossiliferous argillites of the primordial zone or *Etage C*. The rocks of the Etages A and B were by Barrande regarded as azoic, but in 1861, Fritsch of Prague, after a careful search, discovered in certain thin-bedded sandstones of B, the traces of filled-up vertical double tubes; which, according to Salter, [Mem. Geol. Sur. III., 243] are probably the marks of annelides, and are identical with those found in the rocks of the Bangor or Longmynd group in Great Britain; which will be shown to belong to the primordial zone. It is, therefore, probable that the Etage B, which apparently corresponds to the Regio Fucoidarum or basal sandstone of Scandinavia, should itself be included in the primordial zone. It may here be noticed that it is in the crystalline schists of A that Gumbel has found *Eozoon Bavaricum*. To the Etage C in Bohemia, Barrande assigns a thickness of about 1200 feet, and to this his first fauna is confined, while in the succeeding divisions he distinguished a second and a third. The second fauna, which characterizes Etage D, corresponds to that of the Bala group; while the third fauna, belonging to the Etages E, F, G and H, is that of the May Hill, Wenlock and Ludlow formations of Great Britain.

This classification of the ancient Bohemian faunas was first set forth by Barrande in 1846, in his *Notice Preliminaire*, in which he declared that the first fauna was below the base of the Llandeilo of Murchison, unknown in Great Britain, and, moreover, "new and independent in relation to the two Silurian faunas (his second and third) already established in England." This opinion he reiterated in 1859. These three divisions form in Bohemia an apparently continuous series, and being connected with each other by some common species, Barrande was led to look upon the whole as forming a single stratigraphical system;

and finally to assert that these three independent faunas "form by their union an indivisible triad which is the Silurian system." [Bul. Soc. Geol. de Fr. II, xvi, 529-545.] Already, in 1852, in his magnificent work on the Silurian System of Bohemia, Barrande had given to the strata characterized by his first fauna the name of Primordial Silurian. It is difficult to assign any just reason for thus annexing to the Silurian,—already augmented by the whole Upper Cambrian or Bala group of Sedgwick, (Llandeilo and Caradoc)—a great series of fossiliferous rocks lying below the base of the Llandeilo, and unsuspected by the author of the Silurian system; who persistently claimed the Llandeilo beds, with their characteristic second fauna, as marking the dawn of organic life.

Up to this time the primordial palæozoic fauna of Bohemia and of Scandinavia was, as we have said, unknown in Great Britain. The few organic remains mentioned by Sedgwick in 1835 as occurring in the region occupied by his Lower and Middle Cambrian, on Snowdon, were found to belong to Bala beds, which there rest upon the older rocks: nor was it until 1845 that Mr. Davis found in the Middle Cambrian remains of Lingula. In 1846, Sedgwick, in company with Mr. Davis, re-examined these rocks, and in December of the same year described the Lingula-beds as overlaid by the Tremadoc slates and occupying a well-defined horizon in Caernarvon and Merionethshire, beneath the great mass of the Upper Cambrian rocks. [Geol. Jour. II, 75, III, 139.] Sedgwick, at the same time, noticed about this horizon certain graptolites and an Asaphus, which were supposed to belong to the Tremadoc slates, but have since been declared by Salter to pertain to the Arenig or Lower Llandeilo beds, the base of the Upper Cambrian. [Mem. Geol. Sur. III, 257, and Decade II.]

This discovery of the Lingula-flags, as they were then named, and the fixing by Sedgwick of their geological horizon, was at once followed by a careful examination of them by the Government surveyors, and in 1847, Selwyn detected in the Lingula-flags, near Dolgelly, in Merionethshire, the remains of two crustacean forms, the one a phyllopod, which has received the name of *Hymenocaris vermicauda*, Salter, and the other a trilobite which was described by Salter in 1849 as *Olenus micrurus*. [Geol. Survey, Decade II.] A species of Paradoxides, apparently identical with *P. Forchhammeri* of Sweden, was also about this

time recognized among specimens supposed to be from the same horizon. It has since been described as *P. Hicksii*, and found to belong to the basal beds of the Lingula-flags,—the Menevian group.

Upon the flanks of the Malvern Hills there are found resting upon the ancient crystalline rocks of the region, and overlaid by the Pentamerus beds of the May Hill sandstone (originally called Caradoc by Murchison) a series of fossiliferous beds. These consist in their lowest part of about 600 feet of greenish sandstone, which have since yielded an *Obolella* and *Serpulites*, and are overlaid by 500 feet of black schists. In these, in 1842, Prof. John Phillips found the remains of trilobites, which he subsequently described, in 1848, as three species of Olenus. [Mem. Geol. Survey II, part 1, 55.] These black shales, which had not at that time furnished any organic remains, were by Murchison in his Silurian System (p. 416) in 1839 compared to the supposed passage-beds in Caermarthenshire between the Llandeilo and the Cambrian (Bala) rocks; which, as we have seen, were newer and not older strata than the Llandeilo flags. From their lithological characters, and their relations to the Pentamerus beds, these lower fossiliferous strata of Malvern were subsequently referred by the Government geologists to the horizon of the Caradoc proper or Bala group; nor was it until 1851, that their true geological age and significance were made known. In that year, Barrande, fresh from the study of the older rocks of the continent, came to England for the purpose of comparing the British fossils with those of the primordial zone, which he had established in Bohemia and Scandinavia, and which he at once recognized in the Lingula-flags of Sedgwick and in the black schists at Malvern; both of which were characterized by the presence of the genus *Olenus*, and were referred to the horizon of his Etage C. This important conclusion was announced by Salter to the British Association at Belfast in 1852. [Rep. Brit. Assoc., abstracts, p. 56, and Bull. Soc. Geol. de Fr. II, xvi, 537.] Since that time the progress of investigation in the Middle and Lower Cambrian rocks of Wales has shown a fauna the importance and richness of which has increased from year to year.

The paleontological studies of Salter, while they confirmed the primordial character of the whole of the great mass of strata which make up the Middle Cambrian or Festiniog group of Sedgwick, (consisting of the Lingula-flags and the Tremadoc slates,)

led him to propose several sub-divisions. Thus he distinguished on paleontological grounds between the upper and lower Tremadoc slates, and for like reasons divided the Lingula-flags into a lower and an upper portion. For the discussion of these distinctions the reader is referred to the memoirs of the Geol. Survey [III, 240-257.] Subsequent researches led to the division of the original Lingula-flags into three parts, an upper and a middle, to which the names of Dolgelly and Maentwrog were given by Mr. Belt, and a third consisting of the basal beds, which were separated in 1865, by Salter and Hicks, with the designation of Menevian, derived from the ancient Roman name of St. David's in Pembrokeshire. It was here that in 1862, Salter found *Paradoxides* with *Agnostus* and *Lingula* in fine black shales at the base of the Lingula-flags, resting conformably on the green and purple grits of the Lower Cambrian or Harlech beds. The locality was afterwards carefully studied by Hicks, and it was soon made apparent that the genus Paradoxides, both here and in North Wales, was confined to a horizon below the great mass of the Lingula-flags; which, on the contrary, are characterized by numerous species of Olenus. These lower or Menevian beds are hence regarded by Salter as equivalent to the lowest portion of the Etage C of Barrande.

Beneath these Menevian beds there lies, in apparent conformity, the great Lower Cambrian series, frequently called the bottom or basement rocks by the Government surveyors; represented in North Wales by the Harlech grits, and in South Wales, near St. Davids, by a similar series of green and purple sandstones, considered by Murchison, and by others, as the equivalent of the Harlech rocks. They were still supposed to be unfossiliferous until in June, 1867, Salter and Hicks announced the discovery in the red beds of this lower series, at St. Davids, of a Lingulella, very like *L. ferruginea* of the Menevian. [Geol. Jour. XXIII, 339; Siluria 4th ed. 550.] This led to a farther examination of these Lower Cambrian beds, which has resulted in the discovery in them of a fauna distinctly primordial in type, and linked by the presence of several identical fossils to the Menevian; but in many respects distinct, and marking a lower fossiliferous horizon than anything known in Bohemia or in Scandinavia.

The first announcement of these important results was made to the British Association at Norwich in 1868. Further details were, however, laid before the Geological Society in May, 1871,

by Messrs. Harkness and Hicks, whose paper on the Ancient Rocks of St. David's Promontory appears in the Geological Journal for November, 1871. [XXVIII, 384.] The Cambrian sediments here rest upon an older series of crystalline stratified rocks, described by the geological surveyors as syenite and greenstone, and having a north-west strike. Lying unconformably upon these, and with a north-east strike, we have the following series, in ascending order: 1. quartzose conglomerate, 60 feet; 2. greenish flaggy sandstones, 460 feet; 3. red flags or slaty beds, 50 feet, containing *Lingulella ferruginea*, besides a larger species, *Discina*, and *Leperditia Cambrensis*; 4. purple and greenish sandstones, 1000 feet; 5. yellowish-gray sandstones, flags and shales, 150 feet, with *Platonia*, *Conocoryphe*, *Microdiscus*, *Agnostus*, *Theca* and *Protospongia*; 6. gray, purple and red flaggy sandstones, with most of the above genera, 1500 feet; 7. gray flaggy beds, 150 feet, with *Paradoxides*; 8. true Menevian beds, richly fossiliferous, 500 feet. The latter are the probable equivalent of the base of Barrande's Etage C, and at St. David's are conformably overlaid by the Lingula-flags; beneath which we have, including the Menevian, a conformable series of 3370 feet of unerystalline sediments, fossiliferous nearly to the base, and holding a well-marked fauna distinct from anything hitherto known in Great Britain or elsewhere.

The Menevian beds are connected with the underlying strata by the presence of *Lingulella ferruginea*, *Discina pileolus*, and *Obolella sagittatis*, which extend through the whole series; and also by the genus Paradoxides, four species of which occur in these lower strata; from which the genus Olenus, which characterizes the Lingula-flags, seems to be absent. To a large tuberculated trilobite of a new genus found in these lowest rocks the name of *Platonia Sedgwickii* has been given. Hicks has proposed to unite the Menevian with the Harlech beds, and to make the summit of the former the dividing line between the Lower and Middle Cambrian, a suggestion which has been adopted by Lyell. [Proc. Brit. Assoc. for 1868, p. 68, and Lyell, Student's Manual of Geology, 466–469.]

Both Phillips and Lyell give the name of Upper Cambrian to the Lingula-flags and the Tremadoc slates, which together constitute the Middle Cambrian of Sedgwick, and concede the title of Lower Silurian to the Bala group or Upper Cambrian of Sedgwick. The same view is adopted by Linnarsson in

Sweden, who places the line between Cambrian and Silurian at the base of the Llandeilo or the second fauna. It was by following these authorities that I, inadvertently, in my address to the American Association for the Advancement of Science in August, 1871, gave this horizon as the original division between Cambrian and Silurian. The reader of the first part of this paper will see with how much justice Sedgwick claims for the Cambrian the whole of the fossiliferous rocks of Wales *beneath* the base of the May Hill sandstone, including both the first and the second fauna. I cannot but agree with the late Henry Darwin Rogers, who, in 1856, reserved the designation of "the true European Silurian" for the rocks *above* this horizon. [Keith Johnson's Physical Atlas, 2nd ed.]

The Lingula-flags and Tremadoc slates have been made the subject of careful stratigraphical and paleontological studies by the Geological Survey, the results of which are set forth by Ramsay and Salter in the third volume of the Memoirs of the Geological Survey, published in 1866, and also, more concisely, in the Anniversary Address by the former to the Geological Society in 1863. [Geol. Jour. XIX, xviii.] The Lingula flags (with the underlying Menevian, which resembles them lithologically) rest in apparent conformity upon the purple Harlech rocks both in Pembrokeshire and in Merionethshire, where the latter appear on the great Merioneth anticlinal, long since pointed out by Sedgwick. The Lingula-flags, (including the Menevian) have in this region, according to Ramsay, a thickness of about 6000 feet. Above these, near Tremadoc and Festiniog, lie the Tremadoc slates, which are here overlaid, in apparent conformity, by the Lower Llandeilo beds. At a distance of eleven miles to the north-west, however, the Tremadoc slates disappear, and the Lingula-flags are represented by only 2,000 feet of strata; while in parts of Caernarvonshire, and in Anglesea, the whole of the Lingula-flags and moreover the Lower Cambrian rocks, are wanting, and the Llandeilo beds rest directly upon the ancient crystalline schists. In Scotland and in Ireland, moreover, the Lingula flags, are wholly absent, and the Llandeilo rocks there repose unconformably upon grits regarded as of Lower Cambrian age. Thus, without counting the Tremadoc slates, which are a local formation, unknown out of Merionethshire, we have (including the Bangor group and Lingula-flags,) beneath the Llandeilo, over 9,000 feet of fossiliferous strata, which disappear entirely in

the distance of a few miles. From a careful survey of all the facts, the conclusion of Ramsay is irresistible, that there exists between the Lingula-flags and the Llandeilo not merely one, but two great stratigraphical breaks in the succession; the one between the Lingula-flags and the Lower Tremadoc slates, and the other between the Upper Tremadoc slates and the Lower Llandeilo.

