

# THE CLASSIFICATION OF THE EOZOIC AND LOWER PALÆOZOIC ROCKS OF THE BRITISH ISLES.

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[PLATES VII. AND VIII.]

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THE additions which have been made to our knowledge in regard to the history and classification of the older rocks in Great Britain of late years have been very numerous, and yet but few attempts have been made to array them in systematic order, so that their importance may be readily recognized. The most elaborate account recently placed before the Geological world is the address of the President of the Geological Society (R. Etheridge, Esq., F.R.S.), published in the May number of the *Quarterly Journal*. An admirable paper, also, on a portion of these rocks, by Professor C. Lapworth, F.G.S., appeared in the June and July numbers of the *Geological Magazine* for this year.\* In the present paper I propose to give a brief connected statement of the present state of our knowledge of these rocks, and the classification which appears to me the most natural one. Some new names will, of necessity, have to be added to explain local subdivisions, but in regard to the larger formations the terms which have been generally used in my papers of late years appear at present to be sufficient to include all the rocks explored.

## PART I.

### EOZOIC (PRE-CAMBRIAN).

For the sake of uniformity in the names for the larger periods in geological chronology, I adopt here the term which

\* See also papers by the Author, *Quart. Journ. Geol. Soc.* vols. xxxi., xxxiii., xxxiv., and xxxv.; *Proceedings Geol. Assoc.* vols. iii. and vii.; and *Geol. Mag.* Decade II. vols. iii. and vi.

has been used for some time by American authors for the rocks known under the several names of Pre-Cambrian, Archæan, or Primary. Possibly none of the names hitherto suggested can remain in the face of future discoveries; but as long as the term *Palæozoic* continues to be so universally used for the succeeding period, the term *Eozoic* is probably the best that can at present be applied to this more ancient one.

The Eozoic rocks in Britain have of late years received a considerable amount of attention, and much additional information concerning them has in consequence been obtained. Up to a recent period it was supposed that with the exception of a narrow strip along the north-west coast of Scotland and in the Hebrides, there was no satisfactory evidence of the presence of these primary rocks anywhere in Britain. Stratified crystalline rocks had been noticed in other areas, but these were almost universally placed among much more recent deposits, either on theoretical grounds or by misconceptions in stratigraphy. With the exception of careful stratigraphical work nothing has tended so much of late to advance our knowledge in regard to these early rocks, as the recognition of the fact that the metamorphism of great groups of strata does not take place so readily as was formerly supposed, and that it is now tolerably clear that some special conditions, such as do not appear to have prevailed to any great extent over the British areas since the Pre-Cambrian (Eozoic) period, were necessary to produce such results. The unravelling of the history of these primitive rocks is fraught with many difficulties, and in the absence of organic remains the correlation of the groups in different areas is seldom as satisfactory as could be desired. But that there are special characters present which tend to distinguish each important group over wide areas there can be no doubt; and when we look closely into these, and at the same time take note of any influence which local physical conditions may have exerted, we can generally arrive at a tolerably satisfactory correlation.

We now divide the Eozoic rocks which are exposed in the British areas into four distinct formations under the names of Lewisian, Dimetian, Arvonian, and Pebidian.

### 1. *Lewisian*.

The oldest stratified rocks apparently in this country are some gneiss rocks, found chiefly in the Hebrides and along the north-west coast of Scotland, also probably along the north-west coast of Ireland, and perhaps in the Malvern Hills in England. Many years ago Sir R. Murchison expressed the opinion that these gneiss rocks along the north-west coast of

Scotland were the oldest in Great Britain, and, as far as we know at present, this view seems to be correct. He at first associated them with the Laurentian rocks of Canada; but though this correlation is possibly correct, he yet wisely grouped them under the local name Lewisian, after the island of Lewis, where they are largely developed. Dr. Sterry Hunt and myself have at different times pointed out the presence of these rocks in Ireland, and Dr. Holl has done the same in the Malvern Hills. The special characters which distinguish this group may be said to be the prevalence of very highly crystalline rocks, usually massive granitic gneisses, with red felspar and hornblende as their chief minerals, and quartz and mica in small proportion only. The normal strike is about east and west, but it varies to north-west and south-east.

Though but little additional information in regard to these rocks has been recently obtained, we are now better able, in consequence of the very important discoveries made of late years in other Eozoic rocks of Britain, to realize their importance in the classification, as well as the value of the formation in relation to the early history of these islands.

## 2. *Dimetian.*

This formation, like the above mentioned, consists chiefly of highly crystalline gneissic rocks, the prevailing types, however, being the so-called granitoid rocks, made up largely of quartz with some pinkish or white felspar. Hornblende is much less abundant than in the Lewisian rocks, but mica is more frequently met with. It may be said to consist chiefly of acid types of rocks, whilst the former is made up mainly of basic types. Bands of limestone, hornblende, chloritic, and micaceous schists occur occasionally in this formation.

The name Dimetian was first given by me to the group of granitoid and gneissic rocks which had been discovered by the late Mr. Salter and myself, underlying the Cambrian rocks at St. David's, in Pembrokeshire. Since then many additional areas of these rocks have been found, and the formation has been shown to consist of several important groups. In each area certain general resemblances in mineral characters are found to prevail, and these, combined with the physical evidences of contemporaneous deposition, are all the aids we can expect to find in our attempt at correlating such ancient rocks in different areas. That such evidences are important also is clear if we recognize the fact that the rocks must have been for the most part deposited in successive layers of various materials, like the alternating sediments in more recent groups, and in each case under tolerably similar physical conditions; that they also must have suffered changes in propor-

tion to their age, and that the evidences of these changes, which could not have affected more recent deposits, are usually sufficiently well marked to be readily recognized.

I have described rocks belonging to this formation in Anglesey, Caernarvonshire, and many parts of Scotland; and Prof. Bonney and Dr. Callaway have noticed them in Shropshire.

