and serpentine. But perhaps their most intelligible sections are those which they present in Bavaria and Bohemia between the valley of the Danube and the head-waters of the Elbe. They are there divided into two well-marked groups—(*a*) red gneiss, covered by (*b*) grey gneiss. According to Gümbel the former (called by him the Bojan gneiss) may be traced as a distinct formation associated with granite, but with very few other kinds of crystalline or schistose rocks, while the latter (termed the Hercynian gneiss) consists of gneiss with abundant interstratification of many other schistose rocks, graphitic limestone, and serpentine. The Hercynian gneiss is overlaid by mica-schist, above which comes a vast mass of argillaceous schists and shales. Gümbel some years ago found in the marbles associated with the younger gneiss what he considered to be an organism of the same genus as the *Eozoon* of Canada, to which reference will immediately be made. He named it *Eozoon Bavaricum*. More recently a similar substance was obtained in the Archæan series of Bohemia, and named by Fritsch *Eozoon Bohemicum*.

America.—In North America Archæan rocks cover a large part of the continent from the Arctic Circle southwards to the great lakes. They appear likewise, as in Europe, along the central parts of prominent mountain chains, as in the Rocky Mountain range and that of the Appalachians. They have been carefully studied in Canada, where the late Sir W. E. Logan, Director of the Geological Survey of the Dominion, estimated their depth at about 30,000 feet, but neither their top nor their base can there be found. He named them the Laurentian system from their abundant development along the shores of the St Lawrence. They have been divided into two series—(1) a lower formation more than 20,000 feet thick, consisting chiefly of granitic, orthoclase gneiss, with bands of quartz-rock, schists, iron-ore, and limestone; and (2) an upper formation fully 10,000 feet thick, composed also, for the most part, of gneiss, but marked by the occurrence of bands of Labrador felspar, as well as schist, iron-ore, and limestone. The upper division has been stated to lie unconformably on the lower. Mr Selwyn, however, has recently pointed out that this is almost certainly not the case, but that the limestone-bearing series rests conformably upon a massive granitoid gneiss, to which he would restrict the term Laurentian, classing the limestones in the next or Huronian system (*Nat. Hist. Soc. Montreal*, Feb. 1879).

In one of the Laurentian limestones of Canada, specimens have been found of a remarkable mixture of calcite and serpentine. These minerals are arranged in alternate layers, the calcite forming the main framework of the substance with the serpentine (sometimes logunite, pyroxene, &c.) disposed in thin, wavy, inconstant layers, as if filling up flattened cavities in the calcareous mass. So different from any ordinary mineral segregation with which he was acquainted did this arrangement appear to Logan, that he was led to regard the substance as probably of organic origin. This opinion was adopted, and the structure of the supposed fossil was worked out in elaborate detail by Dr Dawson of Montreal, who pronounced the organism to be the remains of a massive foraminifer which he called *Eozoon*, and which he believed must have grown in large thick sheets over the sea-bottom. This opinion was confirmed by Dr W. B. Carpenter, who from a large suite of additional and better preserved specimens, described a system of internal canals having the characters of those in true foraminiferal structures. (See Foraminifera.) Other observers, notably Professors King and Rowney of Galway and Möbius of Kiel, have opposed the organic nature of *Eozoon*, and have endeavoured to show that the supposed canals and passages are merely infiltration veinings of serpentine in the calcite. In some cases, however, the "canal-system" is not filled with serpentine but with dolomite, which seems to show that the cavities must have existed before either dolomite or serpentine were introduced into the substance. Dr Carpenter contends that the disposition of these passages in his decalcified specimens is very regular, and quite unlike any mineral infiltration with which he is acquainted.

The opinion of the organic nature of *Eozoon* has been supposed to receive support from the large quantity of graphite found throughout the Archæan rocks of Canada and the northern parts of the United States. This mineral occurs partly in veins, but chiefly disseminated in scales and laminæ in the limestones and as independent layers. Dr Dawson estimates the aggregate amount of it in one band of limestone in the Ottawa district as not less than from 20 to 30 feet, and he thinks it is hardly an exaggeration to say that there is as much carbon in the Laurentian as in equivalent areas of the Carboniferous system. He compares some of the pure bands of graphite to beds of coal, and maintains that no other source for their origin can be imagined than the deoxidation of carbonic acid by living plants. In the largest of three beds of graphite at St John he has found what he considers may be fibrous structure indicative of the existence of land-plants.

Still further evidence in favour of organized existence during Archæan time in the North American area has been adduced from the remarkably thick and abundant masses of iron ore associated with the Laurentian rocks of Canada and the United States. Dr Sterry Hunt has called attention to these ores as proving the precipitation of iron by decomposing vegetation during the Laurentian period on a more gigantic scale than at any subsequent geological epoch.[1] Some of the beds of magnetic iron ranged up to 200 feet in thickness. Large masses also of hæmatite and titaniferous iron, as well as of iron sulphides, occur in the Canadian Archæan series. These great bands of iron ore run southward, and form an important feature in the economic geology of the Northern States of the Union.

Above the Laurentian rocks in the region of Lake Huron lies a vast mass of slates, conglomerates, limestones, and quartz-rocks, attaining a depth of from 10,000 to 20,000 feet. They are termed Huronian. No fossils have yet been found in them; but they must be much younger than the Laurentian rocks, on which they rest unconformably, and from which they have been in part at least derived.

II. PALÆOZOIC.

Under the general term of Primary or Palæozoic are now included all the older sedimentary formations containing organic remains, up to the top of what is termed the Permian system. These rocks consist mainly of sandy and muddy sediment with occasional intercalated zones of limestone. They everywhere bear witness to comparatively shallow water and the proximity of land. Their frequent alternations of sandstone, shale, conglomerate, and other detrital materials, their abundant, rippled, and sun-cracked surfaces marked often with burrows and trails of worms, as well as the prevalent character of their organic remains, show that they must have been deposited in areas of slow subsidence, bordering continental or insular masses of land. As regards the organisms of which they have preserved the casts, the Palæozoic rocks, as far as the present evidence goes, may be grouped into two divisions—an older and a newer:—the former distinguished more especially by the abundance of its graptolitic, trilobitic, and brachiopodous fauna, and by the absence of vertebrate remains; the latter by the number and variety of its fishes and amphibians, the

[1] *Geology of Canada*, 1863, p. 573.

disappearance and extinction of graptolites and trilobites, and the abundance of its cryptogamic terrestrial flora.

Cambrian.

This name was applied by Sedgwick to the rocks of North Wales (Cambria), where he first investigated them. Their base is there nowhere seen, so that, though they attain a great depth, some part of their total mass must be concealed from view. They pass up continuously into the base of the Silurian system. Considerable diversity of opinion has existed, and still continues, as to the line where the upper limit of the Cambrian system should be drawn. Murchison contended that this line should be placed below the strata where a trilobitic and brachiopodous fauna begins, and that these strata cannot be separated from the overlying Silurian system. He therefore included in the Cambrian only the barren grits and slates of the Longmynd, Harlech, and Llanberis. Sedgwick, on the other hand, insisted on carrying the line up to the base of the Upper Silurian rocks. He thus left these formations as alone constituting the Silurian system, and massed all the Lower Silurian in his Cambrian system. Murchison worked out the stratigraphical order of succession from above, and chiefly by help of organic remains. He advanced from where the superposition of the rocks is clear and undoubted, and for the first time in the history of geology ascertained that the "transition-rocks" of the older geologists could be arranged into zones by means of characteristic fossils as satisfactorily as the Secondary formations had been classified in a similar manner by William Smith. Year by year, as he found his Silurian types of life descend farther and farther into lower deposits, he pushed backward the limits of his Silurian system. In this he was supported by the general consent of geologists and palæontologists all over the world. Sedgwick, on the other hand, attacked the problem rather from the point of stratigraphy and geological structure. Though he had collected fossils from many of the rocks of which he had made out the true order of succession in North Wales, he allowed them to lie for years unexamined. Meanwhile Murchison had studied the prolongations of some of the same rocks into South Wales, and had obtained from them the abundant suite of organic remains which characterized his Lower Silurian formations. Similar fossils were found abundantly on the continent of Europe, and in America. Naturally the classification proposed by Murchison was adopted all over the world. As he included in his Silurian system the oldest rocks containing a distinctive fauna of trilobites and brachiopods, the earliest fossiliferous rocks were everywhere classed as Silurian, and the name Cambrian was discarded by geologists of other countries as indicative of a more ancient series of deposits not characterized by peculiar organic remains, and therefore not capable of being elsewhere satisfactorily recognized. Barrande, investigating the most ancient fossiliferous rocks of Bohemia, distinguished by the name of the "Primordial Zone" a group of strata underlying the Lower Silurian rocks, and containing a peculiar and characteristic suite of trilobites. He classed it, however, with the Silurian system, and Murchison adopted the term, grouping under it the lowest dark slates which in Wales and the border English counties contained some of the same early forms of life.

