ORDINARY MEETING.

DECEMBER 2, 1881.

W. H. HUDLESTON, Esq., M.A., F.G.S., President, in the Chair.

The list of donations to the Library since the last meeting was read, and the thanks of the Association returned to the donors.

The following were elected Members of the Association :—

Jer. Ryan, Esq., Assoc. Inst. C.E.; Richard Phipps, Esq.; Thomas Hart, Esq., F.G.S.; Charles Christopherson, Esq.; W. Kinsey Dover, Esq., F.G.S.; H. J. Jenkinson, Esq., F.R.G.S.; Dr. Rumney; J. Postlethwaite, Esq.; Miss L. H. King; F. J. Hanbury, Esq.

The following paper was then read :—

ON SOME RECENT RESEARCHES AMONG LOWER PALÆOZOIC
ROCKS IN THE BRITISH ISLES.

BY HENRY HICKS, M.D., F.G.S.

INTRODUCTION.

In the paper which I had the pleasure of reading at the meeting of the Geologists' Association, in December last year, I endeavoured to give a brief statement of the chief results of the researches which had been carried on among the pre-Cambrian rocks in the British Isles during the preceding twenty years. In the present paper I hope to give an account of some of the most important results derived from similar researches among the Lower Palæozoic Rocks during the same period. Twenty years ago it was universally believed that in the areas in England and Wales, where the Lower Palæozoic Rocks were known to be best developed, and where they had been chiefly examined, there was no evidence of a true base line, or of the floor upon which these rocks had been deposited.

As explained in my former paper, we are now able to point out many areas where fragments of the old floor may be seen, and to recognise the earliest of the palæozoic sediments resting upon it. It is highly satisfactory to start thus from a good base line, and to have a tolerably clear idea of what the thicknesses of these earlier sediments must be in areas where previously this could only have been arrived at through vague suppositions.

Moreover, these discoveries have enabled us to realize, to some extent, the physical conditions which prevailed at the time of deposition in those areas.

The Lower Palæozoic Rocks of Britain are best divided into three great groups or systems, and to these the names, in ascending order, of Cambrian, Ordovician, and Silurian, have been given.

Lower Cambrian.

The term Cambrian was first used by Prof. Sedgwick, and it was intended by him to include the Harlech and Llanberis groups, with the succeeding rocks, to the top of the Bala series. At present, however, except by the Cambridge school, it is generally used in a more limited sense. The late Mr. Salter and myself, years ago, saw the necessity of restricting the term to the rocks containing the so-called primordial faunas. This view was adopted also by the late Sir Chas. Lyell, and it seems now to meet with very general support from those who have paid much attention to these rocks in this country and abroad.

The Cambrian in this paper, therefore, has its upper limit defined by the top of the Tremadoc rocks. There is really no stratigraphical break at this point. Still the fossil groups above and below are so distinct, on the whole, that the boundary line falls naturally there.

Recently I have divided the Lower Cambrian into three groups, under the names in ascending order of Caerfai, Solva, and Menevian.* Wherever these rocks are found in this country, in contact with any of the pre-Cambrian groups, they are seen to rest unconformably upon them. They usually contain fragments of the older rocks in abundance, and evidences that they must have been built up chiefly from the denudation of the older rocks are everywhere apparent. At the base conglomerates are always seen. In North and South Wales the fragments in the conglomerates are usually well-rounded pebbles, and these are for the most part, identical with the rocks upon which they repose. Angular and subangular fragments also occasionally occur. In the north-west of Scotland, however, huge angular masses are much more frequently found in them, and in some places they have more of the characters of breccias, than of marine conglomerates. In

* "Pop. Science Review," Oct., 1881. See also Etheridge, "Presidential Address," Quart. Journ. Geol. Soc., May, 1881; and Lapworth, "Geol. Mag.," July, 1881.

previous papers* I have endeavoured, from the evidence derived from the conglomerates, and from the appearance of the old floor on which they rest, to point out some of the physical features of the old pre-Cambrian land. The angular character of many of the fragments, and the smoothed and evenly undulating surfaces exhibited by the floor, lead to the conclusion that, to some extent at least, they were due to ice action. The pre-Cambrian continent was, evidently, studded not only with volcanic mountains, but also with high ridges and plateaux in northern latitudes. Therefore we are led to believe that the latter, at least, were covered with ice and snow in their higher parts, and that the plains and valleys had much loose material strewn over them. The thick beds of conglomerate everywhere at the base, and the frequent alternations of conglomerates, grits, and sandstones, throughout the lower several thousands of feet of the Cambrian rocks, seem to prove that an abundance of loose material must have been near and ready at hand to be easily denuded off as each part of the old land became submerged. Marine action on the hard metamorphic rocks could scarcely have produced so much sediment. Moreover, the enormous thickness found, with scarcely a trace of any beds formed by marine life at this period, indicates that some additional force must have been at work. In some places also the sediments were deposited so rapidly as to keep pace with a depression of several thousands of feet. I am inclined to believe that the British area formed a portion only of the western margin of a great continent at this time, and that some of this material might primarily have been derived from a considerable distance. In an east and west line the continent would extend from at least the 100-fathom line beyond the British Isles to Asia. The higher land was probably towards the north-east, with a general trend towards the south-west. The surface appears to have been of an undulating character, with the higher ranges running in the direction of east-north-east and west-south-west. These Lower Cambrian rocks, being the earliest sediments, would vary considerably in thickness in different areas. In Scotland, where they rest almost horizontally on the old floor, they are seen to fill up the unevennesses of the surface, and to attain a greater or less thickness in proportion to their extent. In Wales they have been more disturbed, and are usually tilted up at a tolerably high angle.