The series may be advantageously divided into Upper and Lower groups: the Upper represented by the so-called quartz schists of Porthlisky, St. David's, and probably by the thin quartzose gneisses and mica schists of Gairloch and Ben Fyn, Scotland; and the Lower, by the massive granitoid and gneissic rocks of Bryn-y-Garn, St. David's, and Twt Hill, Caernarvon, and probably also of parts of Ben Fyn and the mountains at the head of Loch Shiel in Scotland. I propose for the groups the local names Porthlisky and Bryn-y-Garn.

The prevailing strike in the formation is from N. W. to S. E.

### 3. *Arvonian.*

This name was given by me in 1878 to a group of rocks, in some important particulars unlike the Dimetian, though up to that time it had been included in that formation. Subsequent researches in North and South Wales have revealed the fact that this is one of the most important of the Pre-Cambrian formations. In Pembrokeshire it occupies large areas (see Sect. 2 and 3, p. 20), and is there found to consist mainly of highly siliceous rocks, of the type called by the Swedish geologists 'hällefrinta.' Breccias, quartz-felsites, and other quartzo-felspathic rocks, also enter largely into its composition. In Caernarvonshire, as I have shown in previous papers, many important ridges, such as the Rivals, and those to the north and south of Llyn Padarn, and between Twt Hill, Caernarvon, and Bangor, consist almost entirely of rocks belonging to this formation. In Anglesey, I pointed out in 1878 an area of these rocks near Ty Croes. This I have since found, in company with Prof. Hughes, to extend much further to the north than I at first supposed, in fact as far as Bodafon Mountain. At the latter place the 'hällefrintas' are perhaps better exposed, and more nearly of the type of those in Pembrokeshire, than in any other place in North Wales.\* In my former paper I mentioned, in describing the Pebidian rocks of the west coast of Anglesey, that 'possibly some, such as the rocks of Holyhead Mountain may prove to be of different age and probably older

\* Since I examined these rocks with Prof. Hughes, Prof. Bonney, in an appendix to an interesting paper by Dr. Callaway (*Quart. Journ. Geol. Soc.*, May 1881), has published some notes on these rocks which seem to confirm the above view. They are, however, called by him 'Quartz-schists.' In Dr. Callaway's map much too small an area is given to these rocks.

(Dimetian?)' I have since then carefully re-examined these rocks, and have come to the conclusion that they should be included rather with the Arvonian. Whether they occupy a higher or a lower, or an equivalent position to those of Bodafon Mountain, it is difficult at present to decide. Still the evidence seems to point to the quartz group at Holyhead being the highest. At St. David's, rocks like those of Holyhead exposed near Llanhowel are, I believe, higher in the succession than the more typical 'hällefintas' of Treffgarn Rock. The strike is usually somewhere near north and south. This formation may be divided into two groups under the names of Treffgarn and Holyhead.

#### 4. *Pebidian.*

This is a formation undoubtedly of enormous thickness, as may be seen from its partial exposure at St. David's (Sect. 1, p. 20), and contains several groups of rocks, in some respects considerably unlike each other. At present, however, it may be sufficient to divide the formation into two main groups. The lower one consists of the thin-bedded gneissic, micaceous, and talcose rocks; and the higher, of the brecciated rocks with their associated schists and slates. At St. David's the lower group is either but partially exposed or cut off by a fault. Some of the beds may be seen at Porthlisky Harbour resting unconformably upon the Dimetian axis. These are rather highly felspathic; others are the so-called talcose rocks, found frequently at this horizon in Canada, and described by Dr. Sterry Hunt as the 'commonly called talcose or nacreous schists, owing their peculiar characters to a soft, hydrous mica, which is not unfrequently disseminated in very quartzose beds and gives to such a schistose character.' Exactly similar rocks to these at Porthlisky occur at Dulas Bay, on the north coast of Anglesey; and I believe it will be found that they occupy a low position in relation to the chlorite-schists so well developed in that island. That the chlorite-schists in Anglesey, with a general north-east and south-west strike, belong to a period in the history of the globe not far removed from that indicated by the Lower Pebidian rocks of St. David's, I feel convinced. The deposits are sufficiently alike in material and in the changes they have undergone to be correlated. That they should now appear to be rather too much altered for this period, is probably due to the readiness of the chief materials entering into their composition to undergo change as compared with those in many of the other rocks. The view put forward by Sterry Hunt and Delesse, that 'talcose and chloritic rocks have been directly formed from the molecular re-arrangement or *diagenesis* of aqueous magnesian sediments,' seems to be the correct one, and to be capable of explaining many of the ap-

parent difficulties in connexion with these old rocks. That some of these chlorite and talc schists occur at various other horizons in the Pebidian, alternating with clay slates, quartz rocks, breccias, and conglomerates, is beyond doubt; and I may mention as spots where these alternations may be well observed, the valley of St. David's, north of the Cathedral, Treginnis, near St. David's, where they occur, as in Anglesey, in association with serpentinous limestone, and Amlwch in Anglesey. It is certain, therefore, that though the larger portion of the Anglesey schists may belong to the lower group of the Pebidian, they are not restricted to that horizon. This partial metamorphism, visible chiefly in rocks most susceptible of change, is highly characteristic of the Pebidian formation wherever it is exposed in Britain. It is sufficiently marked to separate the formation clearly from the succeeding Cambrian; and, on the other hand, it is too imperfect to cause any confusion between the majority of the rocks in this formation and the more completely crystalline groups belonging to the Dimetian or Lewisian.

The upper group is largely made up of brecciated rocks alternating with purplish, reddish, and greenish slates and schistose rocks. Indurated volcanic ashes, lava-flows, and bands of limestone and serpentine occur in both. It may be well to designate these groups by local names, and I propose therefore to call the upper the Treginnis group from being largely exposed at that place, on the shore of Ramsey Sound, near St. David's; and the lower, the Menai group, after the Menai Straits, where they are well displayed. The prevalent strike in this formation is from north-east to south-west.