Investigations during the last twelve years, however, chiefly by the late Mr Salter and Mr Hicks, have brought to light a much more abundant fauna from the so-called primordial rocks of Wales than they were supposed to possess. These fossils were found to be in large measure distinct from those in the undoubted Lower Silurian rocks. Thus the question of the proper base of the Silurian system was re-opened, and the claims of the Cambrian system to a great upward extension were more forcibly urged than ever. But these claims could now be urged on palæontological evidence such as had never before been produced. Accordingly there has arisen a general desire among the geologists of Britain to revise the nomenclature of the older rocks. Though as yet a common accord of opinion has not been reached, there seems a strong probability that ultimately the boundary line between the Cambrian and Silurian systems will be drawn above the primordial zone along the base of the great Arenig group or Lower Llandeilo rocks of Murchison. All his Silurian strata of older date than these rocks will be classed as Cambrian.

According to this classification, the Cambrian system, as developed in North Wales and the border English counties, consists of purple, reddish-grey, and green slates, grits, sandstones, and conglomerates. Its true base is nowhere seen, yet even the visible mass of strata has been estimated to reach the enormous thickness of 25,000 feet. By far the larger part of this vast depth of rock is unfossiliferous. Indeed it is only in some bands of the upper 6000 feet, or thereabouts, that fossils occur plentifully. By fossil evidence the Cambrian system may be divided into Lower and Upper, and each of these sections may be further subdivided into two groups, as in the following table:—

Cambrian of Wales.	Upper.	4. Tremadoc slates.
		3. Lingula flags.
	Lower.	2. Menevian group.
		1. Harlech and Longmynd group.

1. *Harlech and Longmynd Group.*—This includes purple, red, and grey flags, sandstones, and slates, with conglomerates. These strata attain a great thickness, estimated at 4000 feet in South Wales, but more than 8000 in North Wales. They were formerly supposed to be nearly barren of organic remains; but in recent years, chiefly through the researches of Mr Hicks at St Davids, they have yielded a tolerably abundant fauna, consisting of 30 species. Among these are 16 species of trilobite (*Paradoxides*, *Plutonia*, *Microdiscus*, *Palæopyge*, *Agnostus*, *Conocoryphe*), four annelides (*Arenicolites*), a sponge (*Protospongia*), five brachiopods (*Discina*, *Lingulella*), two pteropods (*Theca*), &c. Many of the surfaces of the strata in some parts of this group are marked with ripples, sun-cracks, and rain-pittings as well as with trails of worms—indicative of shallow-water and shore-conditions of deposit. 14 of the 30 species, according to Mr Etheridge, F.R.S., pass up into the Menevian group, and 7 continue into the Lingula flags.

2. *Menevian Group.*—This subdivision has been proposed for a series of sandstones and shales, with dark-blue slates and flags, dark-grey flags and grey grits, which are seen near St David's (Menevia), where they attain a depth of about 600 feet. They pass down conformably into the Harlech group with which, as just stated, they are connected by 14 species in common. The Menevian beds have yielded upwards of 50 species of fossils, of which 24 are confined to the Menevian, while 18 pass up into the lower Lingula flags. Among these the trilobites are specially prominent, Some of them attained a great size, *Paradoxides Davidis* being nearly two feet long. But with these were mingled others of diminutive size. It is noteworthy also, as Mr Hicks has pointed out, that while the trilobites had attained their maximum size at this early period, they are represented among the older Cambrian rocks by genera indicative of almost every stage of development, "from the little *Agnostus* with two rings in the thorax, and *Microdiscus* with four, to *Erinnys* with twenty-four," while blind genera occur together with those having the largest eyes.[1] Upwards of 30 species of trilobites have been obtained from the Menevian beds, the genera *Agnostus* (7 species), *Conocoryphe* (7 species), and *Paradoxides* being specially characteristic. Four species of sponges (*Protospongia*) and some annelide-tracks likewise occur. The mollusca are represented by 6 species of brachiopoda of the genera *Discina*, *Lingulella*, and *Obolella*; 5 pteropods (*Theca*) have been met with. The earliest entomostraca (*Entomis*) and the first cystidean (*Protocystites*) yet discovered occur in the Menevian fauna.

3. *Lingula Flags.*—These strata, consisting of bluish and black slates and flags, with bands of grey flags and sandstones, attain in some parts of Wales a thickness of more than 5000 feet. They received their name from the discovery by Mr E. Davis (1846) of vast numbers of a *Lingula* (*Lingulella Davisii*) in some of their layers. They rest conformably upon, and pass down into, the Menevian beds below them, and likewise graduate into the Tremadoc group above. They are distinguished by a characteristic

[1] Hicks, *Quart. Journ. Geol. Soc.*, xxviii. 174.

suite (78 species) of organic remains. The trilobites include the genera *Agnostus*, *Anapolenus*, *Conocoryphe*, *Dikelocephalus*, *Erinnys*, *Olenus*, and *Paradoxides*. The earliest phyllopods (*Hymenocaris*) and heteropods (*Bellerophon*) occur in these beds. The brachiopods include species of *Lingulella* (*L. Davisii*), *Discina*, *Obolella*, and *Orthis*. The pteropods are represented by three species of *Theca*. Several annelides (*Crucisiana*) and polyzoa (*Fenestella*) likewise occur.

According to a careful census by Mr Etheridge, the Lingula flags may be grouped into three zones, each characterized by a peculiar assemblage of organic remains. The lower division contains 37 species, of which 9 are peculiar to it. The middle zone has yielded 5 species, 2 of which (*Conocoryphe bucephala* and *Lingulella Davisii*) pass down into the lower division, 1 (*Kutorgia cingulata*) into the upper, and 2 (*Lingula squamosa* and *Bellerophon Cambrensis*) are peculiar. The upper zone has yielded 40 species. Of these 9 pass up into the Tremadoc beds, while 2 (*Lingulella lepis* and *L. Davisii*) continue on into the Arenig group.