* "Quart. Journ. Geol. Soc.," 1875, and "Geol. Mag.," 1866.

Here, however, the evidences of their having varied with the unevennesses of the surface are also more or less apparent. Whatever the history of the earlier epochs may have been, it is clear that new physical conditions, on a large scale, were now prevailing over the British Isles. At this period also the history of life, as far as the present reliable evidence is forthcoming, commences. The very earliest of these sediments contain evidences of marine life. Annelid tracts and burrows are found abundantly in the sandstones, that rest immediately upon the conglomerates, and almost as early we find Brachiopods and Crustacea. All are marine forms, and they must have arrived on the scene as soon as the waters encroached on the old land. The question naturally occurs, where did they come from? We have, so far, no evidence of their presence or of that of allied types in any of the pre-Cambrian rocks. They certainly did not attain to their state of perfection by any instantaneous process; therefore their ancestors ought to be found somewhere. Now if my suppositions are correct that the waters at this time encroached from a western direction, it is easy to suppose that in the great Atlantic basin—then, as now, probably, one of the great oceanic basins—they had gradually attained, through numerous stages, the state of development shown. As none of the earlier sediments in this basin can be examined, its life succession is completely hidden from us. We are, therefore, justified, I think, in believing that could we but get at these sediments, we could there trace the history of life to far earlier times. The Eozoon is still regarded of so doubtful a nature that I do not call special attention to it. Moreover, it does not help us in arriving at the character of the immediate ancestors of our Cambrian fauna, with which we have now to deal. It is not at all improbable that ere long we may find some traces of life in the Pebidian rocks—the least altered of the pre-Cambrian groups—for I have frequently noticed markings in the slates of that group which call to mind very strongly some of the annelid markings of the Cambrian rocks. The land, which was being gradually encroached upon, would probably also be clothed with vegetation of some kind though, in the Cambrian rocks, we have but very little evidence of its nature. When at St. David's last summer I spent a considerable time in searching the conglomerates and the immediately overlying sandstones for traces of land plants, and I was

not altogether unsuccessful, for in the sandstones I detected bits of carbonaceous matter which, I think, must have been derived primarily from land plants. There was no structure visible, however, and for the present I prefer to speak of its origin with some doubt. No chapter in physical geology and geography has interested me so much of late years as that which pertains to this period in the history of the globe, and I think I may venture to claim that my paper on the "Physical Conditions under which the Cambrian and Lower Silurian Rocks were Probably Deposited Over the European Area," in the "Quart. Journal Geol. Soc.," Nov., 1875, was instrumental in bringing this question more prominently before the geological world than it had previously been. More recently Prof. Geikie, in "Nature," Aug. 26th, 1880, and Prof. Hull, at the Brit. Assoc., 1881, have put forward views almost identical with those given in my paper in 1875.* The former says,† "I think we have, in the meantime, grounds for concluding that in the north-west of Scotland there is still traceable a fragment of the earliest known land-surface of Europe, that this primeval country had a smooth, undulating aspect, not unlike that of the west of Sutherland at the present time, that it contained rock hollows, some of them filled with water, that into these hollows piles of coarse angular detritus were thrust, that around and beneath the tracts, where this detritus accumulated the gneiss was worn into dome-shaped forms, strongly suggestive of the operation of land-ice, and that though the ice of the last glacial period undoubtedly ground down the platform of gneiss, bared as it was of the overlying formations, it found a surface already worn into approximately the same forms as those which it presents to-day."

Prof. Hull, in his paper,‡ calls attention to the differences in mineral character between the Cambrian of the north-west coast of Scotland and that in Wales and in Shropshire, and he believes that these differences "were due to deposition in distinct basins lying on either side of an archæan ridge of crystalline rocks which ranged probably from Scandinavia, through the Central Highlands of Scotland, and, included the north and west of Ireland, with the counties of Donegal, Derry, Mayo, Sligo, and Galway, in

* See also a paper by me in "Geol. Mag.," April, May, and June, 1876.