This formation occurs in many parts of Scotland, especially in the Grampians; and it is also found, according to Dr. Hunt, in the north-west of Ireland, about Lough Foyle. It occurs also in Charnwood Forest, in Shropshire, in the Malvern Hills, and probably also in Cumberland and in Cornwall. The following table will explain the supposed order in which the Eozoic rocks occur in this country:—

PERIOD.	SYSTEMS OR FORMATIONS.	GROUPS.	CHIEF PETROLOGICAL CHARACTERS.	CHIEF LOCALITIES WHERE EXPOSED.
EOZOIC.	PEBIDIAN.	Treginnis	Conglomerates, Breccias, Schists, and Slates. Contemporaneous Lava Flows and Volcanic Ashes. Limestones and Serpentine.	St. David's, Anglesey, Caernarvonshire, and Harlech Mountains in Wales. Fort William and Grampians in Scotland. Lough Foyle, Ireland. Charnwood Forest, Wrek-in, Malvern, &c.
		Menai	Breccias, Chloritic, Talcose, Felspathic, and Micaceous Schistose Rocks. Limestones and Serpentine.	St. David's, Anglesey, and Lleyn Promontory, Caernarvonshire. Grampians in Scotland.
	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.
	DIRETTAN.	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 Hornblende Gneiss, with but little Quartz or Mica. 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.

## PART II.

## LOWER PALÆOZOIC.

It is not intended to burden this paper with a long history of the various classifications which have been adopted for these rocks from time to time; for classifications must necessarily vary with advancement of knowledge. All hard and fast lines, or the slavish adherence to any arrangement founded only in history and not in truth, are here, as in all other matters, barriers to progress. Numerous papers, however, on the question of history have of late been published, to which the reader may refer.\*

The nomenclature will of necessity in some cases have chiefly a local significance, but as many of the groups have been at present little more than locally examined, this is almost unavoidable. Many of the names, however, are somewhat historical in their application, and have been so frequently used that they are now tolerably well known. The formations to be described are the Cambrian, Ordovian, and Silurian.

1. *Cambrian.*

Wherever these rocks are found in this country in contact with the Eozoic formations, they are unconformable to the latter. Fragments of the older rocks are also found in them in abundance, and evidence that they must have been built up chiefly from the denudation of the Eozoic rocks is everywhere apparent.

The name Cambrian, for these oldest Palæozoic rocks, was first used by Prof. Sedgwick, and it was he who laid the foundation for all future discoveries in these rocks. It is impossible to speak too highly of the value of his researches amongst these at that time barren strata; and if we cannot at present accept fully the divisions, or subdivisions, which he proposed, we reject them with much regret, and because their retention would greatly tend to retard the progress of science.

This formation may with advantage be divided into two main portions, with several groups in each.

The *Lower Cambrian* has a natural base made up of massive conglomerates and sandstones (see Sect. 1, p. 308); its upper boundary is well defined by an important palæontological break. It is

\* See Hunt, *Canadian Naturalist*, 1872, and *Geol. Essays*, 1878; Etheridge, *Quart. Journ. Geol. Soc.* May, 1881; Marr, *Geol. Mag.* June 1881; Lapworth, *Geol. Mag.* June and July, 1881; and Hicks, *Proceedings Geol. Assoc.* 1873, *Quart. Journ. Geol. Soc.* 1875, and *Geol. Mag.* 1876.

clearly divisible—at St. David's, where it has been chiefly explored of late years—into three groups. These are called in ascending order by the local names of Caerfai, Solva, and Menevian (*c, d, e*, in Sections and Plates).

The *Caerfai group* consists chiefly of conglomerates, sandstones, and red, purple, and green slates and shales. Remains of animal life are found throughout. The most important of these were discovered by me, in 1868, in red slates, near the base, and consist of a *Lingulella*, *Discina*, *Leperditia*, a doubtful head of a trilobite, and abundant traces of annelids.

Beds of the same age are also found in the Harlech Mountains. The great slate quarries of Llanberis, Bethesda, and other places in Caernarvonshire, are also on this horizon. Though the basal beds are not exposed in the Longmynd area, it is probable also that some belonging to this group occur there. There is a strong general resemblance between the beds of this group in each of the areas, but as they were at first shore-deposits around a subsiding land-area, some differences in appearance and in thickness must necessarily occur. The great conglomerates which rest on the Eozoic rocks along the north-west coast of Scotland, are supposed to be of Lower Cambrian age, and may possibly be to some extent contemporaneous deposits with the beds of this lower group at St. David's. This group may be conveniently divided into three parts as under:—

CAERFAI GROUP.	{	Upper, 1000 ft.	} Purple Sandstones with <i>Annelids</i> , &c.
		Middle, 50 ft.	} Red Shales and Schists, with <i>Leperditia cambrensis</i> , <i>Lingulella primæva</i> , <i>Discina caerfaiensis</i> , &c.
		Lower, 520 ft.	} Conglomerates and Greenish Flaggy Sandstones with <i>Annelids</i> , <i>Fucoids</i> , &c.

*Solva group*.—Like the underlying Caerfai group, this may be also divided into three parts. The lowest beds are yellowish sandstones, with some conglomerates, and these are succeeded by grey flags. The latter contain an important fauna which I discovered in 1867. It consists of several trilobites, including the genera *Plutonia*, *Paradoxides*, *Conocoryphe*, and *Microdiscus*, also a *Lingulella*, *Theca*, and *Protospongia*. The species are all restricted to this horizon, and the genus *Plutonia* has not been discovered elsewhere as yet. The middle portion of this group consists of red, purple, and grey grits, sandstones, and slates; it is of great thickness, and probably contains several fossiliferous horizons. At present, though fragments have been found in several different beds, the only position in which they appear to occur in any abundance, is towards

the upper part of the series; here are found new species of *Paradoxides* and *Conocoryphe*, as well as fragments of several other fossils. Numerous markings are seen also on the surfaces of these and the underlying beds, similar to those described by Dr. Torell from Scandinavia, under the name of *Eophyton*. These were supposed by him to be land plants. Besides these numerous large so-called fucoidal markings are also frequently found. Whether any of these can be safely attributed to land or marine plants, must still be a matter of doubt, as no indications of true structure have been found in them. The upper beds of this group are grey grits and flags, and these also contain a special fauna. There can be no doubt that the Solva group represents the main portion of the Harlech-grit series as known in Merionethshire, and also probably of the Longmynd rocks. That there are some beds in those areas which may be considered contemporaneous with the Caerfai group, is, as I have already stated, probable; but I believe that the St. David's area was depressed at an earlier epoch than either of those, and therefore that it probably contains a series unrepresented there. I am inclined to think, however, that the lower beds of green grits and slates at Llanberis are nearly on the horizon of the Lower Caerfai rocks at St. David's. The rocks at Bray Head, in Ireland, appear to be more nearly contemporaneous with the Solva group than with the earlier beds. The St. David's fossils have not as yet been discovered in any of the other areas. Annelids and a doubtful trilobite, *Palaeopyge*, were, however, found years ago by Mr. Salter in the Longmynd rocks; and annelids and the curious fossil, *Oldhamia*, have been found in the Bray-Head rocks.