This conclusion is confirmed by the fact that there exists at each of these horizons a nearly complete paleontological break. The fauna of the Tremadoc slates is, according to Salter, almost entirely distinct from that of the Lingula-flags, and not less distinct from that of the so-called Lower Llandeilo or Arenig rocks, (the equivalents of the Skiddaw slates of Cumberland). Hence, says Ramsay, it is evident "that in these strata we have three perfectly distinct zones of organic remains, and therefore, in common terms, three distinct formations." The paleontological evidence is thus in complete accordance with that furnished by stratigraphy. We cannot leave this topic without citing the conclusion of Ramsay that "each of these two breaks necessarily implies a lost epoch, stratigraphically quite unrepresented in our area; the life of which is only feebly represented in some cases by the fossils common to the underlying and overlying formation." In connection with this remark, which we conceive to embody a truth of wide application, it may be said that stratigraphical breaks and discordances in a geological series, may, *à priori*, be expected to occur most frequently in regions where this series is represented by a large thickness of strata. The accumulation of such masses implies great movements of subsidence, which, in their nature, are limited, and are accompanied by elevations in adjacent areas, from which may result, over these areas, either interruptions in the process of sedimentation, or the removal, by sub-aerial or sub-marine denudation, of the sediments already formed. The conditions of succession and distribution, it may be conceived, would be very different in a region where the period corresponding to this same geological series was marked by comparatively small accumulations of sediment upon an ocean-floor subjected to no great movements.

This contrast is strikingly seen between the conformable series of less than 2,000 feet of strata which in Scandinavia are characterized by the first three paleozoic faunas (Cambrian and Silurian) and the repeatedly broken and discordant succession of

more than 30,000 feet of sediments,* which in Wales are their palæontological equivalents. It must, however, be considered that in regions of small accumulation where, as in Scandinavia, the formations are thin, there may be lost or unrepresented zoological epochs whose place in the series is marked by no stratigraphical break. In such comparatively stable regions, movements of the surface sufficient to cause the exclusion, or the disappearance by removal, of the small thickness of strata corresponding to an epoch, may take place without any conspicuous marks of stratigraphical discordance.

The attempt to establish geological divisions or horizons upon stratigraphical or palæontological breaks must always prove fallacious. From the nature of things, these, whether due to non-deposition or to subsequent removal of deposits, must be local; and we can say, confidently, that there exists no break in life or in sedimentation which is not somewhere filled up and represented by a continuous and conformable succession. While we may define one period as characterized by the presence of a certain fauna, which, in a succeeding epoch, is replaced by a different one, there will always be found, in some part of their geographical distribution, a region where the two faunas commingle, and where the gradual disappearance of the old before the new may be studied. The division of our stratified rocks into systems is therefore unphilosophical, if we assign any definite or precise boundaries or limitations to these. It was long since said by Sedgwick with regard to the whole succession of life through geologic time, —that all belongs to one great *systema naturæ*. [Philos. Mag. IV. viii, 359.]

We have already noticed that Barrande, as early as 1852, gave the name of Primordial Silurian to the rocks which, in Bohemia, were marked by the first fauna; although he, at the

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* The Longmynd rocks in Shropshire are alone estimated at 20,000 feet; but their supposed equivalents, the Harlech rocks of Pembrokeshire, have a measured thickness of 3,300, while the Llanberris and Harlech rocks together, in North Wales, equal from 4,000 to 7,000 feet, and the Lingula-flags and Tremadoc slates, united, about 7,000 feet. The Bala group in the Berwyns exceeds 12,000 feet, and the proper Silurian, from the base of the Upper Llandovery or May Hill sandstone, attains from 5,000 to 6,000 feet; so that the aggregate of 30,000 feet may be considered below the truth. [Mem. Geol. Survey, III, part 2, pages 72, 222, and Siluria, 4th ed. 185.]

same time, recognized this as distinct from and older than the second fauna, discovered in the Llandeilo rocks, which Murchison had declared to represent the dawn of organic life. Into the reasons which led Barrande to include the rocks of the first, second and third faunas in one Silurian system, (a view which was at once adopted by the British Geological Survey and by Murchison himself,) it is not our province to inquire, but we desire to call attention to the fact that the latter, by his own principles, was bound to reject such a classification. In his address before the Geological Society in 1842, (already quoted in the first part of this paper,) he declared that the discussion as to the value of the term Cambrian involved the question "whether there was any type of fossils in the mass of the Cambrian rocks different from those of the Lower Silurian series. If the appeal to nature should be answered in the negative, then it was clear that the Lower Silurian type must be considered the true base of what I had named the protozoic rocks; but if characteristic new forms were discovered, then would the Cambrian rocks, whose place was so well established in the descending series, have also their own fauna, and the palæozoic base would necessarily be removed to a lower horizon."

In the event of no distinct fauna being found in the Cambrian series, it was declared that "the term Cambrian must cease to be used in zoological classification, it being, in that sense, synonymous with Lower Silurian." [Proc. Geol. Soc. III, 641 et seq.] That such had been the result of paleontological inquiry Murchison then proceeded to show. Inasmuch as the only portion of Sedgwick's Cambrian which was then known to be fossiliferous, was really above and not below the Llandeilo rocks, which Murchison had taken for the base of his Lower Silurian, his reasoning with regard to the Cambrian nomenclature, based on a false datum, was itself fallacious; and it might have been expected that when the government surveyors had shown his stratigraphical error, Murchison would have rendered justice to the nomenclature of Sedgwick. But when, still later, a farther "appeal to nature" led to the discovery of "characteristic new forms," and established the existence of a "type of fossils in the mass of the Cambrian rocks, different from those of the Lower Silurian series," Murchison was bound by his own principles to recognize the name of Cambrian for the great Festiniog group, with its primordial

fauna, even though Barrande and the government surveyors should unite in calling it Primordial Silurian.

He however chose the opposite course, and now attempted to claim for the Silurian system the whole of the Middle Cambrian or Festiniog group of Sedgwick, including the Tremadoc slates and the Lingula-flags. The grounds of this assumption, as set forth in the successive editions of Siluria from 1854 to 1867, and in various memoirs, may be included under three heads: first that the Lingula-flags have been found to exist in some parts of his original Silurian region; second, that no clearly-defined base had been assigned by him to his so-called system; and third, that there are no means of drawing a line of demarkation between these Middle Cambrian formations and the overlying Llandeilo.

With regard to the first of these reasons, it is to be said that the only known representatives of the Lingula-flags in the region described by Murchison in his *Silurian System* are the black slates of Malvern; and some scanty outliers which, in Shropshire, lie between the old Longmynd rocks and the base of the Stiperstones. The former were then (as has already been shown) supposed by him to belong to the Llandeilo, or rather to the passage-beds between the Llandeilo and Cambrian (Bala); while with regard to the latter, Ramsay expressly tells us that they were not originally classed with the Silurian, but have since been included in it. [Mem. Geol. Sur. III, part 2, page 9; and 242, foot-note.]

The Llandeilo beds were by Murchison distinctly stated to be the base of the Silurian system [Sil. Sys. 222.]; and it was farther declared by him that in Shropshire, (unlike Caermarthenshire,) "there is no passage from the Cambrian to the Silurian strata," but a hiatus, marked by disturbances which excluded the passage-beds, and caused the Lower Silurian to rest unconformably upon the Longmynd rocks. [Ibid, 256; and plates 31, sections 3 and 6; 32, section 4.] But in *Siluria* [1st. ed. 47] the two are stated to be conformable; and in the subsequent sections of this region, made by Aveline, and published by the Geological Survey, the evidences of this want of conformity do not appear. Murchison at that time confounded the rocks of the Longmynd with the Cambrian (Bala) beds of Caermarthenshire and Brecon. [Sil. Sys. 416.] Hence it was that he gave the name of Cambrian to the former; and this mistake, moreover, led him to place the Cambrian of Caermarthenshire beneath the Llandeilo. It is clear that if he claimed no well-defined base to the Llandeilo

rocks in this latter (their typical region), it was because he saw them passing into the overlying Bala beds. There was, in the error by which he placed *below* the Llandeilo, strata which were really *above* them, no ground whatever for afterwards including in his Silurian system, as a downward continuation of the Llandeilo rocks (which are the basal portion of the Bala group), the whole Festiniog group of Sedgwick; whose infra-position to the Bala had been shown by the latter long before it was known to be fossiliferous.

It was however claimed by Murchison that no line of separation can be drawn between these two groups. The results of Ramsay and of Salter, as set forth in the address of the former before the Geological Society in 1863, and more fully in the Memoirs of the Geological Survey [vol. III. part 2] published in 1866, with a preface by himself, as the director of the Survey, are completely ignored by Murchison. The reader familiar with these results, of which we have given a summary, finds with surprise that in the last edition of *Siluria*, that of 1867, they are noticed in part, but only to be repudiated. In the five pages of text which are there given to this great Middle Cambrian division, we are told that the distinction between the Lower Tremadoc and the Lingula-flags "is difficult to be drawn," and that the Upper Tremadoc slate passes into and forms the lower part of the Llandeilo, "into which it graduates conformably." (Siluria, 4th ed. p. 46.) In each of these cases, on the contrary, according to Ramsay, there is observed "a break very nearly complete both in genera and species, and probable unconformity;" the evidence of the paleontological break being furnished by the careful studies of Salter; while that of the stratigraphical break, as we have seen, leaves no reason for doubt. [Mem. Geol. Sur. III, part 2, pages 2, 161, 234.] The student of *Siluria* soon learns that in all cases where Murchison's pretensions were concerned, the book is only calculated to mislead.

The reader of this history will now be able to understand why, notwithstanding the support given by Barrande, by the Geological Survey of Great Britain, and by most American geologists to the Silurian nomenclature of Murchison, it is rejected, so far as the Lingula-flags and the Tremadoc slates are concerned, by Lyell, Phillips, Davidson, Harkness and Hicks in England, and by Linnarsson in Sweden. These authorities have, however, admitted the name of Lower Silurian for the Bala group or

Upper Cambrian of Sedgwick; a concession which can hardly be defended, but which apparently found its way into use at a time when the yet unravelled perplexities of the Welsh rocks led Sedgwick himself to propose, for a time, the name of Cambro-Silurian for the Bala group. This want of agreement among geologists as to the nomenclature of the lower palæozoic rocks, causes no little confusion to the learner. We have seen that Henry Darwin Rogers followed Sedgwick in giving the name of Cambrian to the whole palæozoic series up to the base of the May Hill sandstone; and the same view is adopted by Woodward in his Manual of the Mollusca. The student of this excellent book will find that in the tables giving the geological range of the mollusca, on pages 124, 125 and 127, the name of Cambrian is used in Sedgwick's sense, as including all the fossiliferous strata beneath the May Hill sandstone. On page 123 it is however explained that Lower Silurian is a synonym for Cambrian, and it is so used in the body of the work.

