quent. Among the more frequently recurring species of lamelli-branchs the following may be named—*Cardiola interrupta*, *C. striata*, *Orthonota rigida*, *O. semisulcata*, and a number of species of *Pterinea*. The orthoceratites are numerous, as *Orthoceras Ludense*, *O. subundulatum*, also species of *Phragmoceras* and *Lituites*. The numbers of these straight and curved cephalopods form one of the distinguishing features of the zone. At one locality, near Leintwardine in Shropshire, which has been prolific in Lower Ludlow fossils, particularly in star-fishes and eurypterid crustaceans, a fragment of the fish *Pteraspis* was discovered in 1859. This is the earliest trace of vertebrate life yet detected. It is interesting to note that the *Pteraspis* does not stand low in the scale of organization, but has affinities with our modern sturgeon.

(*b.*) *Aymestry Limestone* is a dark grey somewhat earthy concretionary limestone in beds from 1 to 5 feet thick. Where at its thickest it forms a conspicuous feature, rising above the soft and denuded Lower Ludlow shales and, owing to the easily removable nature of some fuller's earth on which it lies, it has here and there been dislocated by large landslips. It is still more inconstant than the Wenlock limestone. Though well developed at Aymestry it soon dies away into bands of calcareous nodules, which finally disappear, and the lower and upper divisions of the Ludlow group then come together. The most characteristic fossil is the *Pentamerus Knightii*; other common forms are *Rhynchonella Wilsoni*, *Lingula Lewisii*, *Strophomena euglypha*, *Bellerophon dilatatus*, *Pterinea Sowerbyi*, with many of the same shells, corals, and trilobites found in the Wenlock limestone. Indeed, as Murchison has pointed out, except in the less number of species and the occurrence of some of the shells more characteristic of the Upper Ludlow zone, there is not much palæontological distinction between the two limestones.[1]

(*c.*) *Upper Ludlow Rock.*—In the original Silurian district described by Murchison, the Aymestry limestone is covered by a calcareous shelly band full of *Rhynchonella navicula*, sometimes 30 or 40 feet thick. This layer is succeeded by grey sandy shale or mudstone, often weathering into concretions as in the Lower Ludlow zone, and assuming externally the same rusty-brown or greyish olive-green hue. Its harder beds are quarried for building-stone; but the general character of the deposit, like that of the argillaceous portions of the Upper Silurian formations as a whole in the typical district of Siluria, is soft, incoherent, and crumbling, easily decomposing once more into the original mud, and presenting in this respect a contrast to the hard fissile and often slaty shales of the Lower Silurian series. Many of the sandstone beds are crowded with ripple-marks, rill-marks, and annelid-trails, indicative of the shallow littoral waters in which they were deposited. One of the uppermost sandstones is termed the "Fucoid Bed," from the number of its cylindrical sea-weed-like stems. It likewise contains numerous inverted pyramidal bodies, which are believed to be casts of the cavities made in the muddy sand by the rotatory movement of crinoids rooted and half-buried in the micaceous mud.[2] At the top of the Upper Ludlow rock near the town of Ludlow, a brown layer occurs from a quarter of an inch to 3 or 4 inches in thickness, full of fragments of fish, *Pteygotus*, and shells. This layer, termed the "Ludlow Bone-bed," is the oldest from which any considerable number of vertebrate remains has been obtained. In spite of its insignificant thickness it has been detected at numerous localities from Ludlow as far as Pyrton passage, at the mouth of the Severn—a distance of 45 miles from north to south, and from Kington to Ledbury and Malvern—a distance of nearly 30 miles from west to east; so that it probably covers an area (now largely buried under Old Red Sandstone) not less than 1000 square miles in extent, yet it appears never to exceed and usually to fall short of a thickness of 1 foot. Fish remains, however, are not confined to this horizon. They have been detected in strata above the original bone-bed at Ludlow, together with some minute globular bodies believed to be the sporangia of a lycopod. These, with some other plant remains from the same district, are the earliest traces of land vegetation yet found. The higher parts of the Ludlow rock consist of fine yellow sandstone and harder grits known as the Downton sandstone. Originally the whole of these flaggy upper parts of the Ludlow group were called "Tilestones" by Murchison, and being often red in colour were included by him as the base of the Old Red Sandstone, into which they gradually and conformably ascend. Undoubtedly they show the gradual change of physical conditions which took place at the close of the Silurian period in the west of England, and brought in the deposits of the Old Red Sandstone. But as their organic contents are still unequivocally those of the Ludlow group, they are now classed as the uppermost zone of the Silurian system.