SOLVA GROUP.	{	Upper, 150 ft.	} Grey Rocks, with <i>Paradoxides aurora</i> .
		Middle, 1500 ft.	} Grey, purple, and red Rocks, with <i>Paradoxides solvensis</i> , <i>Conocoryphe solvensis</i> , &c.
		Lower, 150 ft.	} Yellowish Grits, Sandstones, and Flags with <i>Paradoxides Harknessii</i> , <i>Plutonia Sedgwickii</i> , and also <i>Eophyton</i> , large Fucoids, &c.

*Menevian group*.—This name was given by the late Mr. Salter and myself in 1865, to a series of beds found to contain a very important fauna new to this country at St. David's. Though there is a gradual passage from the beds of the Solva group into these (as shown in Sect. 1, p. 20, and in Pls. VII. and VIII.), in general appearance the rocks differ considerably from those in the other Lower Cambrian groups. This may be due to the combined influence of deeper water, and the presence of a greater abundance of animal and vegetable life; the

finer material to the former, and the dark colour to carbon and other substances derived from the latter. Though not of great thickness, the group is yet divisible into three well-marked zones, with distinct species in each. The genus *Paradoxides*, of which so many species occur in the Lower Cambrian rocks, does not in this country reach into higher beds than this group; and by it as well as by several other forms (*Anopolenus*, &c.) the Lower Cambrian is palæontologically well marked off from the Upper Cambrian. There is also an indication of some slight physical change at the close of the Menevian, in the sudden appearance of thick grit beds upon very fine muddy deposits. This is partially shown in the view (Pl. VII.) taken of the east side of Porth-y-rhaw, the place where the group was first made out. Whether this change had anything to do with the disappearance of *Paradoxides* and its allied genera or not, is difficult to make out. It was, at any rate, sufficiently important to have produced identical results in North Wales at the same time, for the upper beds are there, as in South Wales, capped by these massive sandstone beds. This group is everywhere distinct from, and should not be included in, the so-called Lower Lingula flags.\* The fauna belonging to this group consists of twenty-three genera, including fifty-two species, and nearly all the species are restricted to it; the range of many is limited to a few beds. This group has been discovered at several places in Merionethshire, and contains there most of the characteristic fossils found by us at St. David's. It is there seen to rest on the well-known Harlech grits, and to be succeeded by Lower Lingula flags.

MENEVIAN GROUP.	{	Upper, 100 ft.	}	Sandstones and Shales, with <i>Orthis Hicksii</i> , &c.
		Middle, 350 ft.		Flags and Slates, with <i>Paradoxides Davidis</i> , &c.
		Lower, 300 ft.		Grey Flags, with <i>Paradoxides Hicksii</i> , &c.

The views, Pls. VII., and VIII., figs. 1-3, show tolerably well the succession, and some of the chief sections of the Lower Cambrian rocks on the north shore of St. Bride's Bay, near St. David's.

The *Upper Cambrian* consists of four groups. The three lower ones were carefully described by the late Mr. Belt in 1867,† and named by him, in ascending order, Maentwrog, Ffestiniog, and Dolgelly groups (*f*, *g*, *h*, in sections and plates).

\* It was by mistake that Mr. Etheridge, in the admirable address already referred to, included *Paradoxides* and some other Menevian genera in the Lower and Upper Lingula flag faunas.

† *Geol. Mag.* 1867 and 1868.

These had been partially described previously by Sedgwick and Salter, as Lower, Middle, and Upper Lingula flags. The fourth, or highest, group, was named by Sedgwick, many years ago, 'Tremadoc,' and this name is still retained for that group.

*Maentwrog group* (Lower Lingula flags).—The lowest beds in this group are described by Mr. Belt as 'grey and yellowish grey, fine-grained pyritic flags, with hard felspathic bands and rusty partings.' Alternations of more arenaceous and gritty beds are not unfrequent, and beds of yellow-grey shale also occur; these are followed by bluish-grey slates and flags. The middle and upper beds also are chiefly flags and slates. At St. David's, the lower beds are thin, ribbony-looking, and much contorted; these are succeeded by dark iron-stained slates and bluish flags. The genus *Olenus* is the characteristic fossil in this group, and it and the Phyllopod crustacean *Hymenocaris* occur here for the first time. The group is divided into upper and lower series, as under:—

MAENTWROG GROUP.	{	Upper, 1800 ft.	} Slates and Flags, with <i>Olenus truncatus</i> and <i>Olenus cataractes</i> , &c.
		Lower, 700 ft.	} Sandy and Slaty Beds, with <i>Olenus gibbosus</i> , <i>Agnostus pisiformis</i> , &c.

*Efestiniog group* (Middle Lingula flags).—This is also divided into upper and lower portions. The lower consists of a series of slightly arenaceous and micaceous grey flags; these are succeeded by thick beds of yellowish-grey arenaceous flags containing hard felspathic layers. The beds in this group are usually easily recognizable, because of the thin alternations of hard and soft layers, and by their peculiar weathering.

*Lingulella Davisii* and *Hymenocaris vermicauda* are the chief fossils in the lower beds. The upper beds are chiefly blue-grey flags, and contain, besides the above-mentioned fossils, a *Conocoryphe* and a *Bellerophon*. The whole group is very barren of animal remains, and appears to have been deposited in shallow water. The well-known fossil, *Cruziana*, which is, I believe, an Alga, occurs abundantly near Bangor and in other areas in this group; and a large species of *Buthotrephis* was found in it by the late Mr. Belt.