The distribution of the Lower and Middle Cambrian rocks in Great Britain may now be noticed. The former, or Bangor group, to which Murchison and the Geological Survey restrict the name of Cambrian, and which they sometimes call the Longmynd, bottom or basement rocks, occupy two adjacent areas in Caernarvon and Merionethshire; the one near Bangor, including Llanberris, to the north-east, and the other, including Harlech and Barmouth, to the south-east of Snowdon; this mountain lying in a synclinal between them, and rising 3571 feet above the sea. The great mass of grits or sandstones appears to be at the summit of the group, but in the lower part the blue roofing-slates of Llanberris are interstratified in a series of green and purple slates, grits and conglomerates. (Some of the Welsh roofing-slates are however supposed to belong to the Llandeilo). [Mem. Geol. Survey III, part 2, pages 54, 258.] The Harlech rocks in this north-western region are conformably overlaid by the Menevian, followed by the true Lingula-flags, or Olenus beds, of the Middle Cambrian. Upon these repose the Tremadoc slates, which are not known in the other parts of Wales. The third area of Lower Cambrian rocks is that already described at St. David's in Pembrokeshire, about 100 miles to the south-west; and the fourth, that of the Longmynd hills, about sixty miles to the south-east of Snowdon. The rocks of the Longmynd, like those of the other Lower Cambrian areas mentioned, consist principally of

green and purple sandstones with conglomerates, shales and some clay-slates. They occasionally hold flakes of anthracite, and small portions of mineral pitch exude from them in some localities. The only evidence of animal life yet found in the rocks of the Longmynd are furnished by worm-burrows, the obscure remains of a crustacean, (the *Pilœopyge Ramsayi*,) and a form like *Histioderma*. This latter organic relic, with worm-burrows, and the fossils named *Oldhamia*, is found on the coast of Ireland opposite Caernarvonshire, in the rocks of Bray Head; which resemble lithologically the Harlech beds, and are regarded as their equivalents.

Still another area of the older rocks is that of the Malvern hills, on the western flanks of which, as already mentioned, the Lingula-flags are represented by about 500 feet of black shales with Olenus, underlaid by 600 feet of greenish sandstones containing traces of fucoids, with Serpulites and an Obolella. It is not improbable, as suggested by Barrande and by Murchison, that these 1100 feet of strata represent, in this region, the great mass of the Lingula-flags,—and, we may add, perhaps the whole series of Lower Cambrian strata, which in Caernarvonshire and Pembrokeshire underlie them; since these sandstones of Malvern, like those of St. David's, rest upon crystalline schists, and are in part made up of their ruins.

These crystalline schists of Malvern, which are described by Phillips as the oldest rocks in England, and by Mr. Holl are conjectured to be Laurentian, seem from the descriptions of their lithological characters to resemble those of Caernarvon and Anglesea, with which they are, by Murchison, regarded as identical. The crystalline schists of these latter localities are, by Sedgwick, described as hypozoic strata, below the base of the Cambrian. Murchison however, in the first edition of his *Siluria*, adopted the suggestion of De la Beche that they themselves were altered Cambrian strata. In fact they directly underlie the Llandeilo rocks, and were apparently conceived by Murchison to represent the downward continuation of these, upon which he had insisted. This opinion is supported by ingenious arguments on the part of Ramsay. [Mem. Geol. Survey, III, part 2, passim.] I am however disposed to regard them, with Sedgwick and Phillips, as of pre-Cambrian age, and to compare them with the Huronian series of North America, which occupies a similar geological horizon, and with which, as seen in northern Michigan, and in the

Green Mountains, I have found the rocks of Anglesea to offer remarkable lithological resemblances.

It may here be noticed that the gold-bearing quartz veins in North Wales are found in the Menevian beds, and also, according to Selwyn, throughout the Lingula-flags. These fossiliferous strata at the gold-mine near Dolgelly appear in direct contact with diorites and chloritic and talcose schists, which are more or less cupriferous, and themselves also contain gold-bearing quartz veins. [Mem. Geol. Survey, part 2, pp. 42; 45, and Siluria, 4th ed., 450, 547.]

The Table on page 32 gives a view of the lower palæozoic rocks of Great Britain and North America, together with the various nomenclatures and classifications referred to in the preceding pages. In the second column, the horizontal black lines indicate the positions of the three important paleontological and stratigraphical breaks signalized by Ramsay in the British succession. [Mem. Geol. Survey, III, part 2, page 2.] In a table by Davidson in the *Geological Magazine* for 1868 [V. 305] showing the distribution of organic remains in these lower rocks, he gives, as the Festiniog group of Sedgwick, only the Dolgelly and Maentwrog beds of Belt (the Upper and Middle Lingula-flags); and makes of the two divisions of the Tremadoc rocks a separate group; the whole being described as the Upper Cambrian of Sedgwick. This however is not the present grouping and nomenclature of Sedgwick, nor was it his earlier one. So far as regards Middle and Upper Cambrian, this discrepancy is explained by the fact already stated, that in 1843 Sedgwick proposed, as a compromise, the name of Cambro-Silurian for his Bala group, previously called Upper Cambrian; by which change the Festiniog or Middle Cambrian became Upper Cambrian. When the true relation between the Lower Silurian of Murchison and the Bala group was made known, Sedgwick, as we have seen, re-claimed for the latter his former name of Upper Cambrian; but this had meanwhile been adopted for the Festiniog group, in which sense it is still used by Lyell, Phillips, Davidson, Harkness and Hicks. The Festiniog group, or Middle Cambrian, as defined by Sedgwick, however, included not only the whole of the Lingula-flags but the Upper and Lower Tremadoc rocks. [Philos. Mag. IV. viii. 362.]

The only change which I have made in the groupings of the British rocks adopted by Sedgwick and by Murchison, is in separating the Menevian or Lower Lingula-flags from the Festiniog,

and uniting it with the Bangor group or Lower Cambrian. In this I follow, with Lyell and Davidson, the suggestion of Salter and Hicks.

In the third column, the sub-divisions are those of the New York and Canada Geological Surveys; in connection with which the reader is referred to a table published in 1863, in the *Geology of Canada*, page 932. Opposite the Menevian I have placed the names of its principal American localities; which are Braintree, Mass., St. John, New Brunswick, and St. John's, Newfoundland. The farther consideration of the American subdivisions is reserved for the third part of this paper. With regard to the classification of Angelin, it is to be remarked that although he designates II as *Regio Olenorum*, and III as *Regio Conocorypharum*, the position of these, according to Linnarsson, is to be reversed; the Conocoryphe beds with Paradoxides being below and not above those holding Olenus. The *Regio Fucoidarum* in Sweden has lately furnished a brachiopodous shell, *Lingula monilifera*, besides the curious plant-like fossil, *Eophyton Linnæanum*. [Linnarsson, Geol. Magazine, 1869, vi. 393.]

Lower Paleozoic Rocks of Europe and North America.

	British sub-divisions.	*North American sub-divisions.*	*Nomenclatures of Sedgwick and Murchison.*	*Barrande's classification.*	*Angelin's divisions.*
14	Ludlow.	Lower Helderberg.	Silurian, *Sedgwick.* Upper Silurian, *Murchison.*	Third fauna including Etages H. G F. E.	VIII. VII. or Regiones E. and DE
13	Wenlock.	Niagara, Clinton,			
12	Upper Llandovery.	Medina, Oneida.			
11	Lower Llandovery.	Hudson-River, Utica,	Upper Cambrian or Bala group, *Sedgwick.* Lower Silurian, *Murchison.*	Second fauna including Etage D.	VI. V. IV. or Regiones D. C. and BC.
10	Caradoc.	Trenton, Birdseye,			
9	Upper Llandeilo.	Black-River.			
8	Lower Llandeilo.	Chazy.	Middle Cambrian or Festiniog group, *Sedgwick.* Primordial Silurian, *Murchison.*	First fauna or Primordial fauna, including Etage C, and probably also Etage B.	III. II. I. or Regiones B. and A. and Regio Fucoidarum.
7	Upper Tremadoc.	Levis.			
6	Lower Tremadoc.	Calciferous.			
5	Dolgelly.	Potsdam.			
4	Maentwrog.				
3	Menevian.	Braintree & St. John.	Lower Cambrian or Bangor group, *Sedgwick.* Cambrian, *Murchison.*		
2	Harlech.	——— ?			
1	Llanberris.	——— ?			

III. Cambrian and Silurian Rocks in North America.

In accordance with our plan we now proceed to sketch the history of the lower paleozoic rocks in North America. While European geologists were carrying out the researches which have been described in the first and second parts of this paper, American investigators were not idle. The geological studies of Eaton led the way to a systematic survey of the state of New York, the results of which have been the basis of most of the subsequent geological work in eastern North America, and which was begun by legislative enactment in 1836. The state was divided into four districts, the work of examining and finally reporting upon which was committed to as many geologists. The first or southeastern district was undertaken by Mather, the second or northeastern by Emmons, the third or central by Vanuxem, and the fourth or western by James Hall; the paleontology of the whole being left to Conrad, and the mineralogy to Beck. After various annual reports the final results of the survey appeared in 1842. The whole series of fossiliferous rocks known, from the basal or Potsdam sandstone to the coal-formation, was then described as the New York system.

At that time the published researches of British geologists furnished the means of comparison between the organic remains found in the rocks of New York, and those then known to exist in the paleozoic strata of Great Britain. Prof. Hall was thus enabled in his Geology of the Fourth District of New York, to declare, from the study of its fossils, that the New York system included the Devonian of Phillips, the Silurian of Murchison, and the Cambrian of Sedgwick; meaning by the latter the Upper Cambrian, or Bala group, which alone was then known to be fossiliferous. From the evidence then before him, he concluded that the Upper Cambrian was represented in the New York system

by the whole of the rocks from the base of the Utica slate, downward, with the probable exception of the Potsdam sandstone; while he conceived, partly on lithological grounds, that the Utica and Hudson-River groups represented the Llandeilo and Caradoc, or the Lower Silurian of Murchison [loc. cit. pages 20, 29, 31]. The origin of the Cambrian and Silurian controversy, and the errors by which the Llandeilo and a part of the Caradoc had by Murchison been classed as a series distinct from the Bala group, were not then known; but in a note to this report [page 20,] Hall informs us of the declaration of Murchison, already quoted from his address of 1842, that the Cambrian, so far as then known, could not, on paleontological grounds, be distinguished from his Lower Silurian.

Emmons meanwhile had examined in eastern New York and western New England a series of fossiliferous rocks, which on lithological and stratigraphical grounds, he regarded as older than any in the New York system; a view which had been previously maintained by Eaton. Holding, with Hall, that the lower members of the New York system were the equivalents of the Upper Cambrian of Sedgwick, he looked upon the fossiliferous rocks which he placed beneath them, as the representatives of the Lower Cambrian. By this name, as we have seen, Sedgwick, in 1838, designated all those unerystalline rocks of North Wales which he subsequently divided into Lower and Middle Cambrian, and which lie beneath the base of the Bala group. When Murchison, in 1842, in his so often quoted declaration, asserted that "the term Cambrian must cease to be used in zoological classification, it being in that sense synonymous with Lower Silurian," he was speaking only on paleontological grounds, and, disregarding the great Lower and Middle Cambrian divisions of Sedgwick, had reference only to the Upper Cambrian. This however was overlooked by Emmons, who feeling satisfied that the sedimentary rocks which he had examined in eastern New York were distinct from those which he, with Hall, regarded as corresponding to the Bala group or Upper Cambrian, (the Lower Silurian of Murchison), and probably equivalent to the inferior portions of Sedgwick's Cambrian; and supposing that the latter term was henceforth to be effaced from geology (as indeed was attempted shortly after, in the copy of Sedgwick's map published in 1844 by the Geological Society) devised for these rocks the name of the Taconic system, as synonymous with the Lower

(and Middle) Cambrian of Sedgwick. These conclusions were set forth by him in 1842, in his report on the Geology of the Northern District of New York [page 162]. See also his Agriculture of New York [I, 49] the fifth chapter of which, "On the Taconic system," was also published separately in 1844; when the presence of distinctive organic remains in the rocks of this series was first announced.

Meanwhile to Prof. Hall, after the completion of the survey, had been committed the task of studying and describing the organic remains of the state, and in 1847 appeared the first volume of his great work on the "Paleontology of New York." Since 1842 he had been enabled to examine more fully the organic remains of the lower rocks of the New York system, and to compare them with those of the old world; and in the Introduction to the volume just mentioned [page xix] he announced the important conclusion that the New York system itself contained an older fauna than the Upper Cambrian of Sedgwick. According to Hall, the organic forms of the Calciferous and Chazy formations had not yet been found in Europe, and our comparison with European fossiliferous rocks must commence with the Trenton group. He however excepted the Potsdam sandstone, which already, in 1842, he had conceived to be below the Upper Cambrian of Sedgwick, and now regarded as the probable equivalent of the Obolus or Ungulite grit of St. Petersburg. Thus Emmons, in 1842, asserted, on lithological and stratigraphical grounds, the existence, beneath the base of the New York system, of a lower and unconformable series of rocks, in which, in 1844, he announced the discovery of a distinctive fauna. Hall, on his part, asserted in 1842, and more fully in 1847, that the New York system itself held an older fauna than that hitherto known in the British rocks.