4. *Tremadoc Slates.*—This name was given by Sedgwick to a group of dark grey slates, about 1000 feet thick, found near Tremadoc in Carnarvonshire, and traceable thence to Dolgelly. Their importance as a geological formation was not recognized until the discovery of a remarkably abundant and varied fauna in them. They contain the earliest crinoids, star-fishes, lamellibranchs, and cephalopods yet found. The trilobites embrace 14 genera, among which, besides some, as *Agnostus*, *Conocoryphe*, and *Olenus*, found in the Lingula flags, we meet for the first time with *Angelina*, *Asaphus*, *Cheirurus*, *Nesuretus*, *Niobe*, *Ogygia*, *Psilocephalus*, &c. The same genera, and in some cases species, of brachiopods appear which occur in the Lingula flags, *Orthis Carausii* and *Lingulella Davisii* being common forms. Mr Hicks has described 12 species of lamellibranchs from the Tremadoc beds of Ramsay Island and St Davids, belonging to the genera *Ctenodonta*, *Palæarca*, *Glyptarca*, *Davidia*, and *Modiolopsis*. The cephalopods are represented by *Orthoceras scriccum* and *Cyrtoceras præcox*; the pteropods by *Theca Davidii*, *T. operculata*, and *Conularia Hounfrayi*; the echinoderms by a beautiful star-fish (*Palasterina ramsegensis*) and by a crinoid (*Dendrocrinus Cambrensis*).[1]

Careful analysis of the fossils yielded by the Tremadoc beds suggests a division of this formation into two zones. According to a census by Mr Etheridge, the Lower Tremadoc rocks have yielded in all 56 species, of which 9 pass down into the Lingula flags and 10 ascend into the Upper Tremadoc zone, 31 being peculiar. The Upper Tremadoc beds contain, as at present ascertained, 33 species, of which 9 are peculiar, and 13 or possibly 15 pass up into the Arenig group. It is at the top of the Upper Tremadoc strata that the line between the Cambrian and Silurian systems is here drawn. According to Professor Ramsay, there is evidence of a physical break at the top of the Tremadoc beds of Wales, so that on a large scale the next succeeding or Arenig strata repose unconformably upon everything older than themselves. Mr Etheridge also shows that the palæontological break is nearly complete, only about 7 per cent. of the fossils of the one series passing over into the other. Out of 184 known Arenig species, not more than 13 are common to the Tremadoc beds underneath. Besides these important facts the character of the Arenig fauna strongly distinguishes it from that of the formations below, and further supports the line of division here adopted between the Cambrian and Silurian systems.

In the north-west of Scotland a mass of reddish-brown and chocolate-coloured sandstone and conglomerate (at least 8000 feet thick in the Loch Torridon district) lies unconformably upon the fundamental gneiss in nearly horizontal or gently inclined beds. It rises into picturesque groups of mountains which stand out as striking monuments of denudation, seeing that the truncated ends of their component flat strata can be traced even from a distance forming parallel bars along the slopes and precipices. The denudation must have been considerable even in early Silurian times, for the sandstones are unconformably overlaid by quartz-rocks and limestones containing Lower Silurian fossils. No trace of organic remains of any kind has been found in the red sandstones themselves. They were at one time regarded as Old Red Sandstone, though Macculloch, and afterwards Hay Cunningham, pointed out that they underlie parts of the schistose rocks of the northern Highlands. The discovery by Mr C. W. Peach of Lower Silurian shells in the overlying limestones showed that the massive red sandstones of western Ross and Sutherland could not be paralleled with those of the eastern tracts of those counties, but must be of older date than part of the Llandeilo rocks of the Lower Silurian period. Sir R. Murchison classed them as Cambrian—an identification which has much support in the lithological resemblance between these rocks of the north-west Highlands and much of the Lower Cambrian system of Wales.

[1] Hicks, *Quart. Journ. Geol. Soc.*, xxix. 39.

In the south-east of Ireland masses of purplish, red, and green shales, slates, grits, quartz-rocks, and schists occupy a considerable area and attain a depth of 14,000 feet without revealing their base, while their top is covered by unconformable formations (Lower Silurian and Lower Carboniferous). They have yielded *Oldhamia*, described originally as a sertularian zoophyte, but now regarded by many palæontologists as an alga; also numerous burrows and trails of annelides (*Histioderma Hibernicum*, *Arenicolites didymus*, *A. sparsus*, *Haughtonia poecila*). No Upper Cambrian forms have been met with in these Irish rocks, which are therefore placed with the Lower Cambrian, the unconformability at their top being regarded as equivalent to the interval required for the deposition of the intervening formations up to the time of the Llandeilo rocks, as in the north-west of Scotland. Some portions of the Irish Cambrian series have been intensely metamorphosed. Thus on the Howth coast they appear as schists and quartz-rocks; in Wexford they pass into gneiss and granite. In West Galway Mr Kinahan has described a vast mass of schists, quartz-rocks, and limestones (8000 feet and upwards) passing up into schistose, hornblendic, and unaltered rocks containing Llandeilo fossils, and he agrees with Griffith and King in regarding these as probably Cambrian. He suggests that they are Upper Cambrian, which would imply that Upper Cambrian rocks pass conformably into the Llandeilo formation without the occurrence of the thick Arenig rocks of Wales. In a difficult country, however, broken by faults and greatly metamorphosed, an unconformability might easily escape detection.

Continental Europe.—According to the classification adopted by M. Barrande, the older Palæozoic rocks of Europe suggest an early division of the area of this continent into two regions or provinces,—a northern province, embracing the British Islands, and extending through North Germany into Scandinavia, on the one hand, and into Russia on the other, and a central-European province, including Bohemia, France, Spain, Portugal, and Sardinia.

Bohemia.—The classic researches of M. Barrande have given to the oldest fossiliferous rocks of Bohemia an extraordinary interest. He has made known the existence there of a remarkable suite of organic remains representative of those which characterize the Cambrian rocks of Britain. At the base of the geological formations of that region lie the Archæan gneisses already described. These are overlaid by vast masses of schists, conglomerates, quartzites, slates, and igneous rocks, which have been more or less metamorphosed, and are singularly barren of organic remains, though some of them have yielded traces of annelides. They pass up into certain grey and green fissile shales, in which the earliest well-marked fossils occur. The organic contents of this zone (Etage C) form what M. Barrande terms his primordial fauna, which contains 40 or more species, of which 27 are trilobites, belonging to the characteristic Cambrian genera—*Paradoxides* (12), *Agnostus* (5), *Conocoryphe* (4), *Ellipsocephalus* (2), *Hydrocephalus* (2), *Arionellus* (1), *Sao* (1). Not a single species of any one of these genera, save *Agnostus* (of which 4 species

appear in the second fauna), has been found by M. Barrande higher than his primordial zone. Among other organisms in this primordial fauna, the brachiopods are represented by 2 species (*Orthis* and *Orbicula*), the pteropods by 5 (*Theca*), and the echinoderms by 5 cystideans.

Scandinavia.—In Norway the vast masses of Archæan gneiss (Tellemark) are overlaid by schists, red sandstones, and conglomerates. These are termed the Sparagmite formation, and have hitherto proved barren of fossils. They are covered, however, by beds containing *Dictyonema Norvegicum*, which may represent the primordial zone of Barrande. In Sweden the sparagmite formation has been more productive of organic remains. It is there represented by a sandy zone not more than 50 or 60 feet thick—a poor equivalent for the great mass of strata in the Cambrian system of Wales. It was originally termed the *Regio Fucoidarum* by Angelin, from the fucoids alone found in it. In more recent years, however, its list of organic remains has been considerably increased; 12 species of plants, chiefly fucoids, but including some (*Eophyton*) of higher grade, 9 species of annelides, 4 brachiopods, a pteropod, a bryozoan, a coral, a crinoid, and a sponge have been obtained. Above the strata containing these organisms comes a zone which has yielded 77 species of primordial trilobites, including the genera *Agnostus* (19 species), *Conocoryphe* (13), *Olenus* (21), *Paradoxides* (9).

North America.—Rocks corresponding in position and in the general character of their organic contents with the Cambrian formations of Britain have been recognized in different parts of the United States and Canada. They appear in Newfoundland, whence, ranging by Nova Scotia and New Brunswick, they enter Canada, the northern parts of New York, Vermont, and eastern Massachusetts. They rise again along the Appalachian ridge, in Wisconsin, Minnesota, Missouri, Arkansas, Texas, and Georgia. Westwards from the great valley of the Mississippi, where they have been found in many places, they reappear from under the Secondary and younger Palæozoic rocks of the Rocky Mountains. They have been divided by American geologists into two formations—(1) Acadian, a mass (2000 feet) of grey and dark shales and some sandstones; and (2) Potsdam (or Georgian), which attains in Newfoundland a depth of 5600 feet, but thins away westward and southward till in the valley of the St Lawrence, where it was studied by Logan and his associates of the Geological Survey of Canada, it is only from 300 to 600 feet thick.