† "Nature," Aug., 1880, p. 403.

‡ See abstract in "Geol. Mag.," Nov., 1881.

all of which the Cambrian beds were absent, so that the Lower Silurian repose directly and unconformably on the crystalline rocks of Laurentian age."

The differences in mineral character between the Cambrian rocks in Scotland and those in Wales are not so important as supposed by Prof. Hull, for, as I have repeatedly shown, they depend to a great extent, especially in the lower beds, on the nature of the underlying rocks. Where they rest on schists the fragments are mainly derived from these; and where, again, as in many parts of Carnarvonshire, they rest on quartz-felsites, the greater part consists of rolled fragments of those rocks. In Scotland it is the same. At Gaerloch, where they rest on greenish and micaceous schists, I noticed that the masses in the conglomerates were mainly portions of these schists. In other areas fragments of gneiss rocks prevail. This shows clearly that we have at these places the old shore lines. I maintained, in a former paper, that there must have been wide depressions at the time the Lower Cambrian rocks were deposited over the European area in lines more or less in the direction of north-east to south-west, and it appears now that there is distinct evidence of these in Scotland, as also in England and Wales, in addition to minor irregular basins.

In Prof. Ramsay's "Memoir on the Geology of North Wales," published in 1866, p. 7, he says that the "Cambrian Rocks of the Longmynd were in the 'Silurian System,' shown by Sir Roderick Murchison to underlie the whole of the Silurian strata, and when in 1846 and 1848 the Geological Survey mapped the equivalent rocks in Merionethshire and Caernarvonshire, they naturally adopted this name for these deposits. Stratigraphically they occupy the same position, and lithologically they much resemble each other." Again, in referring to the Pembrokeshire rocks, he says, "In the same year (1841) at St. David's, I traced a provisional line between the black and the purple slates, and this was afterwards adopted as the line between the Silurian and Cambrian strata." The Cambrian of the Geological Survey therefore is nearly the equivalent to that included in this paper as Lower Cambrian. There is one very important group, however, the "Menevian," unknown at the time the lines of division were drawn by Prof. Ramsay at St. David's, but now known to lie chiefly above that line, which, both on stratigraphical and fossil evidence, must be included with the lower rocks. With this cor-

rection, I see no reason to doubt that the rocks called Cambrian by the Geological Survey are more or less contemporaneous deposits in the several areas in which they have been so marked by them.

In each of the areas they have many important mineral characters in common, and in some, as in the St. David's, Harlech, and Llanberis areas, where they rest upon pre-Cambrian rocks, and are succeeded by easily recognised fossiliferous series, they do not appear to have varied much in their thickness, certainly not more than might be expected in subsiding areas with moderately undulating surfaces.

The Lower Cambrian (Cambrian of the Survey) in Wales has an average thickness of from 5,000 to 8,000ft. It contains several distinct faunas, which have been discovered within comparatively recent years. In these faunas I found, in addition to the Annelids, discovered many years ago by Mr. Salter in the Longmynd rocks, and afterwards by Dr. Kinahan in the Bray Head rocks in Ireland, some Sponges, Brachiopods, Trilobites, Ostracods, Pteropods, and Cystids. The genus *Paradoxides*, which contains the largest trilobites known, appears in this country to be restricted to the Lower Cambrian groups. The majority of the rocks in the lower groups are very barren in organic remains, one thin band only perhaps containing evidence of their presence in over 1,000ft. of beds. The upper group, the Menevian, on the other hand, is highly fossiliferous throughout, with, however, some well-marked zones. Over 50 new species have been found in this group by the late Mr. Salter, Mr. Homfray, and myself in North and South Wales.

With the exception of two or three species, these were first discovered at St. David's, and subsequently around the Merionethshire Anticlinal, where the zones occur exactly as at St. David's. The Menevian rocks there lie upon exactly similar rocks, called the Harlech group, to those I have called at St. David's the Solva group.

I have no doubt that, if carefully searched, the Harlech group will yield similar fossils to those found in the Solva group, for the succession shown by the beds is also exceedingly like that at St. David's. The curious fossil *Oldhamia*, found many years ago in the Bray Head rocks, has not been found as yet in the Welsh or Scotch Cambrian rocks, and no further information as to its true nature has been obtained of late.

Prof. Hughes has recently been fortunate enough to discover what would seem to be the true basal (Conglomerate) beds of the Cambrian in Anglesea, and has traced, with much success, the same beds in the neighbourhood of Bangor and Caernarvon. In neither of these areas, however, have the Menevian, or even the majority of the Cambrian rocks been found. Probably these have been lost through faults. It is possible, however, that they may not have been deposited there. At Caernarvon and Bangor, as indicated by us years ago, they rest, as at Anglesea, on a pre-Cambrian axis.

Upper Cambrian.