It is not necessary to recall in this place the details of the long and unfortunate Taconic controversy, which I have recently discussed in my address before the American Association for the Advancement of Science in August, 1871. It is however to be remarked that Hall, in common with all other American geologists, followed Henry D. Rogers in opposing the views of Emmons, whose Taconic system was supposed to represent either the whole or a part of the Champlain division of the New York system; which included, as is well known, all of the fossiliferous rocks up to the base of the Oneida conglomerate (and also this

latter, according to Emmons); thus comprehending both the first and the second paleozoic fauna; as shown in the table on page 312.

Emmons, misled by stratigraphical and lithological considerations, complicated the question in a singular manner, which scarcely finds a parallel except in the history of Murchison's Silurian sections. Completely inverting, as I have elsewhere shown, the order of succession in his Taconic system, estimated by him at 30,000 feet, he placed near the base of the lower division of the system the Stockbridge or Eolian limestone, including the white marbles of Vermont; which, by their organic remains have since been by Billings found to belong to the Levis formation. A large portion of the related rocks in western Vermont and elsewhere, which afford a fauna now known to be far more ancient than that of the Lower Taconic just referred to, and as low if not lower than anything in the New York system, were, by Emmons, then placed partly near the summit of the Upper Taconic, and partly not only above the whole Taconic system, but above the Champlain division of the New York system. Thus we find in 1842, in his Report on the Geology of the Northern District of New York (where Emmons defined his views on the Taconic system), that he placed above this latter horizon, both the green sandstone of Sillery near Quebec, and the red sandrock of western Vermont, (which he then regarded as the representatives of the Oneida and the Medina sandstones,) and described the latter as made up from the ruins of Taconic rocks [pages 124, 282]. In 1844–1846, in his Report on the Agriculture of New York [I. 119], he however adopted a different view of the red sandrock, assigning it to the Calciferous; and in 1855, in his "American Geology" [ii. 128], it was regarded as in part Calciferous and in part Potsdam. In 1848 Prof. C. B. Adams, then director of the Geological Survey of Vermont, argued strongly against these latter views, and maintained that the red sandrock directly overlaid the shales of the Hudson-River group and corresponded to the Medina and Clinton formations of the New York system. [Amer. Jour. Sci. II, v. 108.] He had before this time discovered in this sandrock, besides what he considered an *Atrypa*, abundant remains of a trilobite, which Hall, in 1847, referred to the genus *Conocephalus* (*Conocoryphe*), remarking at the same time that inasmuch as this genus was (at that time) only described as occurring in

"graywacke in Germany" and elsewhere, no conclusions could be drawn from these fossils as to the geological horizon of the rocks in question. [Ibid. II, xxxiii, 371.] In September, 1861, however, Mr. Billings, after an examination of the rocks in question, pronounced in favor of the later opinion of Emmons, declaring the red sandrock near Highgate Springs, Vermont, containing *Conocephalus* and *Theca*, to belong to the base of the second fauna "if not indeed a little lower," and to be "somewhere near the horizon of the Potsdam." [Ibid. II, xxxii, 232.]

The dark colored fossiliferous shales which were asserted, both by Adams and by Emmons, to underlie this red sandrock, were, by the former, as we have seen, regarded as belonging to the Hudson-River group, while by the latter they were described as an upper member of the Taconic system; which was here declared to be unconformably overlaid by the red sandrock, a member of the New York system. These slates, a few years before, had afforded some trilobites, which after remaining in the hands of Prof. Hall for two years or more, were in 1859, described by him in the 12th "Report of the Regents of the University of New York," as *Olenus Thompsoni* and *O. Vermontana*. He soon however found them to constitute a distinct genus, for which he proposed the name of *Barrandia*, but finding this name preoccupied, suggested in 1861, in the 14th "Regents' Report," that of *Olenellus*, which was subsequently adopted by Billings, in 1865. [Paleozoic Fossils, pages 365, 419.] In 1860, Emmons, in his "Manual of Geology," described the same species, but placed them in the genus *Paradoxides*, as *P. Thompsoni and P. Vermontana*. Hall had already, in 1847, in the first volume of his Paleontology of New York, referred to *Olenus* the *Elliptocephalus asaphoides* of Emmons, and also a fragment of another trilobite from Saratoga Lake; both of which were described as belonging to the Hudson-River group of the New York system, or to a still higher horizon. The reasons for this will appear in the sequel. The *Elliptocephalus*, with another trilobite named by Emmons *Atops*, (referred by Hall to *Calymene*, and subsequently, by Billings to *Conocoryphe*,) occurs at Greenwich, New York. These were by Emmons, in his essay on the Taconic system (in 1844), described as characteristic of that system of rocks.

A copy of the Regent's Report for 1859 having been sent by Billings to Barrande, this eminent paleontologist, in a letter

addressed to Prof. Bronn of Heidelberg, July 16, 1860 [Amer. Jour. Sci. II, xxxi, 212], called attention to the trilobites therein figured, and declared that no paleontologist familiar with the trilobites of Scandinavia would "have hesitated to class them among the species of the primordial fauna, and to place the schists enclosing them in one of the formations containing this fauna. Such is my profound conviction, etc." The letter containing this statement had already appeared in the American Journal of Science for March, 1861, but Mr. Billings in his note just referred to, on the fossils of Highgate, in the same Journal for September of that year, makes no allusion to it. In March, 1862, however, he returns to the subject of the sandrock, in a more lengthy communication [Ibid II, xxxiii, 100), and after correcting some omissions in his former note, alludes in the following language to Mr. Barrande, and to the expressed opinion of the latter, just quoted, with regard to the fossils in question and the rocks containing them: "I must also state that Barrande first determined the age of the slates in Georgia, Vermont, holding *P. Thompsoni* and *P. Vermontana*." He adds "at the time I wrote the note on the Highgate fossils it was not known that these slates were conformably interstratified with the red sandrock. This discovery was made afterwards by the Rev. J. B. Perry and Dr. G. M. Hall of Swanton."

Mr. Billings now blames me [Canadian Naturalist, new series, vi, 318] for having written in my address of last year, with regard to the Georgia trilobites, first described as *Olenus* by Prof. Hall, that Barrande "called attention to their primordial character, and thus led to a knowledge of their true stratigraphical horizon." I had always believed that the letter of Barrande and the explicit declaration of Mr. Billings, just quoted, contained the whole truth of the matter My attention has since been called to a subsequent note by Mr. Billings in May, 1862, [Ibid II, xxxiii, 421] in which, while asserting that Emmons had already assigned to these rocks a greater age than the New York system, he mentions that in sending to Barrande, in the spring of 1860, the Report of Prof. Hall on the Georgia fossils, he alluded to their primordial character, and suggested that they might belong to what Mr. Barrande has called 'a colony' in the rocks of the second fauna. This is also stated in a note by Sir William Logan in the preface to the Geology of Canada [page viii.] As the genus Olenus, to which Prof. Hall had referred

the fossils in question, was at that time (1860) well-known to belong, both in Great Britain and in Scandinava, to the primordial fauna, Mr. Barrande does not seem to have thought it necessary in his correspondence to refer to the very obvious remark of Mr. Billings.

Mr. Billings further showed in his paper in March, 1862, that fossils identical with those of the Georgia slates had been found by him in specimens collected by Mr. Richardson of the Geological Survey of Canada in the summer of 1861, on the Labrador coast, along the strait of Belisle: where *Olenellus* (*Paradoxides*) *Thompsoni* and *O. Vermontana* were found with *Conocoryphe* (*Conocephalus*) in strata which were by Billings referred to the Potsdam group. [See for the further history of these fossils the Geology of Canada, pages 866, 955, and Pal. Fossils of Canada, pages 11, 419.]

The interstratification of the dark-colored fossiliferous shales holding *Olenellus* with the red sandrock of Vermont, announced by Mr. Billings, was further confirmed by Sir William Logan in his account of the section at Swanton, Vermont [Geology of Canada, 281]. They were there declared to occur about 500 feet from the base of a series of 2200 feet of strata, consisting chiefly of red sandy dolomites (the so-called sandrock) containing *Conocephalus* throughout, while the shaly beds held in addition, the two species of *Paradoxides* (*Olenellus*) and some brachiopods. These beds, like those of Labrador, were referred by Logan and by Billings to the Potsdam group. The conclusions here announced were of great importance for the history of the Taconic controversy. The trilobites of primordial type, from Georgia, Vermont, which by Emmons were placed in the Taconic system, lying unconformably beneath a series of rocks belonging to the lower part of the New York system, were now declared to belong to the red sandrock group, a member of this overlying system. Much has been said of these fossils, as if they furnished in some way a vindication of the views of Emmons, and of the Taconic system; a conclusion which can only be deduced from a misconception of the facts in the case. Emmons had, previous to 1860, on lithological and stratigraphical evidence alone, called the Georgia slates Taconic, and placed them unconformably beneath the red sandrock. If now both he and Billings were right in referring the red sandrock to the Calciferous and Potsdam formations, and if the stratigraphical determination of Messrs. Perry

and G. M. Hall, confirmed by those of Logan, were correct, viz: that the trilobites in question occur not in a system of strata lying unconformably beneath the red sandrock, but in beds intercalated with the red sandrock itself, it is clear that these trilobites must belong not to the Taconic, but to the New York system. We shall return to the question of the age of these rocks.

We have seen that Prof. James Hall, in 1847, and again in 1859, referred trilobites regarded by him as species of *Olenus* to the Hudson-River group, or in other words to the summit of the second paleozoic fauna, while it is now well known that they are characteristic of the first fauna. In this reference, in 1847, Prof. Hall was justified by the singular errors which we have already pointed out in the works of Hisinger on the geology of Scandinavia. In his *Anteckningar*, in 1828, while the colored map and accompanying sections show the alum-slates with *Paradoxides* to lie beneath, and the clay-slates with graptolites, above the orthoceratite-limestone, the accompanying colored legend, designed to explain the map and sections, gives these two slates with the numbers 3 and 4, as if they were contiguous and beneath the limestone, which is numbered 5. The student who, in his perplexity, turned from this to the later work of Hisinger, his *Lethæa Suecica*, found the two groups of slates, as before, placed in juxtaposition, but assigned, together, to a position above the orthoceratite-limestone. Thus, in either case, he would be led to the conclusion that in Scandinavia the alum-slates with *Olenus*, *Paradoxides* and *Conocephalus* (*Conocoryphe*) were closely associated with the graptolitic shales; and, upon the authority of the latter work, that the position of both of these was there above the orthoceratite-limestones, and at the summit of the second fauna. The graptolitic shales of Scandinavia were already identified with those of the Utica and Hudson-River formations of the New York system. The red sandrock of Vermont, containing *Conocephalus*, had been, both by Emmons and Adams, alike on lithological and stratigraphical grounds, referred to the still higher Medina sandstone; a view which, as we have seen, was still maintained and strongly defended by Adams. This was in 1847, and Angelin's classification of the transition rocks of Scandinavia, fixing the position of the various trilobitic zones, did not appear until 1854. Prof. Hall had therefore at this time the strongest reasons for assigning the rocks containing *Olenus* to the summit of the second fauna. Before we can understand his reasons for

maintaining a similar view in 1859, we must notice the history of geological investigation in eastern Canada. So early as 1827, Dr. Bigsby, to whom North American geology owes so much, had given us [Proc. Geol. Soc. I, 37] a careful description of the geology of Quebec and its vicinity. He there found resting directly upon the ancient gneiss, a nearly horizontal dark colored conchiferous limestone, having sometimes at its base a calcareous conglomerate, and well displayed on the north shore of the St. Lawrence at Montmorenci and Beauport. He distinguished moreover a third group of rocks, described by him as a "slaty series composed of shale and graywacke, occasionally passing into a brown limestone, and alternating with a calcareous conglomerate in beds, some of them charged with fossils * * * * derived from the conchiferous limestone." (This fossiliferous conglomerate contained also fragments of clay-slate.) From all these circumstances Bigsby concluded that the flat conchiferous limestones were older than the highly inclined graywacke series; which latter was described as forming the ridge on which Quebec stands, the north shore to Cape Rouge, the island of Orleans, and the southern or Point-Levis shore of the St. Lawrence; where besides trilobites, and the fossils in the conglomerates, he noticed what he called vegetable impressions, supposed to be fucoids. These were the graptolites which, nearly thirty years later, were studied, described and figured for the Geological Survey of Canada by Prof. James Hall; who has shown that two of the species from this locality were described and figured under the name of fucoids by Ad. Brongniart, in 1828. [Geol. Sur. Canada, Decade II, page 60.] Bigsby, in 1827, conceived that the limestones of the north shore might belong to the carboniferous period, and noted the existence of what were called small seams of coal in the graywacke series of the south shore, which substance I have since described in the Geology of Canada [page 525.]