Among the organic remains of the North American Cambrian rocks fucoid casts appear in many of the sandstones, but no traces of higher vegetation. The Acadian formation has yielded primordial trilobites of the genera *Paradoxides*, *Conocoryphe*, *Agnostus*, and some others; brachiopods of the genera *Lingulella*, *Discina*, *Obolella*, and *Orthis*; and several kinds of annelide-tracks. The Potsdam rocks contain a few sponges, the earliest forms of graptolite, some brachiopods, including, besides the genera in the Acadian beds, *Obolus*, *Camarella*, and *Orthisina*; some pteropods (*Hyolites* or *Theca*); two species of *Orthoceras*; annelide tracks; trilobites of the genera *Conocoryphe*, *Agnostus*, *Dikelocephalus*, *Olenellus*, *Ptychaspis*, *Chariocephalus*, *Aglaspis*, and *Illænurus*.

M. Barrande has called attention to the remarkable uniformity of character in the organic remains of his primordial zone over the continents of Europe and America. He published in 1871 the subjoined table, to show how close is the parallelism between the proportions in which the different classes of the animal kingdom are represented.[1]

[1] *Trilobites*, Prague, 1871, p. 196. Since the publication of this table the progress of research has increased the number of species from some localities; but the general facies of the primordial fauna has not been materially affected thereby.

Countries.	Crustaceans. Trilobites.	Crustaceans. Other Crustacea.	Crustaceans. Ostracods.	Molluscs. Annelids.	Molluscs. Pteropods.	Molluscs. Heteropods.	Molluscs. Gasteropods.	Molluscs. Brachiopods.	Inferior Classes. Bryozoans.	Inferior Classes. Cystideans.	Inferior Classes. Sponges.	Total by Countries.
1. Bohemia	27	.	.	5	.	.	2	1	5	.		40
2. Spain	9	.	1	.	.	.	2	6	.	1	.	19
3. Scandinavia { Regiones A and B }	77	.	5	.	2	.	.	8	4	.	.	96
4. England { Menevian	33	1	4	4	7	.	.	6	.	1	2	58
England { Harlech, part }												
5. Newfoundland	2	.	.	.	.	.	.	.	.	.	.	2
6. New Brunswick	18	.	.	.	.	.	.	6	.	1	.	25
7. New York	5	.	.	.	.	.	.	.	.	.	.	5
8. Braintree (Massachusetts)	1	.	.	.	.	.	.	.	.	.	.	1
	172	1	10	4	14	.	2	28	5	8	2	=246

Silurian.

The important system of rocks next to be described was first investigated by the late Sir R. Murchison in Wales and the bordering counties of England. He found it to be characteristically developed over the tract once inhabited by the Silures, an ancient British tribe, and he thence chose the name of Silurian as a convenient designation. It there passes down conformably into the Tremadoc slates at the top of the Cambrian series, and is covered conformably by the base of the Old Red Sandstone.

Great Britain.—In the typical area where Murchison's discoveries were first made he found the Silurian rocks divisible into two great and well-marked series, which he termed Lower and Upper. This classification has been found to hold good over a large part of the world. The subjoined table shows the present arrangement and nomenclature of the various subdivisions of the Silurian system.

		Feet.
B. Upper Silurian.	7. Ludlow group	1,950
	6. Wenlock group	1,600
	5. Upper Llandovery group	1,500
A. Lower Silurian.	4. Lower Llandovery group	1,000
	3. Bala and Caradoc group	6,000
	2. Llandeilo group	2,500
	1. Arenig or Stiper Stone group	4,000

Approximate average thickness = 18,550

A. *Lower Silurian.*

1. *Arenig or Stiper Stone Group.*—These rocks consist of dark slates, shales, flags, and bands of sandstone. They are abundantly developed in the Arenig mountain, where, as originally described by Sedgwick, they contain masses of associated porphyry. Throughout that district they have been deposited at a time when streams of lava and showers of volcanic ashes were thrown out in great quantity from submarine vents. They contain an abundant suite of organic remains (184 species), of which only 13 species are common to the Tremadoc beds below. Trilobites occur of the genera *Æglina*, *Agnostus*, *Ampyx*, *Barrandea*, *Calymene*, *Cheirurus*, *Illænopsis*, *Illænus*, *Ogygia*, *Phacops*, and *Trinucleus*. Three species of pteropods (*Conularia*, *Theca*), 18 species of brachiopods (*Lingula*, *Lingulella*, *Obolella*, *Discina*, *Siphonotreta*, *Orthis*), 8 lamellibranchs, 3 gasteropods, and 5 cephalopods have been found; but the most abundant organisms are the graptolites, of which the Arenig rocks of St David's, in Pembrokeshire, have yielded 48 species, which belong to 20 genera, including *Didymograptus*, *Tetragraptus*, *Diplograptus*, *Dendrograptus*, and *Callograptus*.[2] Altogether

[2] Hicks, *Quart. Journ. Geol. Soc.*, xxxi. 167: Hopkinson and Lapworth, *ibid.*, p. 635.

78 species of hydrozoa have been obtained from the British Arenig rocks, but none from any older strata. This sudden and great development of these organisms gives a distinctive aspect to the Arenig rocks. It continues in the overlying Llandeilo group, so that the graptolites form in Britain a convenient character by which to mark off the Cambrian from the Lower Silurian fauna.

2. *Llandeilo Flag Group.*—Dark argillaceous flagstones, sandstones, and shales, some parts often calcareous. These beds were first described by Murchison as occurring at Llandeilo, in Carmarthenshire. They reappear on the coast of Pembrokeshire, and at Builth, in Radnorshire. Up to the present time they have yielded 227 species of fossils. Of these 13 are common to the Arenig below, 82 to the Caradoc or Bala above, while 145 are peculiar. The hydrozoa are still the most abundant forms, 94 species being here met with, no fewer than 81 of these being confined to Llandeilo rocks, and only 9 passing down into the Arenig group. Of crustacea 44 species have been obtained. These include the characteristic trilobites —*Ampyx nudus*, *Asaphus tyrannus*, *Barrandea Cordai*, *Calymene duplicata*, *C. Cambrensis*, *Cheirurus Sedgwickii*, *Ogygia Buchii*, *Trinucleus concentricus*, *T. Lloydii*. The brachiopods number 37 species, including the genera *Orthis*, *Leptæna*, *Strophomena*, *Lingula*, *Siphonotreta*. The lamellibranchs are represented by 6 species, the gasteropods by 10 (*Murchisonia*, *Cyclonema*, *Loxonema*), the heteropods by 7 (*Bellerophon*), the pteropods by 2 (*Conularia*, *Theca*), the cephalopods by 8 (*Orthoceras*, *Cyrtoceras*).

A remarkable feature in the history of the Llandeilo rocks in Britain was the outbreak of volcanic action abundantly in North Wales and in Cumberland. Vast piles of lava and ashes were thrown out, which even to this day remain in mass sufficient to form groups of important hills, as Cader Idris, Aran Mowddwy, the Arenigs, and the Moelwyns in Wales, and Helvellyn and Scaw Fell in Westmoreland and Cumberland.