The Upper Cambrian, consisting in ascending order of the Maentwrog, Ffestiniog, Dolgelly, and Tremadoc groups, attains to a thickness of about 6,000ft. Its lower groups are rather barren in organic remains, especially in comparison with the immediately underlying Menevian group. The upper groups, however, are rich, and contain many new forms. The labours of the late Mr. Salter and Mr. Belt in different parts of North Wales, and of Messrs. Homfray and Ash near Portmadoc, brought to light many new fossils, and have added much to our knowledge of these rocks.

It is to Mr. Belt we owe their arrangement into divisions as adopted in this paper. Their first recognition, however, we owe to the early researches of Prof. Sedgwick. Up to the year 1866 it was supposed that the Upper or Tremadoc group was a comparatively local formation, and not found out of North Wales. In that year, however, I was able to announce the discovery at St. David's of a large series of fossils nearly all new, but more nearly allied to those in this group than to any others known. Since then this group has been found at Shineton, in Shropshire, by Dr. Callaway, and many new species have been added by him to those previously known. He believes that the Shineton beds are chiefly of Lower Tremadoc age, or perhaps passage-beds between the Lingula flags and the Lower Tremadoc. He thinks also that he has detected the same beds at the base of the escarpment of the Stiper-stones, dipping under the Arenig series, and compares the sections and fossils to those worked out many years ago by Dr. Holl at Malvern. Prof. Hughes has also discovered rocks of

Tremadoc age in Anglesea, where they were previously unknown. He finds in these rocks fossils more characteristic of the St. David's Tremadoc rocks than of those of the immediate neighbourhood of Portmadoc. One of these fossils, however, *Neseu-retus*, was also discovered some years ago by Prof. Hughes, Mr. Tawney, and myself, in a slate quarry between the Rivals and Pwllheli in the Llein Promontory of Caernarvonshire. The genus *Olenus* seems to occupy the position in the Upper Cambrian rocks which *Paradoxides* holds in the Lower. The most important of the new types which are found in the Upper Cambrian rocks are Phyllopods, Heteropods, Cephalopods, Lamellibranchs, Crinoids, Asteroids, and Graptolites, but several of these are found only in the Tremadoc group. The Tremadoc group, therefore, may be said, through many of its types of fossils, to link the Cambrian and the overlying Ordovian (Lower Silurian) formations together, whilst it yet marks very distinctly the horizon at which all the truly characteristic types in the primordial faunas are lost. Mr. Salter, in referring to these rocks in North Wales, in the Appendix to Prof. Ramsay's "Memoir," p. 250-251, says that this band (the Tremadoc Slates) "intimately connects the *Lingula* flags with the ordinary Silurian rocks," but "is nevertheless so distinct as to its fossil character from either." Again, "if we were to judge of mineral character alone, we should undoubtedly draw the chief line of separation above the hard arenaceous *Lingula* flags when the peculiar bivalves characteristic of that fauna become scarce enough. Yet the zoological change does not take place here, for with the recurrence of the black band the characteristic genera of the primordial zone return unmixed with those of Lower Silurian character. The black slates do not terminate abruptly, but gradually lose their deep tint, and become grey about the horizon of the flags which contain the *Dictyonema*. The character continues and increases upwards through the beds, which contain the following (Tremadoc) fauna. The beds are also harder, contain flaggy layers here and there, but are not at all common nor otherwise much different from those of the black slab series, except in colour and fossil contents."

At St. David's the Tremadoc rocks rest conformably in good coast sections on the *Lingula* flags, which contain here the usual fossil *Lingulella Davisii* in great abundance. They change gradually also

from the Lingula flags, first as bluish-grey slate and then into an earthy grey thick-bedded rock of peculiar tough texture, with some sandstone courses. As compared with the beds on the same horizon in North Wales, they would appear to have been on the whole deposited in shallower water. This probably accounts for some of the differences noticeable in the faunas in the two areas. The differences, however, are not such as would indicate the presence of a physical break at this point in either of the areas at the time. I am inclined to think that the rate of depression up to this point was tolerably even, but that a great and rather sudden change took place towards the close of the Tremadoc epoch, and that in consequence new conditions prevailed. I have entered rather fully into this question as it seems necessary to explain the reason why this line was adopted by the late Mr. Salter and myself to mark the division between Cambrian and Silurian as then known—now between Cambrian and Ordovician.

Ordovician.

This name * (or rather, its more lengthy equivalent, Ordovician) was given by Prof. C. Lapworth in 1879 to the groups classed by the late Sir C. Lyell, Mr. Salter, and myself, under the name Lower Silurian. The term is derived from the *Ordovices*,* a tribe which inhabited a large portion of North Wales during the time that the *Silures* and *Dimetæ* occupied other portions of Wales. The term is peculiarly appropriate also, as the tribe undoubtedly occupied the whole of the great Bala district where Sedgwick worked out the physical succession among a large portion of the rocks of this intermediate system.