EFESTINIOG GROUP.	{	Upper, 50 ft.	} Bluish-grey Flags, with <i>Conocoryphe bucephala</i> and <i>Bellerophon cambrensis</i> , &c.
		Lower, 2000 ft.	} Arenaceous and Micaceous Yellowish-grey Flags, with <i>Lingulella Davisii</i> , <i>Hymenocaris vermicauda</i> , <i>Cruziana</i> , &c.

*Dolgelly group* (Upper Lingula flags).—This group consists mainly of blue and black slates. It was evidently deposited in a tolerably quiet sea, and contains a rich fauna. The beds are well exposed in the Mawddach Valley, and about Portmadoc in North Wales. The so-called Malvern black shales also belong to this group. At St. David's, fine grey shales chiefly occur at this horizon. The Olenoid forms, *Parabolina*, *Peltura*, and *Sphaerophthalmus*, characterize this group.

DOLGELLY GROUP.	{	Upper, 300 ft. {	Soft Black Slates, with <i>Peltura</i> , <i>Sphaerophthalmus</i> , &c.
		Lower, 300 ft. {	Hard Blue Slates, with <i>Parabolina</i> , &c.

*Tremadoc group*.—This group consists mainly of dark earthy flags, flaggy sandstones, and iron-stained slates. It was carefully examined many years ago in North Wales, by Sedgwick, Salter, and Homfray, and shown to contain a very important fauna. Up to the year 1866, it had only been recognized in North Wales; but in that year I was able to announce the discovery at St. David's of a large series of fossils, more nearly allied to those in this group than to any others known. It has since been found in Shropshire by Dr. Callaway. About sixty species have now been discovered altogether, and nearly all are peculiar to the group. Many genera, and several orders, appear here for the first time in the succession. The Lamellibranchs, Crinoids, Asteroids, and Cephalopods, are not known to occur at a lower horizon, and several of these, as yet, have only been found at St. David's, in these rocks.

TREMADOC GROUP.	{	Upper, 800 ft. {	Iron-stained Flags and Slates, with <i>Asaphus Homfrayi</i> , <i>Angelinia</i> , &c.
		Lower, 200 ft. {	Dark Earthy Flags and Flaggy Sandstones, with <i>Nes-euretus</i> , <i>Niobe</i> , &c.

## 2. Ordovian (Lower Silurian).

The name 'Ordovian,' has been given to this formation by Prof. Lapworth, who has paid great attention to its fossils, especially to the Graptolites, and these somewhat specially characterize the groups in the formation. I adopt this name now in preference to that of Lower Silurian, as less likely to lead to confusion, and as being in many respects an appropriate one. It consists of four well-marked groups, each with a distinct and important fauna. Three of these have been for a long time

well known, but the fourth (Llanvirn group) is now introduced for the first time, though its position has been partially defined in previous papers.\* The groups are named, in ascending order, Arenig, Llanvirn, Llandeilo, and Bala.

*Arenig group.*—This name was first given by Prof. Sedgwick, to a group of rocks well developed in the Arenig district in North Wales. For many years, however, it yielded but few fossils, and its importance was scarcely suspected until after the discovery in it, at St. David's, of a very rich fauna. In a former paper I divided the group into lower, middle, and upper parts. I have since found that the upper, as there defined, is so distinct in its fauna from the underlying or middle part, and, indeed, at present so little known out of the neighbourhood of St. David's, that I have, at the suggestion of Prof. Lapworth, given it a local name, and will therefore describe it as a distinct group. The Arenig proper will, therefore, now be divided into two parts, upper and lower, the former being the portion previously described as the middle part. The group consists almost entirely of black slates, with, however, a few beds of flaggy sandstones, and in North Wales with some grits. Graptolites, which appear for the first time in the underlying Tremadoc rocks,† occur in this group in great abundance; the trilobites, also, are altogether unlike those in the underlying rocks. The evidence, therefore, of a palaeontological break between the Cambrian and Ordovician, is tolerably clear, though stratigraphically it is not seen. The so-called 'Skiddaw slates' belong chiefly to the upper portion of this group. The graptolites hitherto collected in the lower portion are chiefly *Diplograpti* and *Cladophora*; in the upper, the genera *Tetragraptus* and *Didymograptus*.

ARENIG GROUP.	{	Upper.	{ Slates, Flags, and Sandstones, with <i>Æglina</i> , <i>Calymene</i> , &c.
		Lower.	{ Fine Black Slates and Shales, with <i>Ogygia</i> , <i>Trimucleus</i> , &c.

The view, Pl. VIII., fig. 4, shows the Arenig rocks at Whitesand Bay. A few beds of the Tremadoc group are also seen, but most of the beds of this group have been here cut off by a fault.

*Llanvirn group.*—As stated above, this group was described by me formerly as a portion of the Arenig (its position is seen in Sect. 2, p. 20). It consists of a thick series of

\* Hicks, *Quar. Jour. Geol. Soc.* May 1875.

† Found by Dr. Callaway in Shropshire, and also by Mr. Homfray near Portmadoc.

dark slates and shales, with contemporaneous beds of volcanic tuff. It has an average thickness, as now defined, of about 2000 feet, and contains a distinct and important fauna. Most of the species are new, and amongst the trilobites is one genus (*Placoparia*) not elsewhere found in Britain. The fauna, which was worked out by me from the beds at Llanvirn, St. David's, in 1874, is very rich in trilobites; and several genera appear here for the first time in the succession, as *Illænus*, *Illænopsis*, *Barrandea*, *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. Beds belonging to this group have been explored by Mr. Marr near Caernarvon; they are probably to be found also near Shelve, in Shropshire. The lower portion of the so-called Llandeilo at Aberiddy Bay belongs rather to this group than to the typical Llandeilo, and is here included in it. *Didymograptus Murchisonii* is supposed by Prof. Lapworth to be characteristic chiefly of these beds.