In 1842, the Geological Survey of Canada was begun by Sir William Logan, who in a Preliminary Report to the Government, in that year [page 19], says "of the relative age of the contorted rocks of Point Levis, opposite Quebec, I have not any good evidence, though I am inclined to the opinion that they come out from below the flat limestones of the St. Lawrence." He however subsequently adds, in a foot-note, "the accumulation of evidence points to the conclusion that the Point Levis rocks are

superior to the St. Lawrence limestones." In 1845, Captain, now Admiral Bayfield, maintained the same view, fortifying himself by the early observations of Bigsby, and expressing the opinion that the flat limestones of Montmorenci and Beauport passed beneath the graywacke series. These limestones, from their fossils, were declared to be low down in the Silurian, and identical with those which had been observed at intervals along the north shore of the St. Lawrence to Montreal, [Geol. Journal, i. 455] the fossiliferous limestones of which were then well known to belong to the Trenton group of the New York system. The graywacke series of Quebec, which was still supposed by Bayfield to hold in its conglomerates fossils from these limestones, was therefore naturally regarded as belonging to the still higher members of that system; and, as we have seen, the green sandstone near Quebec, a member of that series, had already in 1842, been regarded by Emmons as the representative of the Oneida or Shawangunk conglomerate, at the summit of the Hudson-River group of New York.

It is to be noticed that immediately to the north-east of Quebec, rocks undoubtedly of the age of the Utica and Hudson-River divisions overlie conformably the Trenton limestone, on the left bank of the St. Lawrence; while a few miles to the south-west, strata of the same age, and occupying a similar stratigraphical position, appear on both sides of the St. Lawrence, and are traced continuously from this vicinity to the valley of Lake Champlain. These moreover offer such lithological resemblances to the so-called graywacke series of Quebec and Point Lévis, (which extends thence some hundreds of miles north-eastward along the right bank of the St. Lawrence,) that the two series were readily confounded, and the whole of the belt of rocks along the south-east side of the St. Lawrence, from the valley of Lake Champlain to Gaspé, was naturally regarded as younger than the limestones of the Trenton group. It was in 1847 that Sir William Logan commenced his examination of the rocks of this region, and in his report the next year [1848, page 58] we find him speaking of the continuous outcrop "of recognized rocks of the Hudson-River group from Lake Champlain along the south bank of the St. Lawrence to Cape Rosier." In his Report for 1850, these rocks were farther noticed as extending from Point Lévis south-west to the Richelieu, and north-east to Gaspé, [pages 19, 32]. They were described as consisting, in ascending

sequence from the Trenton limestone and the Utica slate, of clay-slates and limestones, with graptolites and other fossils, followed by conglomerate-beds supposed to contain Trenton fossils, red and green shales and green sandstones; the details of the section being derived from the neighborhood of Quebec and Point Lévis, and from the rocks first described by Bigsby. As farther evidence with regard to the supposed horizon of these rocks, to which he subsequently (in 1860,) gave the name of the Quebec group, we may cite a letter of Sir William Logan, dated November, 1861, [Amer. Jour. Sci. II, xxxiii, 106,] in which he says "In 1848 and 1849, founding myself upon the apparent superposition in Eastern Canada of what we now call the Quebec group, I enunciated the opinion that the whole series belonged to the Hudson-River group and its immediately succeeding formation; a *Leptæna* very like *L. sericea*, and an *Orthis*, very like *O. testudinaria*, and taken by me to be these species, being then the only fossils found in the Canadian rocks in question. This view supported Prof. Hall in placing, as he had already done, the Olenus rocks of New York in the Hudson-River group, in accordance with Hisinger's list of Swedish rocks as given in the *Lethæa Suecica* in 1837, and not as he had previously given it."

The concurrent evidence deduced from stratigraphy, from geographical distribution, from lithological and from paleontological characters, thus led Logan, from the first, to adopt the views already expressed by Bigsby, Emmons and Bayfield, and to assign the whole of the paleozoic rocks of the south-east shore of the St. Lawrence, below Montreal, to a position in the New York system above the Trenton limestone. While thus, as he says, founding his opinion on the stratigraphical evidence obtained in Eastern Canada, Logan was also influenced by the consideration that the rocks in question were continuous with those in western Vermont. Part of the rocks of this region had, as we have seen, originally been placed by Emmons at this horizon, while the others, referred by him to his Taconic system, were maintained by Henry D. Rogers to belong to the Hudson-River group; a view which was adopted by Mather and by Hall, and strongly defended by Adams, at that time engaged in a Geological Survey of Vermont, with which in 1846 and 1847, the present writer was connected.

As regards the subsequent paleontological discoveries in these

rocks in Canada, it is to be said that the graptolites first noticed by Bigsby in 1827, were re-discovered by the Geological Survey, at Point Lévis in 1854, and having been placed in the hands of Prof. James Hall, (who in that year first saw the rocks in question) were partially described by him in a communication to Sir W. E. Logan, dated April, 1855, and subsequently at length in 1858 [Report Geol. Survey for 1857, page 109, and Decade II.] They were new forms, it is true, but the horizon of the graptolites, both in New York and in Sweden, was the same as that already assigned by Logan to the Point-Lévis rocks. Thus these fossils appeared to sustain his view, and they were accordingly described as belonging to the Hudson-River group.

Up to 1856, no other organic remains than the graptolites and the two species of brachiopods noticed by Sir William Logan, were known to the Geological Survey as belonging to the Point Lévis rocks; the trilobites long before observed by Bigsby not having been re-discovered. In 1856, the present writer, while engaged in a lithological study of the various rocks of Point Lévis, found in the vicinity of the graptolitic shales, beds of what were described by him in 1857, [Report Geol. Surv. 1853-56, page 465,] as "fine granular opaque limestones, weathering bluish-gray, and holding in abundance remains of orthoceratites, trilobites, and other fossils; which are replaced by a yellow-weathering dolomite." In these, which are probably what Bigsby had long before described as fossiliferous conglomerates, the dolomitic matter is so arranged as to suggest a resemblance to certain beds which are really conglomerate in character, and were, at the same time, described by me as interstratified with the fossiliferous limestones, and as holding pebbles of pure limestone, of dolomite, and occasionally of quartz and of argillite; the whole cemented by a yellow-weathering dolomite, and occasionally by a nearly pure carbonate of lime. [Ibid 466.] The included fragments of argillite, (previously noticed by Bigsby) which are greenish or purplish in color, with lustrous surfaces, are precisely similar to those which form great beds in the crystalline schists of the Green Mountain series of the Appalachian hills, which extend in a north-east and south-west course along the south-eastern border of the rocks of the Quebec group. I conceive that these argillite fragments, (like those in the Potsdam conglomerate near Lake Champlain, referred to in my address of last year,) are derived from the ancient schists of the Appallachians.

This re-discovery of fossiliferous limestones at Point Lévis led to farther exploration of the locality, and in 1857, and the following years, a large collection of trilobites, brachiopods, and other organic remains was obtained from these limestones by the Geological Survey of Canada.

Mr. Billings, who in 1856, had been appointed paleontologist to the Geological Survey, at once commenced the study of these fossils from Point Lévis, and at length arrived at the important conclusion that the organic remains there found, belonged not to the summit of the second fauna, but were to be assigned a position in the first or primordial fauna. This conclusion he communicated to Mr. Barrande in a letter, dated July 12, 1860, [Amer. Jour. Sci. II, xxxi, 220] and gave descriptions of many of the organic forms in the Canadian Naturalist for the same year. I have already alluded, in describing the rocks of Point Lévis, to the peculiarities of aspect which probably led Dr. Bigsby, in 1827, to confound these fossiliferous limestones, penetrated by dolomite, with the true dolomitic conglomerates associated with them, and helped him to suppose the fossils to be derived from the limestones of the north shore, now known to be younger rocks. This mistake was a very natural one at a time when comparative paleontology was unknown.

Sir William Logan meanwhile made a careful stratigraphical examination of the rocks of Point Lévis, and notwithstanding the peculiarities of the limestones which there contain the primordial fauna, declared himself, in December, 1860, satisfied that "the fossils are of the age of the strata." In consequence of the discovery of Mr. Billings, Logan now proposed to separate from the Hudson-River group the graywacke series of Bigsby and Bayfield, and ascribed to it a much greater antiquity; regarding it as "a great development of strata about the horizon of the Chazy and Calciferous, brought to the surface by an overturn anticlinal fold, with a crack and a great dislocation running along the summit," by which the rocks in question were "brought to overlap the Hudson-River formation." This series, to which was assigned a thickness of from 5000 to 7000 feet, he named the Quebec group, which included the green sandstones of Sillery, regarded as the summit, the fossiliferous limestones and graptolitic shales at the base, which afterwards received the name of the Levis formation, and a great intermediate mass of barren shales and sandstones, called the Lauzon

formation. The first account of this change in the stratigraphical views of Logan occurs in his letter to Barrande, dated December 31st, 1860. [Amer. Jour. Sci. II, xxxi, 216.]

This important distinction once established, it was found necessary to draw a line from the St. Lawrence, near Quebec, to the vicinity of Lake Champlain, separating the true Hudson-River group, with its overlying Oneida or Medina rocks, on the northwest side, from the so-called Quebec group, on the south and east. This division was by Logan ascribed to a continuous dislocation, which had disturbed a great conformable paleozoic series, including the whole of the members of the New York system from the base of the Potsdam to the summit of the Hudson-River group, and, throughout the whole distance of 160 miles, had raised up the lower formations in a contorted and inclined attitude, and caused them to overlie in many cases the higher formations of the system. This dividing line was by Logan traced north-eastward through the island of Orleans, the waters of the lower St. Lawrence, and along the north shore of Gaspé; and south-westward through Vermont, across the Hudson, as far at least as Virginia; separating, throughout, the rocks of the Quebec and Potsdam groups, with their primordial fauna, from those of the Trenton and Hudson-River groups, with the second fauna. This is shown in the geological map of eastern America from Virginia to the St. Lawrence, which appears in the Atlas to the Geology of Canada, published in 1865. In an earlier geological map published by Sir William Logan at Paris in 1855, before this distinction had been drawn, the region in question in Eastern Canada is colored partly as the Oneida formation, and partly as the Hudson-River group; while in the accompanying text the Sillery sandstone is spoken of as the equivalent of the Shawangunk grit or Oneida conglomerate of the New York system. [Esquisse Géologique du Canada; Logan and Sterry Hunt, Paris, 1855, page 51.] These rocks were by Logan traced southwards across the frontier of Canada, into Vermont, where they included the red sandrock and its associated slates; which were thus by Logan, as well as by Adams, looked upon as occupying a position at the summit of the second fauna. When therefore in 1859, Prof. Hall described the trilobites found in these slates in Georgia in Vermont, he referred them to the genus *Olenus*, whose primordial horizon in Europe was then well determined, but in deference to

the conclusions of Adams and of Logan, assigned them to a position at the summit of the Hudson-River group; Hall himself never having examined the region stratigraphically. [Amer. Jour. Sci. II, xxxi, 221.] In justification of this position he appended to his description the following note, [Ibid. pages 213, 221:] "In addition to the evidence heretofore possessed regarding the position of the slates containing the trilobites, I have the testimony of Sir W. E. Logan that the shales of this locality are in the upper part of the Hudson-River group, or forming part of a series of strata which he is inclined to rank as a distinct group, above the Hudson-River proper. It would be quite superfluous for me to add one word in support of the opinion of the most able stratigraphical geologist of the American continent." Paleontology and stratigraphy here came into conflict, and it was not till in 1860, when Mr. Billings, in the face of the evidence adduced from the latter, asserted the primordial age of the Point Lévis fauna, that Sir William Logan attempted a new explanation of the stratigraphy of the region; declaring at the same time, that "from the physical structure alone no person would suspect the break which must exist in the neighborhood of Quebec; and without the evidence of the fossils every one would be authorized to deny it." [Ibid. page 218.]