Neither Murchison nor Sedgwick, however, could fairly lay claim to this formation as a whole. Sedgwick undoubtedly recognised the true position of the Arenig and Bala groups, but he included in these the Llandeilo rocks which Murchison had already explored and claimed as members of his system in South Wales and Shropshire. Both may be said to have done excellent work in these groups, while on the other hand, as stated by Lapworth, it cannot be denied that the work of both appears, "to our eyes, in the light of later discoveries, to have been more or less inaccurate or deficient." Moreover, "time has already done justice to the

* See "Geol. Mag.," Jan., 1879, p. 13.

value of the discoveries of both Murchison and Sedgwick by assigning them each a system in which their labours were accurate and complete." *

There can be no doubt also, as stated by Lapworth, "that the present needs of our science demand, with a unanimous voice that partizanship can no longer silence a distinct title for the rocks of the *Second Fauna*. The experiment of naming them in such a way as to recognise the claims of both Murchison and Sedgwick has been tried again and again with the same result. It has invariably ended in prolonging and greatly intensifying the original controversy." It is to be hoped, however, that ere long both parties will see the necessity of dividing the Lower Palæozoic Rocks into the three systems here defined, which are acknowledged to be characterised by three great and distinct faunas, and to be partially also marked off by physical boundaries. The controversies which have taken place have undoubtedly tended hitherto to prevent researches being carried on with that freedom which is necessary to scientific progress. The Sedgwickian and the Murchisonian schools may each feel at first that the sacrifice is great; still I am convinced that in the end the better feeling that will be produced, and the increased stimulus to research which it will give, will amply compensate them for it.

In papers published in 1872 and 1875, after examining several areas of the Tremadoc and Arenig rocks in North Wales, with Mr. Homfray and others, I ventured to propose that the boundary line between what we then recognised as Upper Cambrian and Lower Silurian should be slightly altered, as I found that the so-called Upper Tremadoc rocks in some places were identical with those called Arenig in other areas. The line which I then proposed is that which is here recognised as the actual boundary between Cambrian and Ordovician.

The Ordovician contains four distinct groups. Three of these are the well-known groups Arenig, Llandeilo, and Bala. I have, however, recently † interpolated a new group between the Arenig and Llandeilo under the name Llanvirn. I did so mainly at the suggestion of Prof. Lapworth, and because the fossil remains in these beds at a place called Llanvirn, near St. David's, are so distinct

* See "Geol. Mag.," Jan., 1879, p. 12.

† "Popular Science Review," October, 1881, p. 14.

from those found in the beds above and below that it seemed advisable they should be placed in a separate group. This group has an average thickness of about 2,000 feet. Most of the species found in it are new. The fauna which I worked out from the beds at Llanvirn, St. David's, in 1874 and previous years, is very rich in trilobites, and several genera appear here for the first time in the succession, as *Illænus*, *Illænopsis*, *Barrandeia*, *Phacops*, *Placoparia*, and *Acidaspis*. The fauna also contains many graptolites, chiefly of the genera *Diplograptus* and *Didymograptus*, and there are also large Cephalopods, Gasteropods, Brachiopods, and Lamellibranchs. The lower portion of the so-called Llandeilo at Aberiddy Bay belongs rather to this group than to the typical Llandeilo, and is now included in this group.

At present the fauna of this group has been chiefly worked out at St. David's, but beds holding an equivalent position in the succession have been explored by Mr. Marr, near Caernarvon,* with much success. In an appendix to his paper,† published 1876, I ventured to correlate the beds with the Llanvirn rocks of St. David's, then known as Upper Arenig, and at the same time said that in "some respects the fauna would indicate a position intermediate between the Upper Arenig and Lower Llandeilo, a passage from the one into the other." There can be no doubt that these rocks will now have to be included in the Llanvirn group. Rocks on the same horizon were recognised years ago by Mr. Hopkinson and Prof. Lapworth, near Shelve; and I am informed by Dr. Callaway that he has also discovered some of the more typical fossils of the group, as *Placoparia*, &c., in rocks in that area.

By referring to Mr. Morton's interesting paper on the Shelve rocks,‡ it is clear that his list also contains some fossils belonging to this group. Prof. Lapworth, in a letter to me (Nov. 25th, 1881), says "that *Didymograptus Murchisoni* in its typical form is characteristic of the Llanvirn (Upper Group), but forms very like it range down into the Arenig below. The *D. Murchisoni* Zone (Upper Llanvirn) is beautifully developed at Shelve, as well as in the Carneddau Hills near Builth, and close to the town of

* "Quart. Journ. Geol. Soc.," vol. xxxii., p. 134.

† *Ibid.*, p. 136.

‡ "Proceed. Geol. Soc.," Liverpool, 1868-1869.