LLANVIRN GROUP.	{	Upper.	{ Fine Black Slates interstratified with Beds of Tuff containing <i>Didymograptus Murchisonii</i> , &c.
		Lower.	Dark-grey Flags and Slates, with <i>Placoparia</i> , &c.

*Llandeilo group*.—In the typical area (Llandeilo), Sir R. Murchison described the rocks belonging to this group in ascending order, as dark schists and shales with sandstone courses, followed by calcareous grits and pebble beds, and succeeded by schists in which *Asaphus tyrannus* is conspicuous; upon these occur calcareous, dark-coloured, finely laminated flagstones and schists. This group as it occurs in Pembrokeshire, after excluding the lower beds which I propose now to place in the Llanvirn group, may be divided into two parts; the lower consisting of black calcareous shales and flags, followed by tolerably compact limestone; and the upper portion of black slates, flags, and flaggy sandstones. The beds are well exposed on the north shore of Aberiddy Bay, near St. David's (see Sect. 2, p. 20), and are there highly fossiliferous, *Ogygia Buchii*, *Calymene duplicata*, *Cheirurus Sedgwickii*, *Trinucleus fimbriatus*, occurring in abundance. The Glenkiln slates of Scotland are supposed by Lapworth to be the equivalents of the upper beds of this group.

LJANDEILO GROUP.	{	Upper.	Black Slates, Flags, and Flaggy Sandstones, with <i>Ogygia Buchii</i> , &c.
		Lower.	Calcareous Shales and Flags, &c., with <i>Asaphus tyrannus</i> , &c.

*Bala group.*—The beds of this group are particularly well developed in the neighbourhood of Bala, N. Wales, therefore the name suggested by Sedgwick is peculiarly appropriate. The rocks have also been called by other authors by the name Caradoc, from the Caradoc mountain range in Shropshire, where they are also exposed. The group consists of sandstones, shales, and flags, alternating with calcareous bands and contemporaneous volcanic ash. It attains to a great thickness, but varies considerably in different areas in consequence of the presence of so much volcanic material. Of late years but little work has been done in this group in Wales, but in Scotland the researches of Prof. Lapworth have added considerably to our knowledge of the fauna. The fauna of the Bala group is an exceedingly rich one, especially in trilobites. Graptolites also occur in abundance, chiefly Diplograptidæ and Dicranograptidæ. Prof. Lapworth calls special attention\* to the ‘total distinction in palæontological features between the graptolite faunas of the Bala and Arenig’ groups. ‘In the true Bala beds not a single example of the families of the Dichograptidæ or Phyllograptidæ has hitherto been detected. So far as our present information enables us to judge, they appear to have become wholly extinct, and their place is occupied by the very distinct families of the Diplograptidæ and Dicranograptidæ.’ It is important also to notice, as bearing on the physical history of this epoch, that the ‘mortality in families, genera, and species of Rhabdophora in the Upper Caradoc (Bala) beds,’ is very great. And that the palæontological break between this last member of the Ordovician formation and the overlying Silurian, so far as the Rhabdophora are concerned, is almost complete. The Hartfell shales of Scotland belong to this horizon.

BALA GROUP.	{	Upper.	Shales, Flags, and Limestones.
		Lower.	Sandstones and Shales, with Calcareous Bands.

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\* *Annals and Mag. of Natural History*, series 5, vol. iii.

3. *Silurian* (*Upper Silurian*, *Murchison*).

Though this name was intended by Murchison to include, perhaps, all the fossiliferous rocks below the Devonian, it has been quite evident for a long time that the restricted meaning in which it is here used is the only way to get rid of much confusion in geological nomenclature. The groups here included in it are, in ascending order, Llandovery, Wenlock, and Ludlow.

*Llandovery group*.—The name was given to this group by Sir R. Murchison in consequence of the great development of rocks of this age near the town of Llandovery, S. Wales. It is supposed to attain a thickness, there and in Pembrokeshire, of over 2000 feet; whilst it is well known that in some other areas in Wales it thins out to about as many hundred feet. The physical break between this group and the underlying Bala has been frequently referred to by Sedgwick, Ramsay, and others, and there can be no doubt that it is the most important one in the Lower Palæozoic rocks. To a great extent, however, it must be considered to have been produced by local influences. For whilst in the Longmynd and other areas there is ample evidence now to show that there was dry land at the time, there is equally convincing proof that marine conditions continued during the same period in Cardiganshire and Pembrokeshire. In Sect. 3, p. 20, the Lower Llandovery rocks rest conformably upon the Bala beds. The rocks which compose this group vary considerably in different areas, but may be said to consist chiefly of conglomerates, sandstones, shales, and slates. It is usually divided into lower and upper portions,—the latter being also called frequently the ‘May-Hill Sandstone series.’ The so-called ‘Tarannon shales’ and ‘Denbighshire grit and flag series,’ are probably on the horizon of the upper members of this group. In the last-mentioned series I have recently discovered the earliest indications of land-plant remains hitherto found in Britain. They are all in a fragmentary condition and must have been carried into their present positions from some neighbouring lands by floods. These beds have yielded to Prof. Lapworth, in Scotland, a rich fauna of Graptolites, the prevailing family in the lower beds being the Diplograptidæ, whilst in the upper beds the Monograptidæ are dominant.

LLANDOVERY GROUP.	}	Upper.	Conglomerates, Sandstones, Shales, and Slates.
		Lower.	Conglomerates, Sandstones, and Shales.

*Wenlock Group*.—This group has a considerable thickness,

and is usually divided into an upper series, under the name of 'Wenlock limestone and shale,' and a lower by the name of 'Woolhope beds.' In North Wales the lower beds rest conformably on the Denbighshire grit and flag series. The Woolhope limestone is supposed to be only locally developed. The fauna of the group consists mainly of Crinoids and Corals; but Brachiopods occur also in great abundance, and numerous new species have been lately added to the fauna by the researches of Mr. G. Maw and Mr. Davidson. Mr. Maw estimates the thickness of the group in Shropshire at over 2500 feet. As previously stated, I exclude the typical so-called Denbighshire grit and slate series from the group, believing that those beds are for the most part on a lower horizon than any rocks usually included in this group in Shropshire.