3. *Caradoc or Bala Group.*—Under this name are placed the thick yellowish and grey sandstones of Caer Caradoc in Shropshire, and the grey and dark slates, grits, and sandstones round Bala in Merionethshire. In the Shropshire area some of the rocks are so shelly as to become strongly calcareous. In the Bala district the strata contain two limestones separated by a sandy and slaty group of rocks 1400 feet thick. The lower or Bala limestone (25 feet thick) has been traced as a variable band over a large area in North Wales. It is usually identified with the Coniston limestone of the Westmoreland region. The upper or Hirnant limestone (10 feet) is more local. Bands of volcanic tuff and large beds of various felsitic lavas occur among the Bala beds, and prove the contemporaneous ejection of volcanic products. These attain a thickness of several thousand feet in the Snowdon region.

A large suite of fossils has been obtained from this formation:—the sponges represented by *Sphærospongia* and other genera; the graptolites by *Diplograptus pristis*, *Graptolithus priodon*, and *G. Sedgwickii*, &c.; the corals by species of *Heliolites*, *Favosites*, *Monticulipora*, *Halysites*, *Petraia*; the echinoderms by encrinites of the genera *Cyathocrinus* and *Glyptocrinus*, by cystideans of the genera *Echinosphærites* and *Sphæronites*, and by star-fishes of the genera *Palæaster* and *Stenaster*; the annelides by *Serpulites*, *Tentaculites*, and numerous burrows and tracks; the trilobites by many species of the genera *Phacops*, *Cheirurus*, *Cybele*, *Lichas*, *Acidaspis*, *Calymene*, *Remopleurides*, *Asaphus*, *Illænus*, *Ampyx*, and *Trinucleus*; the polyzoa by *Fenestella*, *Glauconome*, and *Ptilodictya*; the brachiopods by *Atrypa*, *Rhynchonella*, *Leptæna*, *Orthis* (many species), *Strophomena*, *Discina*, and *Lingula*; the lamellibranchs by *Modiolopsis*, *Mytilus*, *Palæarca*, *Pterinea*, *Orthonota*, and *Ctenodonta*; the gasteropods by *Murchisonia*, *Pleurotomaria*, *Raphistoma*, *Cyclonema*, *Euomphalus*, *Maclurea*, *Holopea*; the pteropods by *Conularia*, *Theca*, and *Ecculiomphalus*; the heteropods by various species of *Bellerophon*; and the cephalopods by many species of *Orthoceras*, with forms of *Cyrtoceras* and *Lituites*.

4. *Lower Llandovery Group.*—In North Wales the Bala beds about 5 miles S.E. of Bala Lake begin to be covered with grey grits, which gradually expand southwards until they attain a thickness of 1000 feet in South Wales. These overlying rocks are well displayed near the town of Llandovery, where they contain some conglomerate bands, and where Mr Aveline detected an unconformability between them and the Bala group below them, so that the subterranean movements had already begun, which in Wales marked the close of the Lower Silurian period. Elsewhere they seem to graduate downwards conformably into that group. They cover a considerable breadth of country in Cardigan and Carmarthenshire, owing to the numerous undulations into which they have been thrown. Their chief interest lies in the transition which they present between the fauna of the Lower and Upper Silurian formations. They have yielded in all about 128 species of fossils, whereof 11 are peculiar, 93 are common to the Bala group below, and 83 pass up into Upper Llandovery rocks above. Some of the peculiar fossils are *Nidulites favus*, *Meristella crassa*, *M. angustifrons*, and *Murchisonia angulata*. Among the forms which come up from the Bala group and disappear here are the corals *Heliolites interstinctus*, *Petraia subduplicata*, and *Favosites aspera*; the trilobites *Lichas laxatus* and *Illænus Bowmanni*; the brachiopods *Orthis Actoniæ* and *O. insularis*; the gasteropods *Murchisonia gyrogonia* and *Cylonema crebristria*; and the cephalopod *Orthoceras tenuicinctum*. But many of the Lower Silurian forms continue on into the Upper Llandovery beds. From the abundance of the peculiar brachiopods termed *Pentamerus* in the Lower, but still more in the Upper Llandovery rocks, these strata were formerly grouped together under the name of "Pentamerus beds." Though the same species are found in both divisions, *Pentamerus oblongus* is chiefly characteristic of the upper group and comparatively infrequent in the lower, while *Stricklandinia* (*Pentamerus*) *lens* abounds in the lower but appears more sparingly in the upper.

The Lower Silurian rocks, typically developed in Wales, extend over nearly the whole of Britain, though largely buried under more recent formations. They rise into the hilly tracts of Westmoreland and Cumberland, where they consist of the following subdivisions in descending order:—

(Lower Llandovery not represented.)	
Coniston Limestone and Shale	= Bala beds.
Volcanic series: tuffs and lavas without any intermixture of ordinary sedimentary strata except at the base, 12,000 ft.....	= Part of Bala, whole of Llandeilo, and perhaps part of Arenig formation.
Skiddaw Slates, 10,000 or 12,000 ft. base not seen	= Arenig, with perhaps Tremadoc and Lingula Flags.

Apart from the massive intercalation of volcanic rocks these strata present considerable lithological and palæontological differences from the typical subdivisions in Wales. The Skiddaw slates are black or dark-grey argillaceous, and in some beds sandy rocks, often much cleaved though seldom yielding workable slates, sometimes soft and black like Carboniferous shale. As a rule they are singularly unfossiliferous, but in some of their less cleaved and altered portions they have yielded about 40 species of graptolites (chiefly of the genera *Didymograptus*, *Diplograptus*, *Dichograptus*, *Tetragraptus*, *Phyllograptus*, and *Climacograptus*) *Lingula brevis*, traces of annelides, a few trilobites (*Æglina*, *Agnostus*, *Asaphus*, &c.), some phyllopods (*Caryocaris*), and remains of plants (*Buthotrephis*, &c.). In many places the slates have been metamorphosed, passing into chiastolite-slate, mica-schist, andalusite-schist, &c.

with protrusions of granite, syenite, and other crystalline rocks. Towards the close of the long period represented by the Skiddaw slates, volcanic action manifested itself, first by intermittent showers of ashes and streams of lava which were interstratified with the ordinary marine sediment, and then by a more powerful and continuous series of explosions, whereby a huge volcanic mountain or group of cones was piled up above the sea-level. The length of time occupied by this volcanic episode in Cumbrian geology may be inferred from the fact that all the Llandeilo and nearly all the Bala beds are absent here. The volcanic island slowly sank into a sea where Bala organisms flourished. Among these we find such familiar Bala species as *Favosites fibrosa*, *Heliolites interstinctus*, *Cybele verrucosa*, *Leptæna sericea*, *Orthis Actoniæ*, *O. biforata*, *O. calligramma*, *O. elegantula*, *O. porcata*, and *Strophomena rhomboidalis*. These organisms and their associates gathered on the submerged flanks of the sinking volcano into a bed of limestone—the Coniston limestone—which can still be traced for many miles through the Westmoreland hills, as the Bala limestone which it represents can be followed through the volcanic tracts of North Wales. The Coniston limestone is covered by certain flags and grits which from their organic remains are referred to the Upper Silurian series.