Llandeilo. I have examined it in all these localities." Rocks on this horizon have also been recently explored by Prof. Hughes with much success on the north coast of Anglesea.

The underlying or true Arenig rocks have yielded to our researches at St. David's a new and important fauna of Graptolites, and these have been carefully described by Messrs. Hopkinson and Lapworth. To these authors also we owe the recognition of many of these forms in equivalent rocks at Shelve.

The so-called Skiddaw slates, so well known through the researches of Messrs. Harkness and Nicholson, are chiefly on the horizon of the Arenig rocks, but in part also are the equivalents of our Llanvirn group.

The two upper groups, Llandeilo, and Bala, have not of late years been much worked in Wales, though in other areas very many important additions to our knowledge of them have been made. Of these I would especially call attention to the remarkable researches of Prof. C. Lapworth in the Southern Highlands of Scotland, which have been published in the "Quart. Journ. Geol. Soc.,"* and elsewhere. Previous to his researches there was much confusion as to the proper succession of the rocks in this area, and as to their representatives elsewhere. His discoveries, however, have now enabled him "to propose a new theory of the succession which is in consonance both with the stratigraphical and palæontographical evidences, and brings the South Scottish Silurians into perfect harmony with those of other countries. The district which has yielded the most conclusive proofs of the true sequence lies in the neighbourhood of Moffat. At the head of Moffatdale a deep gorge known as Dobb's Linn affords a magnificent section of the black graptolite shales." He has shown that the black shales of this spot are arranged in an anticlinal form, and come out conformably from below the greywackes of the district. "These black shales fall into the three natural divisions denominated the Glenkiln, Hartfell, and Birkhill shales. Each of these three divisions contains a special graptolite fauna of its own, and breaks up again into many subordinate zones individualized by special mineralogical and palæontological distinctions."† In Ireland the valuable researches of Mr.

* Vol. xxxiv.

† "Trans. Geol. Soc.," Glasgow, p. 80, April, 1878.

Swanston, F.G.S., have shown, according to Lapworth,* that the black shales of County Down, though excessively contorted and shattered, exhibit a general grouping similar to, if not identical with, that of the Moffat Series in Scotland, the Glenkiln (Llandeilo), Hartfell (Bala), and the Birkhill (Lower Llandovery) being all represented there.

The Bala (or Caradoc) rocks of the Girvan district and their fossils have also been described in elaborate memoirs by Prof. Nicholson and Mr. R. Etheridge, Jun. The additions to the fauna of the Caradoc contained in these memoirs are highly important. Though, as already stated, the Welsh Llandeilo and Bala groups have not furnished of late many new forms, and have not been worked with much zeal, yet the information given in Prof. Ramsay's memoir, and especially in the Appendix by Mr. Salter, in 1866, shows clearly that they had, up to that time, received an unusual amount of attention, Sedgwick, Murchison, McCoy, Salter, and the officers of the Geological Survey, having all devoted much critical attention to them.

During the Ordovician period, volcanic eruptions, chiefly beneath the sea, were frequent, especially in the Welsh areas.

It is possible also, as suggested by Prof. Ramsay, that islands may have in consequence been formed, which sometimes raised their craters for various periods above the water. There is no evidence, however, that any portion of the crust itself was raised above sea level until towards the close of the Bala epoch.

Hence these rocks are made to form the upper boundary of the Ordovician. The physical break at this point, however, does not appear to have extended over all the British area. The evidence of it is very marked in the more central portions of Wales, but less so as we travel to the north-east into Denbighshire, or to the south-west into Cardiganshire and Pembrokeshire.

Silurian.

This name, as all know, was given by the late Sir R. Murchison to the fossiliferous rocks in Shropshire, which lie immediately below the Old Red Sandstone, and amongst which he had been working assiduously for years, with great success. The term was

* "Proceed. Belfast Naturalists' Field Club." Appendix, 1876-1877, p. 125.

afterwards, as already stated, extended from time to time by him and his followers, in a downward direction, to include rocks in all areas in which fossils were found, and it was with no little surprise that I noticed in the Appendix to "Siluria," 1867, p. 550, in a paragraph referring to a discovery I had just then made at St. David's, an attempt to carry this downward extension to a most unwarrantable extent by using the term "Primordial Silurian." It has been quite clear, for years, to those who have been working among these old rocks, that the term ultimately would have to be limited to the rocks concerning which there could be no controversy, and where his work is acknowledged to have been complete as far as was possible at the time. The upward limit has remained tolerably correct from the first.

The groups which we include, therefore, at present in the Silurian from below upwards, are the Llandovery, Wenlock, and Ludlow.