WENLOCK GROUP.	}	Upper.	Shale and Limestone.
		Lower.	Shale, Limestone, and Flaggy Beds.

*Ludlow Group.*—This group in Shropshire attains a thickness of from 1400 to 1800 feet. It consists mainly of dark grey argillaceous shales with calcareous concretions, and limestone. It is divisible, however, into two portions. The upper consisting of light-coloured grits and shales, and the lower of the 'Aymestry Limestone series.' The fauna of this group is important from its including the first indications of vertebrate life as fish remains. Until the discovery by me lately of the land-plant remains in the Denbighshire grit series; it was also supposed that the first evidences of a terrestrial flora occurred in these rocks. The fauna of this group for the most part is highly Silurian in type, but the topmost beds appear lithologically and palæontologically to be passage-beds connecting the Silurian and Devonian formations.

LUDLOW GROUP.	}	Upper.	Shales, Flaggy Sandstones, and Grits.
		Lower	Hard Flaggy Shales, with Bands of impure Limestone.

TABLE OF BRITISH LOWER PALÆZOIC STRATA (1881).

		PETROLOGICAL CHARACTERS.	THICKNESS OF STRATA.	CHARACTERISTIC TYPES AND ORDER OF APPEARANCE OF LIFE.	LOCALITIES WHERE EXPOSED.
Upper Silurian (Murchison).	SILURIAN.	LUDLOW GROUP	Feet. 1800	Pisces . . . . .	Ludlow, Ledbury, Downton, Kingsston, Lesmahago, Whitchiffe, Malvern, Longhope, Aymestry, View Edge, &c.
		WENLOCK GROUP	2500	. . . . .	Wenlock Edge, Dudley, May Hill, Malvern, Liangollen, &c.
		LIANDOVERY GROUP	160 to 2500	Plantæ (land plants) . . . . .	Liandovery, Haverfordwest, May Hill, Corwen, Faranonn, Birkhill, Girvaal, &c.
Upper Cambrian (Seewick).	ORDOVIAN.	BALA GROUP	4000 to 12,000	. . . . .	Bala, Caradoc Ridge, Horderly, Norbury, Snowdon, Haverfordwest, Wexford, Kildare, Hartfell.
		LLANDEILO GROUP	3000	Actinozoa . . . . .	Dumfriesshire, Llandeilo, Builth, Abergiddy Bay, &c.
		LLANVERN GROUP	2000	. . . . .	Llanvorn and Coast of Abergiddy Bay, Ramsey Island, Shelve, &c.
		ARENIG GROUP	2500	Gasteropoda . Echinodermata ( <i>Crinoidea</i> , <i>Asteroidæa</i> )	Arenig, Shelve, Ramsey Island and and Whitesand Bay (St. David's), Skiddaw (Cumberland).
		TREMADOC GROUP	1000	Hydrozoa ( <i>Graptolites</i> ). Lamelli-branchiata and Cephalopoda .	Portmadoc, Ramsey Island and Whitesand Bay (St. David's), Shineton (Shropshire).
Lower Silurian.	UPPER CAMBRIAN.	DOLGELLY GROUP	600	Byozoa ( <i>Dictyonema</i> ) . . . . .	Portmadoc, Dolgelly, Malvern, Whitesand Bay, &c.
		FESTINIÖG GROUP	2000	Heteropoda, Plantæ ( <u>marine-plants</u> )	Maentwrog, Dolgelly, Malvern, Ramsey Island, Solva.
		MAENTWROG GROUP	2500	Crustacea ( <i>Phyllopora</i> ) . . . . .	Maentwrog, Dolgelly, Solva.
Lower Cambrian (Seewick).	LOWER CAMBRIAN.	MENEVIAN GROUP	750	Echinodermata ( <i>Cystidea</i> ) . . . . .	St. David's, Solva, Maentwrog, Dolgelly.
		SOLVA GROUP	1800	Pteropoda Crustacea ( <i>Ostracoda</i> , <i>Trilobites</i> ) .	Solva, St. David's, Harlech Mountains, Longmynd Range, Bray Head, &c.
		CAERPAI GROUP	1600 to 4000	Brachiopoda, Protozoa, Annelida, Plantæ? .	St. David's, Whitesand Bay, Bangor, Llanberis, &c.

## EXPLANATION OF PLATES VII. AND VIII.

*Views from Photographs taken by E. H. Griffiths, Esq., M.A., F.G.S.,  
and H. T. Hall, Esq., B.A.*

## PLATE VII.

- FIG. 1. View of the East side of Porth-y-rhaw to Cradle Rock, showing junction of Menevian and Maentwrog groups.  
 FIG. 2. View of the Coast from Porth-clais to Caerfai, showing Caerfai and Solva group .

## PLATE VIII

- FIG. 3. View of the East side of Caerbwddy Harbour, showing fault near junction of Caerfai and Solva groups.  
 FIG. 4. View of the North coast of Whitesand Bay, showing the Arenig rocks.

The small letters have the same signification as in the woodcut sections.

\*\* Indicate the chief fossiliferous localities.

† Indicates intrusive rock.

F Fault.