In the South of Scotland, according to the detailed researches of the Geological Survey, the Lower Silurian formations are represented by the subjoined groups of strata in descending order:—

Sandstones and conglomerates, Girvan valley	= Llandovery.
Conglomerates, grits, shales, and lenticular bands of limestone, Peeblesshire, Dumfriesshire, S.W. Ayrshire, sometimes 2000 ft.	= Caradoc or Bala.
Carsphairn group, coarse pebbly grits and greywacke, 1200 ft.....	= Llandeilo (14 000 ft.)
Upper Black Shale, with graptolites, 550 ft.	
Lowther group, olive, grey, and blue shales, and sandstones, 4000 ft. ...	
Dalveen group, greywacke and shale, with band of fine conglomerate, 3500 ft.....	
Queensberry group, massive greywackes and grits, with occasional conglomerate bands and some shales, 4500 ft.....	
Lower or Moffat Black Shale group, 200–400 ft.	
Ardwell group, brown flags, greywackes, and shales, sometimes purplish and red; base not seen	

As a whole these strata are singularly barren of organic remains. Most of the fossils which the Llandeilo groups contain lie in the bands of dark anthracitic shale which have been traced across nearly the whole breadth of the country. These shales are crowded with graptolites of recognizable Llandeilo forms, *Climacograptus teretiusculus*, *Diplograptus pristis*, and *Graptolithus sagittarius* being particularly abundant. Crustacea are exceedingly rare, but two phyllopods, *Discinocaris Browniana* and *Peltocharis apiychoides*, occur; while from Dumfriesshire two obscure trilobites are referred doubtfully to *Encrinurus* and *Phacops*. The vast thickness of sandy, gritty, and shaly unfossiliferous strata is the distinguishing feature of the Lower Silurian series in the south of Scotland. The Caradoc or Bala group lies unconformably upon the upper parts of the Llandeilo rocks. It contains in the eastern districts some calcareous conglomerates which here and there swell out into local masses of limestone. In the south-west of Ayrshire the limestones attain considerable dimensions. In these calcareous bands numerous Caradoc species have been found, among them *Cheirurus gelasinosus*, *Encrinurus punctatus*, with species of *Illænus* and *Asaphus*, *Orthis calligramma*, *O. confinis*, *Leptæna sericea*, *Maclurea*, and such corals as *Heliolites*, *Favosites*, *Omphyma*, and *Strephodes*. In the south-west of Ayrshire certain shales and sandstones full of Caradoc fossils are overlaid with sandstones, shales, and conglomerates containing *Pentamerus oblongus*, *Atrypa hemispherica*, *Meristella angustifrons*, *Lichas laxatus*, *Petraia elongata*, *Nidulites favus*, and numerous other fossils which indicate the horizon of the Llandovery rocks.

The Highlands of Scotland consist mainly of crystalline rocks—gneiss, mica-schist, chlorite-schist, clay-slate, quartz-rock, schistose flagstone, and many others, often much invaded by granite and other intrusive masses. It was at one time supposed that these rocks all belonged to the so-called primary or primitive series, older than any of the fossiliferous systems. But the discovery by Mr C. W. Peach, already referred to, that recognizable fossils occur in the limestone of Durness in Sutherlandshire, led Murchison to infer that the whole of the overlying gneissose and schistose masses are really metamorphosed Lower Silurian rocks—a generalization which has been completely confirmed by subsequent investigation. At the base of this great series of rocks masses of white quartz-rock are found lying with a marked unconformability upon the red sandstones described in a previous page. These quartzose beds are merely hardened and somewhat metamorphosed sandstones; they still show their original false-bedding, and the casts of sea-weeds and worm-burrows. They contain a band of limestone which in Assynt swells out to a thickness of 1000 feet or more, and can be traced almost continuously from the Kyles of Skye to the north coast of Sutherlandshire. Over these strata, in perfect conformable sequence, and with a complete lithological gradation, come quartzose flagstones dipping like the rocks below at gentle angles to the south-east. They become more schistose and crumpled as they are traced upwards, until, after a thickness of several thousand feet has been passed over, they begin to undulate in steep folds and pass into the ordinary schistose rocks which cover so much of the Highlands. The gradation from the comparatively unaltered lower quartz-rocks and limestones on the west to the intensely crumpled crystalline upper schists and flagstones on the east can be followed step by step in numerous fine natural sections from the north of Sutherland to the Kyles of Skye. The proof is thus complete that a vast mass of schists and other crystalline rocks overlies fossiliferous limestones in the Scottish Highlands. It therefore becomes of the utmost importance to determine the geological horizon of the fossils in the limestones. This was done by the late Mr Salter, who declared his conviction that they were unequivocally Lower Silurian, and bore a most remarkable resemblance to a group of fossils from the Lower Silurian rocks of North America. Five of the species he regarded as identical with known American forms (*Orthoceras arcuoliratum*, Hall; *Orthis striatula*, Emmons; *Ophileta compacta*, Salt.; *Murchisonia gracilis*, Hall; *M. bellicincta*, Hall), 4 as representative, 3 doubtful, and 1 new genus, found also in Canada. "That this truly North American assemblage," he remarks, "should be found in the extreme north of Scotland on the same parallel as the Canadian,—that species of *Maclurea* and *Raphistoma*, resembling those of the St Lawrence basin, and *Orthoceratа*, bearing large siphuncles like those of North America, Scandinavia, and Russia, should occur in Scotland and yet be scarcely known further south, is at least suggestive of a geographical distribution—perhaps even of climatal conditions—not very unlike that of more modern times."[1] From this palæontological decision it follows that the overlying schistose series of the Scottish Highlands is a mass of metamorphosed Silurian strata. Examined in detail they show very unequal and sporadic metamorphism. Some portions are scarcely more changed than the ordinary greywackes and shales of unaltered districts. False-bedding, pebble-beds, and other common features of sedimentation occur abundantly throughout the whole vast series of schists. Here and there the metamorphism has become extreme, the rocks passing into coarsely crystalline schists full of garnets, with bands of hornblende-rock, actinolite-schist, and other metamorphic products, and passing even into granitic gneiss and true granite. No more convincing proof could be obtained that vast masses of schist do not necessarily belong to an azoic period of the earth's history, but may have been produced by the alteration of previously existing sediments.

It is not necessary to believe that the sediments so altered were in all cases mere ordinary marine sand and mud. The white quartz-rocks were no doubt at one time pure white siliceous sand, the rounded grains of which can still be readily detected in them. The quartzose flagstones were stratified sand with thin partings of clay or mud. The clay slates were evidently thick accumulations of mud. But the rocks containing a marked percentage of magnesia, such as chlorite-slate, actinolite-schist, hornblende-rock, &c., may have resulted from the alteration of volcanic sediments and submarine lavas. The evidence from Cumberland and Wales proves how voluminous and long continued were the volcanic eruptions of the Lower Silurian period in Britain. The abundant diffusion of volcanic detritus over the present sea-bottom is now well known. The "Challenger" researches have also shown us that, besides the glauconite previously known to be deposited from sea-water in the chambers of foraminifera and other dead organisms on the ocean-bottom, true magnesian silicates are now in the process of elimination from sea-water in some of the abysses of the ocean. It is quite possible therefore that some of the rocks of the metamorphic series rich in magnesian silicates may have arisen from the alteration of volcanic tuffs or submarine lavas, and that others may owe their distinctive composition to original chemical precipitation, as ably contended by Sterry Hunt, though their present crystalline structure must be regarded as a part of the general metamorphism by which the whole of the Lower Silurian rocks of the Highlands have been affected.

In the south-east of Ireland, grey, greenish, and purple grits, and grey and dark shales, lie unconformably upon the Cambrian rocks, and contain a few fossils of Llandeilo age. They present interstratified beds of tuff and felsitic lavas indicating contemporaneous volcanic action. In the north-east of the island a broad

[1] *Quart. Jour. Geol. Soc.*, xx. 881.

belt of Lower Silurian rocks runs from the coast of Down into the heart of Roscommon and Longford. This belt is evidently a prolongation of that in the southern uplands of Scotland. It is marked by the occurrence of similar dark anthracitic shales crowded with graptolites. The richest fossiliferous localities among the Irish Lower Silurian rocks are found at the Chair of Kildare, Portrane near Dublin, Pomeroy in Tyrone, and Lisbellan in Fermanagh, where small protrusions of the older rocks rise as oases among the surrounding later formations. Portlock brought the northern and western localities to light, and Murchison pointed out that, while a number of the trilobites (*Trinucleus*, *Phacops*, *Calymene*, and *Illænus*), as well as the simple plaited *Orthidæ*, *Leptænæ*, and *Strophomenæ*, some spiral shells, and many *Orthocerata*, are specifically identical with those from the typical Caradoc and Bala beds of Shropshire and Wales, yet they are associated with peculiar forms, first discovered in Ireland, and very rare elsewhere in the British Islands. Among these distinctive fossils he cites the trilobites, *Remopleurides*, *Harpes*, *Amphion*, and *Bronteus*, with the smooth forms of *Asaphus* (*Isotelus*), which, though abundant in Ireland and America, seldom occur in Wales or England, and never on the Continent.[1]

In the north and west of Ireland a large area of surface is occupied by crystalline rocks—gneiss, schists, quartz-rocks, limestone, granite, &c.—which are manifestly a continuation of those of the Highlands of Scotland. They run south-westward parallel with the belt of unaltered Lower Silurian rocks from which, in some places, as in county Tyrone, they are only a few miles distant. The district of Pomeroy, so rich in Silurian fossils, promises to afford the greatest light on the interesting but difficult problem of the metamorphism of the Lower Silurian rocks of the Scottish Highlands and the north-west of Ireland. It will be seen from the evidence furnished by the sections in West Mayo (p. 337) that the metamorphism must have taken place prior to the deposition of the Upper Silurian formations of the west of Ireland.