The lowest deposits in this system, as was pointed out to have been the case at the base of the Cambrian, in consequence of the presence of land areas, vary in thickness as we approach to or are distant from those areas. The Llandovery group, in Pembrokeshire, and, as has been recently shown by Mr. Keeping,* in Cardiganshire, attains to a great thickness. In these areas also the Lower Llandovery rocks appear to rest quite conformably on the Bala beds. On the other hand, the evidence that a physical change was taking place in other parts of the Welsh and some adjoining areas at this time is most marked. The lower beds are entirely absent in the Longmynd and other Shropshire areas, and the whole group, which I believe cannot be much less than two thousand feet in thickness in Pembrokeshire, and is also of great thickness in Cardiganshire, as proved by the very important researches of Mr. Keeping, is represented in the Shropshire areas by about 100 feet of conglomerates and sandstones.

In Denbighshire, where they have been explored by Prof. Hughes, Mr. Marr, Mr. Ruddy and myself, only a moderate thickness of the beds occurs. I have in previous papers attempted to show that there was no actual evidence of an unconformity between the Bala and the Lower Llandovery rocks about Corwen, in Merionethshire, or in Denbighshire.

* "Quart. Journ. Geol. Soc.," May, 1881.

I believe that this area, like that in the south-west, was under water during the time that other Welsh areas were above water, and that it also received sediments during the time that the majority of the Lower and Upper Llandovery rocks of South Wales were being deposited. As the typical fossils of the Upper Llandovery rocks of South Wales and of May Hill have not been discovered in Denbighshire, it is rather difficult to correlate the beds correctly with those of the south, but I am inclined to believe that at least the lower portion of the so-called Denbighshire grit series, with the so-called Tarannon shales, will have to be placed on that horizon, or at least entirely below the true Wenlock beds of Shropshire. I have just heard from Prof. Lapworth, however, that he has found graptolites characteristic of the Middle and Lower Llandovery rocks, as known in Scotland, in the beds near Corwen and elsewhere, immediately underlying the Tarannon shales. In his letter to me (Nov. 25th) he says that he feels "quite confident that the lower, middle, and upper Llandovery are all present in North Wales, but in a greatly attenuated form—that the Tarannon is grandly developed, that the Penyglog beds are the equivalents of the Pencerrig beds of Builth with *Cyrtograptus Murchisoni*, which are there mapped as the base of the Wenlock, and that the Denbigh Grits, therefore, are in the so-called Wenlock shale of South Wales as mapped by Murchison and his successors." Before the true May Hill beds of Sedgwick can be properly correlated with these beds, further researches, it seems to me, are still necessary.

The labours bestowed, of late years, upon the Llandovery rocks by Lapworth in Scotland, by Hughes and Maw in Wales, and in the lake district by Harkness and Nicholson, also in the last-mentioned area, and by Keeping in Central and West Wales, have already removed most of the difficulties connected with these rocks which have baffled the attempts made to correlate them in different areas. Doubtless these difficulties were in great part due to the fact that an important physical change had taken place just before these sediments were deposited, and that they therefore varied in their mineral character in different areas, and that the fauna also was more or less affected by these local physical conditions. The evidence of these land areas in parts of Wales is made clear also by the fact, which I recently made known, that undoubted remains of land plants occur in

TABLE OF BRITISH Eozoic and Lower Palæozoic Strata (1881).