The typical Potsdam sandstone of the New York system, as seen in the Ottawa basin in northern New York and the adjacent parts of Canada, affords but a very meagre fauna, including two species of brachiopods, one or two gasteropods, and a single crustacean, *Conocephalites* (*Conocoryphe*) *minutus*, found at Keeseville, New York. In 1852, however, David Dale Owen found and described an extensive fauna in Wisconsin, from rocks which were regarded as the equivalent of the Potsdam sandstone; while the observations of Shumard in Texas, in 1861, and the latter ones of Hayden and Meek in the Black Hills, have since still further extended our knowledge of the distribution and the organic remains of the rocks which are supposed to represent, in the west, the Potsdam and Calciferous formations of the New York system.

As early as 1842, Prof. Hall, in a comparison of the lower paleozoic rocks of New York with those of Great Britain, declared the Potsdam to be lower than the base of the Upper Cambrian or Bala group of Sedgwick. In 1847, as we have seen,

he extended this observation to the Calciferous and Chazy, both of which he placed below this horizon; which until a year or two previous had been looked upon as the base of the paleozoic series in Great Britain, and was subsequently made the lower limit of the second fauna of Barrande. Although from these facts it was probable that these lower members of the New York system might correspond to the primordial fauna of Barrande, we still remained, in the language of Prof. Hall, without "the means of parallelizing our formations with those of Bohemia, by the fauna there known. The nearest approach to the type of the primordial trilobites was found in the Potsdam of the northwest, described by Dr. D. D. Owen; but none of these had been generically identified with Bohemian forms, and the prevailing opinion, sanctioned as I have understood, by Mr. Barrande, was that the primordial fauna had not been discovered in this country until the re-discovery (in 1856) of *Paradoxides Harlani* at Braintree, Mass. The fragmentary fossils published in vol. I of the Paleontology of New York, and similar forms of the so-called Taconic system, were justly regarded as insufficient to warrant any conclusions." [Amer. Jour. Sci. II. xxxi, 225]. Such, according to Prof Hall, was the state of the question up to 1860. The *Conocephalus*, detected by him from the red sandrock of Vermont, in 1847, and subsequently recognized in Europe as an exclusively primordial type, seems to have been forgotten by Hall, and overlooked by others, until it was re-discovered in the sandrock by Billings in 1861. He had previously, in 1860, detected the same genus at Point Levis, together with Arionellus, and other purely primordial types. Associated with these, and with many other trilobites belonging to the second fauna, were found several species of Dikellocephalus and Menocephalus, genera first made known by Owen from the Potsdam of Wisconsin. It is by an error that Messrs. Harkness and Hicks, in a recent paper [Quar. Geol. Jour., xxvii, 395] have asserted that Owen, in 1852, found there, together with these genera, Conocephalus and Arionellus; the history of the first discovery of these genera in America, being as above given. The limestones of Point Levis thus furnished what was hitherto wanting, a direct connecting link between the fauna of the American Potsdam and the primordial zone of Bohemia.

The history of the *Paradoxides Harlani*, alluded to by Prof. Hall, is as follows: In 1834, Dr. Jacob Green received from Dr.

Richard Harlan, the cast of a large trilobite occurring in a silicious slate, which was in the collection of Francis Alger, of Boston, and, it was supposed, might have come from Trenton Falls, New York. Dr. Green, who at once pointed out the fact that the rock was wholly unlike any found at this locality, declared the fossil to resemble greatly the *Paradoxides Tessini*, Brongn.,—the former *Entomolithus paradoxus* of Linnaeus, from Westrogothia, —and named the species *P. Harlani*. [Amer. Jour., Sci. I, xxv, 336]. In 1856, the attention of Prof. William B. Rogers was called to a locality of organic remains in Braintree, on the border of Quincy, Massachusetts, where, on examination, he at once recognized the *Paradoxides Harlani* in a silicious slate similar to that of the original specimen. This was announced by him in a communication to the American Academy of Sciences [Proc., vol. iii], as a proof of the protozoic age of some of the rocks of eastern Massachusetts. Prof. Rogers then called attention to the fact that this genus of trilobites is characteristic of the primordial fauna, and noticed that Barrande had already remarked that, from the casts of *P. Harlani*, in the London School of Mines, and the British Museum (which had been made from the original specimen, and distributed by Dr. Green), this species appeared to be identical with *P. spinosus* from Skrey in Bohemia.

In 1858, Salter found in specimens sent to the Bristol Institution, in England, by Mr. Bennett, of Newfoundland, from the promontory between St. Mary's and Placentia Bays, in the southwestern part of the island, a large trilobite, described by him as *Paradoxides Bennettii* [Geol. Jour., xv, 554], which appears, according to Mr. Billings, to be identical with *P. Harlani*. On the same occasion Salter described under the name of *Conocephalites antiquatus*, a trilobite from a collection of American fossils sent by Dr. Feuchtwanger of New York to the London Exhibition of 1851. This was said to occur in a boulder of brown sandstone from Georgia, and, as I have been informed by Dr. F., was found near the town of Columbus in that state.

The slates of St. John, New- Brunswick, and its vicinity have recently yielded an abundant fauna, examined by Prof. Hartt, who at once recognized its primordial character. This conclusion was first announced, on the authority of Prof. Hartt, in a paper by Mr. G. F. Matthew, in May 1865 [Geol. Jour., xxi, 426]. The rocks of this region have afforded two species of *Paradoxides*, and fourteen of *Conocoryphe*, together with *Agnostus* and *Micro-*

discus, all of which have been described by Prof. Hartt. It may here be noticed that in 1862, Prof. Bell found in the black shales of the Dartmouth valley, in Gaspé, a single specimen of a large trilobite, which, according to Mr. Billings, closely resembles *Paradoxides Harlani*, but from its imperfectly preserved condition cannot certainly be identified with it. [Geol. Canada, 882].

The geological examinations of Mr. Alexander Murray in Newfoundland since 1865, have shown that the south-eastern part of that island contains a great volume of Cambrian rocks, estimated by him at about 6,000 feet in all. No traces of the Upper Cambrian or second fauna have been detected among these, but some portions contain the Paradoxides already mentioned, while others yield the fauna which Mr. Billings has called Lower Potsdam. This name was first given in an appendix (prepared by Sir W. E. Logan,) to Mr. Murray's report on Newfoundland for 1865, published in 1866 [page 46; see also Report of the Geol. Survey of Canada for 1866, page 236.] The Lower Potsdam was there assigned a place above the Paradoxides beds of the region, which were called the St. John group,—the fossiliferous strata of St. John, New Brunswick, being referred to the same horizon; which corresponds to the Menevian of Wales, now recognized as the summit of the Lower Cambrian. The succession of the rocks containing these two faunas in south-eastern Newfoundland is not yet clear; the Lower Potsdam fauna is regarded by Mr. Billings as identical with that found on the strait of Bellisle, at Bic, (on the south shore of the river St. Lawrence, below Quebec,) at Georgia, Vermont, and at Troy, New York; but in none of these other localities is it as yet known to be accompanied by a Menevian fauna. The trilobites hitherto described from these rocks belong to the genera *Olenellus*, *Conocoryphe* and *Agnostus;* neither *Paradoxides*, which characterizes the Menevian and the underlying Harlech beds in Wales, nor *Olenus*, which there abounds in the rocks immediately above this horizon, having as yet been described as occurring in the Lower Potsdam of Mr. Billings. Future discoveries may perhaps assign it a place below instead of above the Menevian horizon.

The characteristic Menevian fauna in and near St. John, New Brunswick, is found in a band of about 150 feet, towards the base of a series of nearly vertical sandstones and argillites, underlaid by conglomerates, and resting upon crystalline schists,

in a narrow basin. The series, the total thickness of which is estimated by Messrs. Matthew and Bailey at over 2000 feet, contains Lingula throughout, but has yielded no remains of a higher fauna. The same Menevian forms have been found in small outlying areas of similar rocks, at two or three places north of the St. John basin, but to the south of the New Brunswick coal-field. To the north of this is a broad belt of similar argillites and sandstones, which extends south-westward into the state of Maine. This belt has hitherto yielded no organic remains, but is compared by Mr. Matthew to the Cambrian rocks of the St. John basin, and to the gold-bearing series of Nova Scotia, [Geol. Jour. xxi, 427,] which at the same time resembles closely the Cambrian rocks of southeastern Newfoundland. This was remarked by Dr. Dawson in 1860, when he expressed the opinion that the auriferous rocks of Nova Scotia were "the continuation of the older slate series of Mr. Jukes in Newfoundland, which has afforded Paradoxides," and probably the equivalent of the Lingula flags of Wales. [Supplement to Acadian Geology (1860,) page 53; also Acad. Geol. 2nd ed., page 613.] Associated with these gold-bearing strata, along the Atlantic coast of Nova Scotia, occur fine grained gneisses, and mica-schists with andalusite and staurolite; besides other crystalline schists which are chloritic and dioritic, and contain crystallized epidote, magnetite and menaccanite. These two types of crystalline schists, (which, from their stratigraphical relations, as well as from their mineral condition, appear to be more ancient than the unerystalline gold-bearing strata,) were in 1860, as now, regarded by me as the equivalents respectively of the White Mountain and Green Mountain series of the Appalachians; as will be seen by reference to Dr. Dawson's work just quoted. At that time, however, and for many years after, I held, in common with most American geologists, the opinion that these two groups of crystalline schists were altered rocks of a more recent date than that assigned to the auriferous series of Nova Scotia by Dr. Dawson; who was much perplexed by the difficulty of reconciling this view with his own. The difficulty is however at once removed when we admit, as I have maintained for the last two years, that both of these groups are pre-Cambrian in age. [Amer. Jour. Sci. II, l. 83; address to the Amer. Assoc. Adv Sci. August, 1871.]

A notice by Mr. Selwyn of some of these crystalline schists in

Nova Scotia will be found in the Report of the Geological Survey of Canada for 1870, [page 271]. He there remarks moreover the close lithological resemblances of the gold-bearing strata to the Harlech grits and Lingula-flags of North Wales, and announces the discovery among these strata at the Ovens gold-mine in Lunenberg, Nova Scotia, of peculiar organic markings regarded by Mr. Billings as identical with the *Eophyton Linnæanum*, which is found in the Regio Fucoidarum, at the base of the Cambrian in Sweden. In the volume just quoted [page 269] will be found some notes by Mr. Billings on this fossil, which occurs also near St. John, New Brunswick, in strata supposed to underlie the Paradoxides beds. The same form is found in Conception Bay, in south-eastern Newfoundland, in strata regarded by Mr. Murray as higher than those with *Paradoxides*, and containing also two new species of *Lingula*, a *Cruziana* and several fucoids. Still more recently, *Eophyton*, accompanied by these same fucoids, has been found by Mr. Billings at St. Laurent, on the island of Orleans near Quebec, in strata hitherto referred by the Geological Survey, on stratigraphical grounds, to the Quebec group. The evidence adduced by Mr. Billings shows that this organic form, whatever its nature, belongs to a very low horizon in the Cambrian.

As regards the probable downward extension of these forms of ancient life, I cannot refrain from citing the recent language of Mr. Hicks. [Quar. Jour. Geol. Soc., May 1872, page 174.] After a comparative study of the Lower Cambrian fauna, including that of the Harlech and Menevian rocks in Wales, and the representatives of the latter in other regions, he adds:

"Though animal life was restricted to these few types, yet at this early period the representatives of the several orders do not show a very diminutive form, or a markedly imperfect state; nor is there an unusual number of blind species. The earliest known brachiopods are apparently as perfect as those which succeed them; and the trilobites are of the largest and best developed types. The fact also that trilobites had attained their maximum size at this period, and that forms were present representative of almost every stage in development, from the little *Agnostus*, with two rings to the thorax, and *Microdiscus* with four, to *Erinnys* with twenty-four; and blind genera along with those having the largest eyes; leads to the conclusion that for these several stages to have taken place numerous previous faunas

must have had an existence, and moreover, that even at this time in the history of our globe, an enormous period had elapsed since life first dawned upon it."