B. *Upper Silurian.*

The formations which in the British Islands are classed as Upper Silurian occur in two very distinct types. So great indeed is the contrast between these types that it is only by a comparison of organic remains that the whole can be grouped together as the deposits of one great geological period. In the original region described by Murchison, and from which his type of the system was taken, the strata are comparatively flat, soft, unaltered, consisting mainly of somewhat incoherent sandy mud with occasional bands of limestone. But as these rocks are followed into North Wales, they are found to swell out into a vast series of grits and shales so like portions of the hard altered Lower Silurian rocks that, save for the evidence of fossils, they would naturally be grouped as part of that more ancient series. In Westmoreland and Cumberland, and still further north in the border counties of Scotland, also in the south-west of Ireland, it is the North Welsh type which prevails, so that in Britain the general lithological characters and minute palæontological subdivisions ascertained in the typical Silurian district are almost confined to that limited region, while over the rest of the British area for thousands of square miles the hard sandy and shaly type of North Wales is prevalent.

Taking first the Silurian tract of the south-west of England, and the east and south of Wales, we find a decided unconformability separating the Lower from the Upper Silurian formations. In some places the latter are found passing across the edges of the former, group after group, till they come to lie directly upon the Cambrian rocks. Indeed, in one district between the Longmynd and Wenlock edge, the base of the Upper Silurian rocks is found within a few miles to pass from the Caradoc group across to the Lower Cambrian rocks. It is evident, therefore, that in the Welsh region very great disturbance and extensive denudation preceded the commencement of the deposition of the Upper Silurian rocks. As Professor Ramsay has pointed out, the area of Wales, previously covered by a wide though shallow sea, was ridged up into a series of islands, round the margin of which the conglomerates at the base of the Upper Silurian series began to be laid down. This took place during a time of submergence, for these conglomeratic and sandy strata are found creeping up the slopes and even capping some of the heights, as at Bogmine, where they reach a height of 1150 feet above the sea.[2] The subsidence probably continued during the whole of the interval occupied by the deposition of the Upper Silurian strata, which thus were piled to a depth of from 3000 to 5000 feet over the disturbed and denuded platform of Lower Silurian rocks.

Arranged in tabular form, the subdivisions of the Upper Silurian rocks of Wales and the adjoining counties of England are in descending order as follows:—

		Base of Old Red Sandstone.	
3. Ludlow group		Tilestones. Upper Ludlow Rock. Aymestry Limestone. Lower Ludlow Rock.	
2. Wenlock-group	Wenlock or Dudley Limestone Wenlock Shale Woolhope or Barr Limestone and Shale	=	Denbighshire Grits of North Wales.
1. Upper Llandovery group...	Tarannon Shale. May Hill Sandstones. Lower Llandovery Rocks.		

1. *Upper Llandovery Group.*—(*a.*) *May Hill Sandstones.*—The position of these rocks as the true base of the Upper Silurian formations was first shown in 1853 by Sedgwick, who named them the May Hill Sandstones from the locality in Gloucestershire where they are so well displayed. Appearing on the coast of Pembrokeshire at Marloes Bay, they range across South Wales until they are overlapped by the Old Red Sandstone. They emerge again in Carmarthenshire, and trend north-eastward as a narrow strip at the base of the Upper Silurian series, from a few feet to 1000 feet or more in thickness, as far as the Longmynd, where as a marked conglomerate wrapping round that ancient Cambrian ridge they disappear. In the course of this long tract they pass successively and unconformably over Lower Llandovery, Caradoc, Llandeilo, and Cambrian rocks. They consist of yellow and brown ferruginous sandstones, often full of shells, which are apt to weather out and leave casts. Their lower parts are commonly conglomeratic, the pebbles being largely derived from older parts of the Silurian formations. Here and there, where the organic remains become extraordinarily abundant, the strata pass into a kind of sandy limestone, known as the "Pentamerus limestone," from the numbers of this brachiopod contained in it. The species of fossils found in the May Hill Sandstones number about 230.

Among these are some traces of fucoids; sponges (*Cliona*, *Ischadites*); the widely diffused *Graptolithus priodon*; a number of corals (*Petraia*, *Heliolites*, *Favosites*, *Halysites*, *Syringopora*, &c.); a few crinoids; some annelides, particularly the *Tentaculites anglicus*, which is abundant; a number of trilobites, of which *Phacops Stokesii*, *P. Weaveri*, *Encrinurus punctatus*, and *Calymene Blumenbachii* are common; numerous brachiopods, as *Atrypa hemisphærica*, *A. reticularis*, *Pentamerus oblongus*, *Stricklandinia lirata* (*S. lens* also occurs), *Leptæna transversalis*, *Orthis calligramma*, *O. elegantula*, *O. reversa*, *Strophomena compressa*, *S. pecten*, and *Lingula parallela*; lamellibranchs of the mytiloid genera *Orthonota*, *Mytilus*, and *Modiolopsis*, with forms of *Pterinea*, *Ctenodonta*, and *Lyrodesma*; gasteropods, particularly the genera *Murchisonia*, *Pleurotomaria*, *Cyclonema*, *Holopella*; and cephalopods, chiefly *Orthocerata*, with some forms of *Actinoceras* and *Phragmoceras*, and the old species *Lituites cornu-arietis*.

(*b.*) *Tarannon Shale.*—Above the Upper Llandovery beds comes a very persistent zone of fine, smooth, light grey or blue slates, which has been traced down the whole length of Wales from the mouth of the Conway into Carmarthenshire. These rocks, termed the "paste-rock" by Sedgwick, have an extreme thickness of 1000 to 1500 feet. Barren in organic remains, their chief interest lies in the fact that

[1] *Siluria*. p. 174.

[2] *Physical Geology of Britain*, p. 91.

the persistence of so thick a band of rock between what were supposed to be continuous and conformable formations should have been unrecognized until it was proved by the detailed mapping of the Geological Survey.

2. *Wenlock Group.*—(*a.*) *Woolhope Limestone.*—In the original typical Upper Silurian tract of Shropshire and the adjacent counties, the Upper Llandovery rocks are overlaid by a local group of grey shales containing nodular limestone which here and there swells out into beds having an aggregate thickness of 30 or 40 feet. These strata are well displayed in the picturesque valley of Woolhope in Herefordshire, which lies upon a worn quaquaversal dome of Upper Silurian strata rising in the midst of the surrounding Old Red Sandstone. They are seen likewise to the north-west at Presteign, Nash Scar, and Old Radnor in Radnorshire, and to the east and south in the Malvern Hills (where they include a great thickness of shale below the limestone), and May Hill in Gloucestershire. These strata have yielded many characteristically Upper Silurian fossils, among which may be mentioned *Bumastus Barriensis*, *Homalonotus delphinocephalus*, *Phacops caudatus*, *Atrypa reticularis*, *Orthis calligramma*, *Strophomena imbrex*, *Rhynchonella borealis*, *R. Wilsoni*, *Ewomphalus sculptus*, *Orthoceras annulatum*.