PERIOD.	SYSTEMS OR FORMATIONS.	GROUPS.	PETROLOGICAL CHARACTERS.	CHARACTERISTIC TYPES AND ORDER OF APPEARANCE OF LIFE.	LOCALITIES WHERE EXPOSED.
PALÆOZOIC (LOWER).	SILURIAN.	Ludlow ...	Grits, Sandstones, Shales, and Limestone	Pisces	Ludlow, Ledbury, Downton, Kingston, Lesmahago, Whitcliffe, Malvern, Longhope, Aymestry, View Edge, &c.
		Wenlock ...	Shales and Limestone		Wenlock Edge, Dudley, May Hill, Malvern, Llangollen, &c.
		Llandovery	Conglomerates, Sandstones, Slates, and Shales	Plantæ (land plants)	Llandovery, Haverfordwest, May Hill, Corwen, Tarannon, Birkhill, Girvan, &c.
	ORDOVICIAN.	Bala ...	Sandstones, Flags, Shales, and Limestone		Bala, Caradoc Ridge, Horderly, Norbury, Snowdon, Haverfordwest, Wexford, Kildare, Hartfell.
		Llandeilo...	Calcareous Shales, Flags, and Sandstones	Actinozoa	Dumfriesshire, Llandeilo, Builth, Abereddy Bay, &c.
		Llanvirn ...	Grey Flags and Black Slates		Llanvirn and Coast of Abereddy Bay, Ramsey Island, Shelve, Builth, Caernarvon, &c.
		Arenig ...	Slates, Flags, and Sandstones	Gasteropoda	Arenig, Shelve, Ramsey Island and Whitesand Bay (St. David's), Skiddaw (Cumberland).
	CAMBRIAN (UPPER).	Tremadoc	Dark Slates and Flaggy Sandstones	Hydrozoa (<i>Graptolites</i>). Lamellibranchiata and Cephalopoda	Portmadoc, Ramsey Island and Whitesand Bay (St. David's), Shinetun (Shropshire).
		Dolgelly ...	Soft Black Slates and Shales	Bryozoa (<i>Dictyonema</i>)... ..	Portmadoc, Dolgelly, Malvern, Whitesand Bay, &c.
		Ffestiniog	Grey Arenaceous and Micaceous Flags	Heteropoda, Plantæ (marine-plants)	Maentwrog, Dolgelly, Malvern, Ramsey Island, Solva.
		Maentwrog	Slates, Flags, and Sandstones	Crustacea (<i>Phyllopoda</i>)	Maentwrog, Dolgelly, Solva.
	CAMBRIAN (LOWER).	Menevian...	Dark Slates and Flags	Echinodermata (<i>Cystidea</i>)	St. David's, Solva, Maentwrog, Dolgelly.
		Solva ...	Purple, Red, and Grey Grits, Flags, and Slates	Pteropoda	Solva, St. David's, Harlech Mountains, Longmynd Range, Bray Head, &c.
		Caerfai ...	Purple, Green, and Red Sandstones and Slates, Conglomerates	Crustacea (<i>Ostracoda</i> , <i>Trilobita</i>)	St. David's, Whitesand Bay, Bangor, Llanberis, &c.
	PRESIDIAN.	Treginnis	Conglomerates, Breccias, Schists, and Slates. Contemporaneous Lava Flows and Volcanic Ashes. Limestones and Serpentine	Brachiopoda, Protozoa, Annelida, Plantæ?	St. David's, Anglesey, Caernarvonshire, and Harlech Mountains in Wales. Fort William and Grampians in Scotland. Lough Foyle, and in South-West of Ireland. Charnwood Forest, Wrekin, Malvern, &c.
		Menai ...	Breccias, Chloritic, Talcose, Felspathic, and Micaceous Schistose Rocks. Limestones and Serpentine	Annelida?	St. David's, Anglesey, and Llyn Promontory, Caernarvonshire. Grampians in Scotland.
EOZOIC.	ARVONIAN.	Holyhead...	Schistose and Compact Quartz Rocks		Llanhowell, near St. David's, and Holyhead Mountain in Anglesey.
		Treffgarn...	Breccias, Hälleflintas, and Quartz Felsites		Treffgarn Mountain, Roch Castle and near St. David's in Pembrokeshire, Bodafon Mountain and Ty Croes in Anglesey, and several ridges in Caernarvonshire.
	DIMEFIAN.	Porthlisky	Highly Quartzose Gneissic Rocks, with Limestone Bands		Porthclais and Porthlisky near St. David's, Anglesey, and North-western Highlands of Scotland.
		Bryn-y-garn	Granitoid and Gneissic Rocks. Usually of a white, light grey, greenish, or pinkish colour		St. David's and Brawdy in Pembrokeshire, Twt Hill, and Rhos Hirwain, Caernarvonshire, Anglesey, and North-western Highlands of Scotland.
	LEWISIAN.		Massive Hornblendic Gneiss. Of a black, dark grey or rusty colour		The Hebrides and North-west Coast of Scotland, North-west of Ireland, and Malvern Hills in England.

abundance in the Penyglog slate quarry at the base of the Denbigh Grit series near Corwen, North Wales. The specimens found are all in a fragmentary condition, showing that they must have drifted into their present positions from some neighbouring land.

By the time the Wenlock rocks were deposited, most of the land had again been submerged, and the sediments are such as would accumulate in a quiet and moderately deep sea.

The most important researches of late years connected with the Wenlock and Ludlow groups are those of Prof. Lapworth and Mr. Hopkinson among the Graptolites, Messrs. Davidson and Maw among the Brachiopoda, Dr. Woodward on the Eurypterida, Prof. Rupert Jones on the Ostracoda, and Mr. Vine on the Polyzoa. In the admirable paper by Prof. Sollas* on the Silurian rocks near Cardiff, many facts of great importance are also given.

The important discovery of fish remains in the Ludlow made many years ago, chiefly by Sir R. Murchison, is still, as far as I am aware, the earliest indication of vertebrate life in the Silurian Rocks. It is to be hoped, however, that further researches will reveal the presence of still earlier forms, both marine and fresh-water. My recent researches among the beds containing the land plants near Corwen have raised these hopes, for it is well known that up to the time of this discovery the earliest land plants found in Britain were fragments and supposed spores found in association with the vertebrate remains in the Ludlow rocks.

The subjoined Table shows the succession of the strata up to this point as at present recognised in Britain.

* "Quart. Journ. Geol. Soc.," May, 1881.