The facts insisted upon by Hicks do not appear to be inconsistent with the view that at this horizon the trilobites had already culminated. Such does not, however, appear to be the idea of Barrande, who in a recent learned essay upon the trilobitic fauna [1871] has drawn from its state of development at this early period, conclusions strongly opposed to the theory of derivation.

The strata holding the first fauna in south-eastern Newfoundland, rest unconformably, according to Mr. Murray, upon what he has called the Intermediate series; which is of great thickness, consists chiefly of crystalline rocks, and is supposed by him to represent the Huronian. He has however included in this intermediate series several thousand feet of sandstones and argillites which, near St. Johns in Newfoundland, are seen to be unconformably overlaid by the fossiliferous strata already noticed, and have yielded two species of organic forms, lately described by Mr. Billings. One of these is an *Arenicolites*, like the *A. spiralis* found in the Lower Cambrian beds of Sweden, and the other a patella-like shell, to which he has given the name of *Aspidella Terranovica*. [Amer. Jour. Science, III, iii, 223.] These, from their stratigraphical position, have been regarded as Huronian; but from the lithological description of Mr. Murray, the strata containing them appear to be unlike the great mass of the Huronian rocks of the region. Their occurrence in these strata, in either case, marks a downward extension of these forms of paleozoic life.

Mr. Billings has described from the rocks of the first fauna certain forms under the name of *Archeocyathus*, one of the species of which, according to Dr. Dawson, belonged to a calcareous chambered foraminiferal organism similar in its nature to much of the *Stromatopora* of the second, and closely related *Coenostroma* of the third fauna. All of these Dawson shows to have strong affinities to *Eozoon*, which is represented by *E. Canadense* of the Laurentian, and by similar forms in the newer crystalline schists of Hastings, Ontario, as well as by the *E. Bavaricum* of the upper crystalline schists of Bavaria. The succession of related foraminiferal organisms, is farther seen in the Devonian limestones of Michigan, where occur great masses

like Stromatopora, which present, according to Dawson a structure intermediate between the Eozoon of the Laurentian and the genera Parkeria and Loftusia of the Cretaceous and the Eocene. The details are taken from Dr. Dawson's recent presidential address to the Natural History Society of Montreal, in May, 1872, where he has announced some of the results of his studies, yet in progress, on the earlier foraminifera.

In 1856 the late Prof. Emmons described [Amer. Jour. Sci. II, xxii, 389] under the name of *Palæotrochis*, certain forms regarded by him as organic, found in North Carolina in a bed of auriferous quartzite, among rocks referred to his Taconic system. Their organic nature has also been maintained by Prof. Wurtz, but from my own examinations, I agree with the opinion expressed by Prof. Hall, and subsequently supported by the observations of Prof. Marsh, [Ibid. II, xxiii, 278; xvl. 217] that the forms to which the name of Palæotrochis has been given are nothing more than silicious concretions.

As regards the geological horizon of the series of strata to which Sir William Logan has given the name of the Quebec group, the Sillery and Lauzon divisions have as yet yielded to the paleontologist only two species of *Obolella* and one of *Lingula*. Our comparisons must therefore be based upon the fauna of the Levis limestones and graptolitic shales, which have already been compared with the Middle Cambrian or Festiniog group of Sedgwick, by the combined labors of Billings and Salter. The former has moreover carefully compared this fauna with that of the lower members of the New York system; in which the succession of organic life appears to have been very much interrupted. Thus, according to Mr. Billings, of the ninety species known to exist in the Chazy limestone of the Ottawa basin, only twenty-two species have been observed to pass up into the directly-overlying Birdseye and Black-River limestones. The break between the Chazy and the underlying Calciferous sandrock, in this region, is still more complete; since, according to the same authority, of forty-four species in the latter only two pass up into the Chazy limestone. This latter break in the succession appears to be filled, in the region to the eastward of the Ottawa basin, by the Levis limestone; which has been studied near Quebec, and also near Phillipsburg, not far from the outlet of Lake Champlain. This formation (including the accompanying graptolitic shales,) has yielded, up to the present

time, 219 species of organic remains, (comprising seventy-four of crustacea, and fifty-one of graptolitidiæ) none of which, according to Mr. Billings, have been found either in the Potsdam or in the Birdseye and Black River limestone. Twelve of the species of the Levis formation are however met with in the Calciferous, and five in the Chazy of the Ottawa basin, and the Levis is therefore regarded by Mr. Billings as the connecting link between these two formations.

With regard to the British equivalents of these rocks, the Levis limestone, according to Salter, corresponds to the Tremadoc beds; although the species of *Dikellocephalus* found in the Levis rocks are by him compared with those found in the Upper Lingula flags or Dolgelly beds. The graptolitic strata of Levis however clearly represent the Lower Llandeilo or Arenig rocks of North Wales, the Skiddaw group of Sedgwick in Cumberland, the graptolitic beds which in Esthonia, according to Schmidt, are found below the orthoceratite-limestones, [Can. Naturalist, I. vi. 345] and those of Victoria in Australia, [Mem. Geol. Sur. III, part 2, 255, 304.] In the Lower Llandeilo and Upper Tremadoc beds there appears to be in North Wales, a mingling of forms of the first and second faunas, as in the Levis and Chazy formations. The latter was already, by Hall, in 1847, declared to be beneath the Silurian horizon then recognized in Great Britain. By its fauna it is comparatively isolated from the strata both below and above it, and stratigraphically as well as paleontologically it would appear to belong rather than to the lower than to the higher rocks. According to a private communication from Prof. James Hall, the Chazy limestone at Middleville, Herkimer county, New York, to the south of the Adirondacks, is wanting, and the basal beds of the Trenton group (the Birdseye limestone) there rest unconformably upon the Calciferous sandrock.

The relations of the various members of the Quebec group to each other, and of the group, as a whole, to the succeeding Trenton and Hudson-River groups, require further elucidation. If, as I am disposed to believe, the southeastward-dipping series of the older strata near Quebec, exhibits the northwest side of an overturned and eroded anticlinal, in which the normal order of the strata is inverted, then the Lauzon and Sillery divisions, which there appear to overlie the Levis limestones and shales, are older rocks, occupying the position of the Potsdam or still

lower members of the Cambrian. Sir William Logan supposes the appearance of these rocks in their present attitude by the side of the strata of the Trenton and Hudson River-groups, in the vicinity of Quebec, to be due to a great dislocation and uplift, subsequent to the deposition of these higher rocks; but, as suggested in my address of last year, I conceive the Quebec group to have been in its present upturned and disturbed condition before the deposition of the Trenton limestones. The supposed dislocation and uplift, extending from the gulf of St. Lawrence to Virginia, is according to this view, but the outcrop of the rocks of the first fauna from beneath the unconformably overlying strata of the second fauna. The later movements along the borders of the Appalachian region have however, to some extent, affected these, in their turn, and thus complicated the relations of the two series. This unconformity, which corresponds to the marked break between the Levis and Trenton faunas, is farther shown by the stratigraphical break and discordance in Herkimer county, New York; and by the fact that beyond the limits of the Ottawa basin, on either side, the limestone of the Trenton group rests directly on the crystalline rocks; the older members of the New York system being altogether absent at the northern outcrop, as well as in the outliers of Trenton limestone seen to the north of Lake Ontario, and as far to the north-east as Lake St. John on the Saguenay. This distribution shows that a considerable movement, just previous to the Trenton period, took place both to the west and the east of the Adirondack region, which formed the southern boundary of the Ottawa basin.

The Levis and Chazy formations, as we have seen, offer a commingling of forms of the first and second faunas, which shows them to belong to a period of transition between the two; but it is remarkable that so far as yet observed, no representatives of the later of these faunas are known to the east and south of the Appalachians, along the Atlantic coast; the first fauna, whether in Massachusetts, New Brunswick or southeastern Newfoundland, being unaccompanied by any forms of the second. The third fauna, on the contrary, is represented in various localities both within and to the east of the Appalachian region, from Massachusetts to Newfoundland. In parts of Gaspé, and also in Nova Scotia, strata holding forms referred to the Clinton and Niagara divisions are met with, as well as other beds of Lower Helderberg age, associated with species of shells and of plants

which connect this fauna with that of the succeeding Lower Devonian or Erian period. To this Lower Helderberg horizon (corresponding to the Ludlow of England) appear to belong certain fossiliferous beds found along the Atlantic coast of Maine and of New Brunswick, in Nova Scotia and (?) in Newfoundland; as well as others included in the Appalachian belt in Massachusetts, New Hampshire, Vermont and Quebec, along the Connecticut valley and its north-eastern prolongation. The fossiliferous strata just noticed, both in the Connecticut valley, and along the Atlantic coast, occur in small areas among the older crystalline schists, often made up of the ruins of these, and in highly inclined attitudes. The same is true in some places of the similarly situated strata of Cambrian, Devonian and Lower Carboniferous periods. These derived strata, of different ages, have, from their lithological resemblances to the parent rocks, been looked upon as examples of a subsequent alteration of paleozoic sediments; and by a farther extension of this notion, the pre-Cambrian crystalline schists themselves throughout this region have been looked upon as the result of an epigenic change of these various paleozoic strata; portions of which, here and there, were supposed to have escaped conversion, and to have retained more or less perfectly their sedimentary character, and their organic remains, elsewhere obliterated.

From the absence of the second fauna we may conclude that the great Appalachian area was, at least in New England and Canada, above the ocean during its period, and suffered a partial and gradual submergence in the time of the third fauna. This movement corresponds to the well-marked palæontological and stratigraphical break between the second and third faunas in the great continental basin to the westward, made evident by the appearance of the Oneida or Shawangunk conglomerate (apparently derived from the ruins of Lower Cambrian rocks) which, in some parts, overlies the strata of the Hudson-River group, The break is elsewhere shown by the absence of this conglomerate, and of the succeeding formations up to the Lower Helderberg division. This latter, in various localities in the valleys of the Hudson and the St. Lawrence, rests unconformably upon the strata of the second fauna, as it does upon the older crystalline rocks to the eastward.

In Ohio, according to Newberry, the base of the rocks of the third fauna (Clinton and Medina) is represented by a conglo-

merate which holds in its pebbles the organic remains of the underlying strata of the second fauna.

To the north-eastward, the island of Anticosti in the gulf of St. Lawrence, presents a succession of about 1400 feet of calcareous strata rich in organic remains, which, according to Mr. Billings, include the species of the Medina, Clinton and Niagara formations, and were named by him, in 1857, the Anticosti group. They rest upon nearly 1000 feet of almost horizontal strata, consisting of limestones and shales rich in organic remains, with many included beds of limestone-conglomerate. This series has by the Geological Survey of Canada been referred to the Hudson-River group, but notwithstanding the large number of forms of the second fauna which it contains, Prof. Shaler is disposed to look upon it as younger, and belonging rather to the succeeding division. There seems not to have been any marked paleontological break between the second and third faunas in this region; and it is worthy of note, in this connection, that in the outlying basin of paleozoic rocks, found at Lake St. John, to the north of Anticosti, *Halysites catenulatus* is met with in limestones associated with many species of organic remains characteristic of the Trenton and referred to that group. [Geology of Canada, page 165.]

The strata to which, in 1857, Mr. Billings gave the name of the Anticosti group were at the same time designated by him Middle Silurian, in which he subsequently included the local sub-division known as the Guelph formation, which in western Ontario succeeds the Niagara; the name of Upper Silurian being thus reserved for the Lower Helderberg division and the underlying Onondaga formation [Report Geol. Sur. Can. 1857, page 248, and Geol. Can. page 20.] Both the Guelph and the Onondaga have been omitted from the table on page 32; the Guelph because it was not recognized in the New York system, and is by some regarded as but a sub-division of the Niagara; and the Onondaga, for the reason that it is a local deposit of magnesian limestones, wiih gypsums and rock-salt, destitute of organic remains.

As to the name of Middle Silurian, it had some years previously been used by the officers of the government Geological Survey in Great Britain to designate the Lower and Upper Llandovery rocks; but is referred to in 1854 by Sedgwick as one that had, at that time, already been abandoned, (L. E. & D.