It is a characteristic of the older Palæozoic limestones to occur in a very lenticular form, swelling in some places to a great thickness and rapidly dying out, to reappear again perhaps some miles away with increased proportions. This local character is well exhibited by the Woolhope limestone. Where it dies out, the shales underneath and intercalated with it join on continuously to the overlying Wenlock shale, and no line for the Woolhope group can then be satisfactorily drawn. The same discontinuity is strikingly traceable in the Wenlock limestone to be immediately referred to.

(*b.*) *Wenlock Shale.*—This is a group of grey and black fine shales, traceable from the banks of the Severn near Coalbrook Dale across Radnorshire to near Carmarthen—a distance of about 90 miles. The same strata reappear in the protrusions of Upper Silurian rock which rise out of the Old Red Sandstone plains of Gloucestershire, Herefordshire, and Monmouthshire. In the Malvern Hills they were estimated by Professor Phillips to reach a thickness of 640 feet, but towards the north they thicken out to 1000 or even 1400 feet. On the whole the fossils are identical with those of the overlying limestone. The corals, however, so abundant in that rock are here comparatively rare. The brachiopods (of the genera *Leptæna*, *Orthis*, *Strophomena*, *Atrypa*, and *Rhynchonella*) are generally of small size—*Orthis biloba*, *O. hybrida*, and the large flat *O. rustica*, being characteristic. Of the higher mollusca thin-shelled forms of *Orthoceras* are specially abundant. Among the trilobites, *Encrinurus punctatus*, *E. variolaris*, *Calymene Blumenbachii*, *C. tuberculosa*, *Phacops caudatus*, and *P. longicaudatus* are common. The *Graptolithus priodon*, so frequent among the Bala beds of the Lower Silurian series, also occurs in the Wenlock shale. *Graptolithus Flemingii* is here a characteristic species.

(*c.*) *Wenlock Limestone* is a thick-bedded, sometimes flaggy, usually more or less concretionary limestone, grey or pale pink, often highly crystalline, occurring in some places as a single massive bed, in others as two or more strata separated by grey shales, the whole forming a thickness of rock ranging from 100 to 300 feet. As its name denotes, this stratum is typically developed along Wenlock Edge in Shropshire, where it runs as a prominent ridge for fully 20 miles, also between Aymestry and Ludlow. It likewise appears at the detached areas of Upper Silurian strata above referred to, being specially well seen near Dudley (whence it is often spoken of as the Dudley limestone), Woolhope, Malvern, May Hill, and Usk in Monmouthshire.

A distinguishing characteristic of the Wenlock limestone is the abundance and variety of its corals, of which 58 species have been described. The rock seems indeed to have been formed in part by massive sheets and bunches of coral. Among characteristic species are *Halysites catenularia*, *Heliolites interstinctus*, *H. tubulatus*, *Alveolites Labechei*, *Favosites aspera*, *F. fibrosa*, *F. Gothlandica*, *Cœnites juniperinus*, *Syringopora fascicularis*, and *Omphyma turbinatum*. The crinoids are also specially abundant, and are often beautifully preserved: *Periechocrinus moniliformis* is one of the most frequent species; others are *Orotalocrinus rugosus*, *Cyathocrinus goniodactylus*, and *Marsupiocrinus costatus*; with several cystideans, as *Pseudocrinites quadrifasciatus*. The crustaceans include numerous trilobites, among which we miss some of the persistent Lower Silurian genera, such as *Asaphus*, *Ogygia*, and *Trinucleus*, none of which ascend into the Wenlock group. The most abundant trilobite is the long-lived *Calymene Blumenbachii*, which ranges from the Llandeilo flags up to near the top of the Upper Silurian formations. It occurs abundantly at Dudley, where it received the name of the "Dudley Locust." Other common forms are *Encrinurus punctatus*, *E. variolaris*, *Phacops caudatus*, *P. Downingiæ*, *P. Stokesii*, *Bumastus Barriensis*, *Homalonotus delphinocephalus*, and *Cheirurus bimucronatus*. The brachiopods continue to be abundant; among typical species may be noted *Atrypa reticularis*, *Meristella tumida*, *Spirifer elevatus*, *S. plicatellus*, *Rhynchonella borealis* (very common), *R. cuneata*, *R. Wilsoni*, *Orthis elegantula*, *O. rustica*, *Strophomena rhomboidalis*, and *Pentamerus galeatus*. The lamellibranchs are not well represented; but several species of *Pterinea* are abundant, with *Grammysia cingulata*, and some species of *Modiolopsis* and *Ctenodonta*. The gasteropods are most characteristically marked by 8 or 9 species of *Euomphalus*, 3 or more of *Murchisonia*, with species of *Pleurotomaria*, *Acroculia*, and *Cyclonema*. The cephalopods are confined to few genera, *Lituites*, *Actinoceras*, *Cyrtoceras*, *Orthoceras*, and *Phragmoceras*; of these the orthoceratites are by far the most abundant both in species and individuals. *Orthoceras annulatum* is the most common form. The pteropods appear in the beautiful and very abundant *Conularia Sowerbyi*, and the heteropods in the common and characteristic *Bellerophon Wenlockensis*.

3. *Ludlow Group.*—This series of strata consists essentially of shales, with occasionally a calcareous band in the middle. It graduates downward into the Wenlock group, so that when the Wenlock limestone disappears the Wenlock and Ludlow shales form one continuous argillaceous formation. It is in this united form that the two groups stretch to the south-west through Brecon and Carmarthen. The Ludlow rocks are typically seen between Ludlow and Aymestry. They appear likewise at the detached Silurian areas from Dudley to the mouth of the Severn. They were grouped by Murchison into three zones.

(*a.*) *Lower Ludlow Rock.*—This is a group of soft dark-grey to pale greenish-brown or olive sandy shales, often with calcareous concretions. Much of the rock, however, presents so little fissile structure as to get the name of mudstone, weathering out into concretions which fall to angular fragments as the rock crumbles down. It becomes more sandy and flaggy towards the top. From the softness of the shales this zone of rock has been extensively denuded, and the Wenlock limestone rises up boldly from under it.

An abundant suite of fossils has been yielded by these shales. No fewer than 18 species of star-fishes, belonging to 6 genera, have been described (*Protaster*, like the brittle-stars of the British seas, *Palæocoma*, *Palasterina*). A few graptolites occur, particularly the persistent *Graptolithus priodon* (common), *G. colonus*, and *G. Flemingii*. A few of the Wenlock corals survive in the Lower Ludlow rock, but the conditions of deposit were evidently unfavourable for their growth. The trilobites are less numerous than in older beds; they include the venerable *Calymene Blumenbachii*, *Phacops caudatus*, and its still longer-tailed variety *P. longicaudatus*; also *Acidaspis Brightii*, *Homalonotus delphinocephalus*, and *Cyphaspis megalops*. But other forms of crustacean life occur in some number. As the trilobites begin to wane numerous phyllopods appear, the genus *Ceratiocaris* being represented by 10 or more species. Large eurypterids now make their entrance upon geological history — *Eurypterus*, *Pterygotus*, and *Hemiaspis*. Though brachiopods are not scarce, hardly any seem to be peculiar to the Lower Ludlow rock, the *Lingula lata*, which Murchison suggested might be peculiar, having been obtained from what is supposed to be representative of this group of strata in Westmoreland. *Rhynchonella Wilsoni*, *Spirifer exporrectus*, *Strophomena euglypha*, *Atrypa reticularis*, and *Chonetes minima* are not infre-