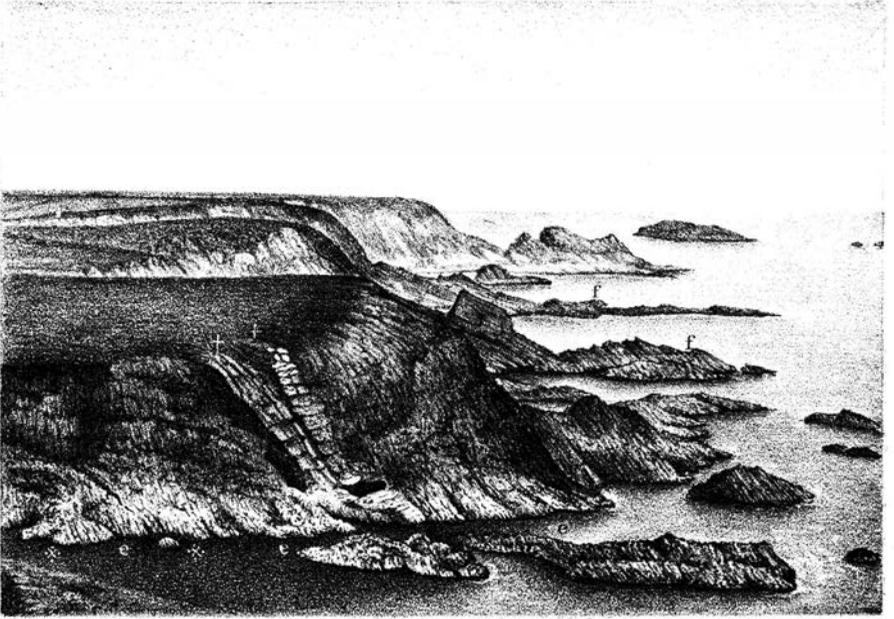


FIG. 1. EAST SIDE OF PORTH-Y-RHAW.

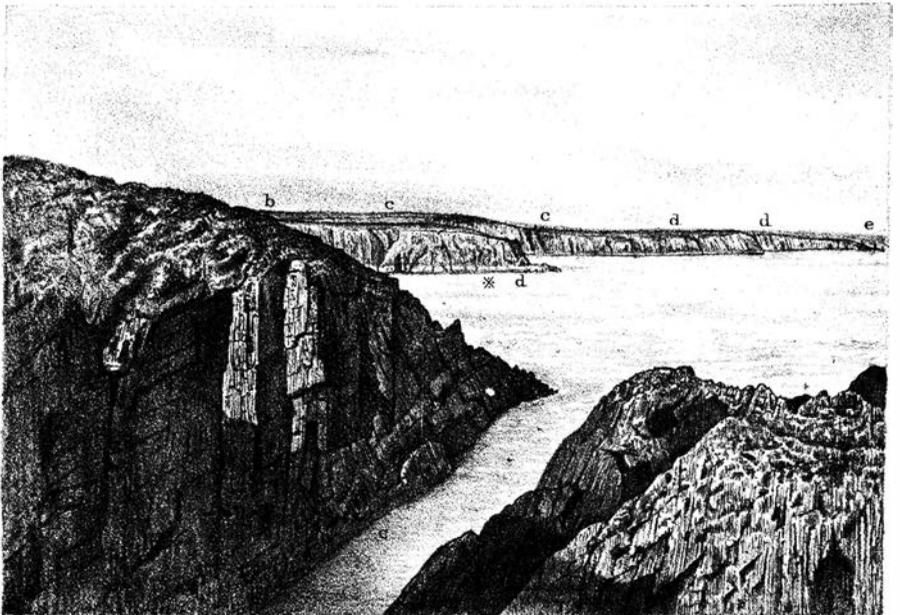


FIG. 2. COAST FROM PORTH-CLAIS TO CAERFAI.

Mintern Bros imp

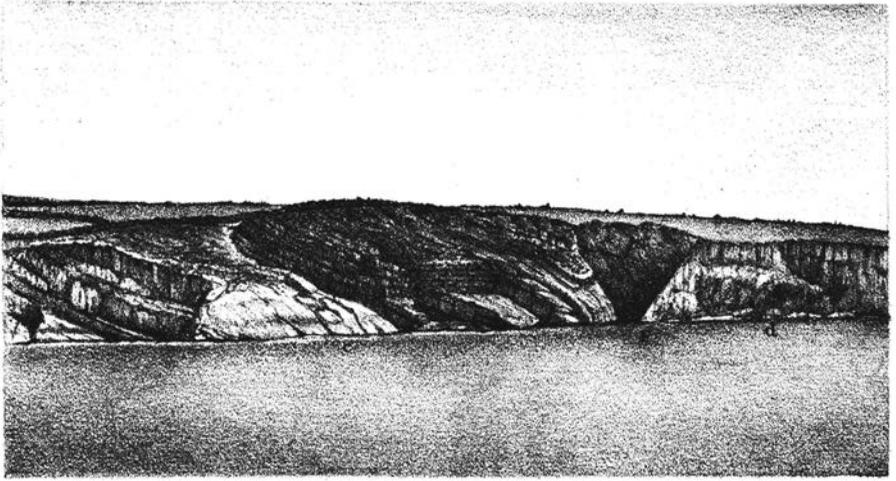


FIG. 3. EAST SIDE OF CAERBWDDY HARBOUR.

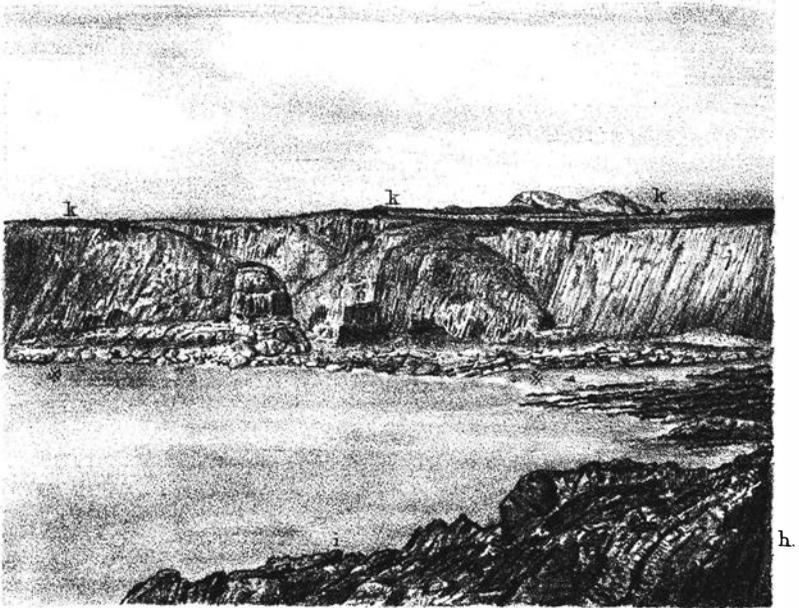


FIG. 4. NORTH COAST OF WHITESAND BAY.

Mintern Bros. imp.