Philos. Mag. III, viii, 303, 367, 501,) and is also rejected by Lyell, (Student's Manual of Geology, page 452.) It is not used by Murchison, either in his *Silurian System* or in the various editions of *Siluria*, or by Ramsay, who however speaks of the Llandovery rocks as an intermediate series, (Mem. Geol. Survey III, part 2, page 2.) Inasmuch as the name of Silurian was erroneously applied to the rocks of the second fauna, and properly belongs to those of the third fauna only, that of Middle Silurian should be rejected from our nomenclature in North America, as has already been done in England. The strata to which it has been applied, on both sides of the Atlantic, are however important as illustrations of the passage from one fauna to another.

The history of the introduction of the names of Silurian and Devonian into North American geology demands our notice. Prof. Hall, as we have seen, while recognizing in the rocks of the New York system the representatives alike of the British Cambrian, Silurian and Devonian, wisely refrained from adopting this nomenclature, drawn from a region where wide diversities of opinion and controversies existed as to the value and significance of these divisions. Lyell however in the account of his first journey to the United States, published in 1845, applied the terms Lower and Upper Silurian and Devonian to our paleozoic rocks. Later, in 1846, de Verneuil, the friend and the colleague of Murchison in his Russian researches, visited the United States, and on his return to France published, in 1847, (Bul. Soc. Geol. de Fr. II, iv, 12, 646) an elaborate comparison between the European paleozoic deposits and those of North America, as made known by Hall and others. He proposed to group the whole of the rocks of the New York system, up to the summit of the Hudson-River group, in the Lower Silurian, and the succeeding members, including the Lower Helderberg, and the overlying Oriskany, in the Upper Silurian; the remaining formations to the base of the Carboniferous system being called Devonian. This essay by de Verneuil was translated and abridged by Prof. Hall, and published by him in the American Journal of Science (II. v. 176, 359; vii. 45, 218,) with critical remarks, wherein he objected to the application of this disputed nomenclature to North American geology.

Meanwhile the Geological Survey of Canada was in progress under Logan, who in his preliminary report in 1842, and in his

subsequent ones for 1844 and 1846, adopted the nomenclature of the New York system, without reference to European divisions. Subsequently however, the usage of Lyell and de Verneuil was adopted by Logan, who in his report for 1848 (page 57) spoke of the Clinton group as the base of the "Upper Silurian series," while in that for 1850 (page 34) he declared the whole of a great series of fossiliferous rocks in Eastern Canada, including the Trenton, Utica and Hudson-River divisions, and the shales and sandstones of Quebec, (then supposed to be superior to these,) to "belong to the Lower Silurian." In the report for 1852 (page 64) the Lower Silurian was made by Mr. Murray to include not only the Utica and Trenton, but the Chazy limestone, the Calciferous sandrock and the Potsdam sandstone of the New York system. From this time the Silurian nomenclature, as applied by Lyell and de Verneuil to our North American rocks, was employed by the officers of the Canadian Geological Survey (myself among the others,) and was subsequently adopted by Prof. Dana in his Manual of Geology, published in 1863.

The Geological Survey of Pennsylvania, under the direction of Prof. Henry Darwin Rogers, was begun, like that of New York, in 1836, and the paleozoic rocks of the state were at first divided, on stratigraphical and lithological grounds, into groups, which were designated, in ascending order, by Roman numerals. Subsequently, as he informs us in the preface to his final Report on the Geology of Pennsylvania, Prof. H. D. Rogers, in concert with his brother, Prof. William B. Rogers, then directing the Geological Survey of Virginia, considered the question of geological nomenclature. Rejecting, after mature deliberation, the classification and nomenclature both of the British and New York Geological Surveys they proposed a new one for the whole paleozoic column to the top of the coal-measures, founded on the conception of a great paleozoic day, the divisions of which were designated by names taken from the sun's apparent course through the heavens. (Geology of Penn. I. vi, 105.) So far as regards the three great groups which we have recognized in the lower paleozoic rocks, the later names of Rogers, and his earlier numerical designations, with their equivalents in the New York system, were as follows:

Primal, (I.) This includes the mass of 2500 feet or more of shales and sandstones, which in Pennsylvania and Virginia, and farther southward, form the base of the paleozoic series, and rest

upon crystalline schists. The Primal division was regarded by the Messrs. Rogers as the equivalent both of the Potsdam and the still lower members of the Cambrian.

Auroral, (II.) This division, which, with the last, includes the first fauna, consists in great part of magnesian limestones, and corresponds to the Calciferous and Chazy formations. Its thickness in Pennsylvania varies from 2500 to 5000 feet, and with the preceeding division, it includes the first fauna. The representatives of the Primal and Auroral divisions attain a great development in eastern Tennessee, where they have been studied by Safford.

Matinal, (III.) In this, which represents the second fauna, were comprised the limestones of the Trenton group, together with the Utica and Hudson-River shales.

Levant, (IV.) This division corresponds to the Oneida and Medina conglomerates and sandstones.

Surgent, *Scalent* and *Pre-Meridional* (V. VI.) In these divisions were included the representatives of the Clinton, Niagara and Lower Helderberg groups of New York, making, with division IV., the third fauna.

The parallelism of these divisions with the British rocks was most clearly and correctly pointed out by H. D. Rogers himself, in an explanation prepared, as I am informed, with the collaboration of Prof. William B. Rogers, and published in 1856, with a geological map of North America by the former, in the second edition of Keith Johnson's Physical Atlas. The paleozoic rocks of North America are there divided into several groups, of which the first, including the Primal, Auroral and Matinal, is declared to be the near representative of "the Europe in paleozoic deposits from the first-formed fossiliferous beds to the close of the Bala group; that is to say the proximate representatives of the Cambrian of Sedgwick." A second group embraces the Levant, Surgent, Scalent and Pre-Meridional. These are said to be "the very near representatives of the true European Silurian, regarding this series as commencing with the May-Hill sandstone." The Levant division is farther declared to be the equivalent of the sandstone just named; while the Matinal is made to correspond to the Llandeilo, Bala or Upper Cambrian; the Auroral with the Festiniog or Middle Cambrian; and the Primal with the Lingula flags, the Obolus sandstone of Russia and the Primordial of Bohemia.

The reader of the last few pages of this history will have seen how the Silurian nomenclature of Murchison and the British Geological Survey has been, through Lyell, de Verneuil and the Canadian Survey, introduced into American geology in opposition to the judgment, and against the protests of James Hall and the Messrs. Rogers, the founders of American paleozoic geology.

Three points have I think, been made clear in the first and second parts of this sketch: First, that the series to which the name of Cambrian was applied by Sedgwick in 1835, (limited by him as to its downward extension, in 1838) was co-extensive with the rocks characterized by the first and second faunas. Second, that the series to which the name of Silurian was given by Murchison in 1835, included the second and third faunas; but that the rocks of the second fauna, the Upper Cambrian of Sedgwick, were only included in the Silurian system of Murchison by a series of errors and misconceptions in stratigraphy, on the part of the latter, which gave him no right to claim the rocks of the second fauna as a lower member of his Silurian. Third, that there was no ground whatever for subsequently annexing to the Silurian of Murchison, the Lower and Middle Cambrian divisions of Sedgwick, which the latter had separated from the Upper Cambrian on stratigraphical grounds, and which were subsequently found to contain a distinct and more ancient fauna.

The name of Silurian should therefore be restricted, as maintained by Sedgwick and by the Messrs. Rogers, to the rocks of the third fauna, the so-called Upper Silurian of Murchison; and the names of Middle Silurian, Lower Silurian, and Primordial Silurian banished from our nomenclature. The Cambrian of Sedgwick however includes the rocks both of the first and second faunas. To the former of these, the lower and middle divisions of the Cambrian, (the Bangor and Festiniog groups of Sedgwick,) Phillips, Lyell, Davidson, Harkness, Hicks and other British geologists, agree in applying the name of Cambrian. The great Bala group of Sedgwick, which constitutes his Upper Cambrian, is however as distinct from the last as it is from the overlying Silurian, and deserves a not less distinctive name [illegible] these two. Its original designation of Upper Ca[illegible] when the zoological importance of Lowe[illegible] an was as yet unknown, is not sufficiently [illegible]acteri[illegible] and the same is to be said of the name of Lower Silurian, wrongly imposed

upon it. The importance of this great Bala group in Britain, and of its North American equivalent, the Matinal of Rogers,—including the whole of the limestones of the Trenton group, with the succeeding Utica and Hudson-River shales,—might justify the invention of a new and special name. That of Cambro-Silurian, at one time proposed by Sedgwick himself, and adopted by Phillips and by Jukes, was subsequently withdrawn by him, when investigations made it clear that this group had been wrongly united with the Silurian by Murchison. Deference to Sedgwick should therefore prevent us from restoring this name, which moreover, from its composition, connects the group rather with the Silurian than the Cambrian. Neither of these objections can be urged against the similarly constructed term of Siluro-Cambrian, which moreover has the advantage that no other new name could possess, of connecting the group both with the true Silurian, to which it has very generally been united, and with the Cambrian, of which, from the first, it has formed a part. I therefore venture to suggest the name of Siluro-Cambrian, as a convenient synonym for the Upper Cambrian of Sedgwick, (the Lower Silurian of Murchison,) corresponding to the second fauna; reserving at the same time the name of Cambrian for the rocks of the first fauna,—the Lower and Middle Cambrian of Sedgwick,—and restricting with him the name of Silurian to the rocks of the third fauna,—the Upper Silurian of Murchison.*

The late Prof. Jukes, it may here be mentioned, in his Manual of Geology, published in 1857, still retained for the Bala group the name of Cambro-Silurian (which had been withdrawn by Sedgwick in 1854) and reserved the name of the "true Silurian period" for the Upper Silurian of Murchison. In his recent

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* Dr. Dawson, in his address as president of the Natural History Society of Montreal, in May 1872, has taken the occasion of the publication in the *Canadian Naturalist*, of the first and second parts of this sketch, to review the subject here discussed. Recognizing the necessity of a reform in the nomenclature of the paleozoic rocks, in conformity with the views of Sedgwick, he would restrict to the rocks of the third fauna the name of Silurian, making it a division equivalent to Devonian; and while reserving with Lyell, Phillips and others, the name of Cambrian for the first fauna only, agrees with me in the propriety of adopting the name of Siluro-Cambrian for the second fauna.

and much improved edition of this excellent Manual (1872), Prof. Giekie, the director of the Geological Survey of Scotland, has substituted the nomenclature of Murchison; with the important exception, however, that he follows Hicks and Salter in separating the Menevian from the Lingula-flags, and uniting it with the underlying Harlech rocks (as has been done in the table on page 32), giving to the two the name of Cambrian [loc. cit., pages 526–529], and thus, on good paleontological grounds, extending this name above the horizon admitted by Murchison. Barrande, on the contrary, in his recent essay on trilobites (1871, page 250), makes the Silurian to include not only the Lingula-flags proper (Maentwrog and Dolgelly), but the Menevian, and even a great part of the Harlech rocks themselves (the Cambrian of Murchison and the Geological Survey), for the reason that the primordial fauna has now been shown by Hicks to extend towards their base. This, although consistent with Barrande's previous views as to the extension of the name Silurian, is a still greater violation of historic truth. By thus making the Silurian system of Murchison to include successively the Upper Cambrian and the Middle Cambrian of Sedgwick, and finally his Lower Cambrian, (the Cambrian system of Murchison himself,) we seem to have arrived at a *reductio ad absurdum* of the Silurian nomenclature; and we may apply to Siluria, as Sedgwick has already done, the apt quotation once used by Conybeare, with reference to the Graywacke of the older geologists, which it replaces; "*est Jupiter quodcunque vides.*"

It would be unjust to conclude this historical sketch of the names Cambrian and Silurian in Geology, without a passing tribute to the venerable Sedgwick, who to-day, at the age of eighty-seven years, still retains unimpaired his great powers of mind, and his interest in the progress of geological science. The labors of his successors in the study of British geology, up to the present time, have only served to confirm the exactitude of his early stratigraphical determinations; and the last results of investigations on both continents unite in showing that in the Cambrian series, as defined by him more than a generation since, he laid, on a sure foundation, the bases of paleozoic geology.

—(*From the* CANADIAN NATURALIST *for April and July* 1872.)