A considerable suite of organic remains has been obtained from the Upper Ludlow rock, which on the whole are the same as those in the zones underneath. Vegetable remains, some of which seem to be fucoids, but most of which are probably terrestrial and lycopodiaceous, abound in the Downton sandstone and passage-beds into the Old Red Sandstone. Corals, as might be supposed from the muddy character of the deposit, seldom occur, though Murchison mentions that the encrusting form *Alveolites fibrosus* may not infrequently be found enveloping shells, *Cyclonema corallii* and *Murchisonia corallii* being, as their names imply, its favourite habitats. Some annelides (*Serpulites longispinus*, *Cornulites serpularius*, *Tentaculites tenuis*, and *Trachyderma coriacea*) are not uncommon. The crustacea are represented chiefly by small ostracods (*Beyrichia Klœdeni*, *Leperditia marginata*, *Entomis tuberosa*), and by species of *Ceratiocaris*, *Dictyocaris*, *Eurypterus*, *Hemiaspis*, *Pterygotus*, and *Stylonurus*; the trilobites having still further waned, though *Homalonotus Knightii*, *Encrinurus punctatus*, *Phacops Downingiæ*, and a few others still occur, and even the persistent *Calymene Blumenbachii* may occasionally be found. Of the brachiopods the most abundant forms are *Rhynchonella nucula*, *Chonetes striatella*, *Discina rugata*, and *Lingula cornea*. The most characteristic lamelli-branchs are *Orthonota amygdalina*, *Goniophora cymbæformis*, *Pterinea lineata*, *P. retroflexa*; some of the commonest gasteropods are *Murchisonia corallii*, *Platyschisma helicites*, and *Holopella obsoleta*. The orthoceratites are specifically identical with those of the Lower Ludlow rock, and are sometimes of large size, *Orthoceras bullatum* being specially abundant. The fish remains consist of bones, teeth, shagreen-like scales, plates, and fin-spines. They include some plagiostomous (placoid) forms (*Thelodus*, shagreen-scales, *Sphagodus*, skin, *Onchus*, spines) and some ostracostean (*Cephalaspis*, *Auchenaspis*, and *Pteraspis*).

In the typical Silurian region of Shropshire and the adjacent counties, nothing can be more decided than the lithological evidence for the gradual disappearance of the Silurian sea, with its crowds of graptolites, trilobites, and brachiopods, and for the gradual introduction of those geographical conditions which brought about the deposit of the Old Red Sandstone. The fine grey and olive-coloured muds, with their occasional zones of limestone, are succeeded by bright red clays, sandstones, cornstones, and conglomerates. The evidence from fossils is equally explicit. Up to the top of the Ludlow rocks the abundant Silurian fauna continues in hardly diminished numbers. But as soon as the red strata begin the organic remains rapidly die out, until at last only the fish and the large eurypterid crustaceans continue to occur.

Turning now from the interesting and extremely important though limited area in which the original type of the Upper Silurian rocks is developed, we observe that whether we pass northwards or south-westwards the soft mudstones and thick limestones give way to hard slates, grits, and flagstones, among which it is scarcely possible sometimes even to discriminate what represents the Wenlock from what may be the equivalent of the Ludlow group. It is in Denbighshire and the adjacent counties that this change becomes most marked. The Tarannon shale above described passes into that region of North Wales, where it forms the base of the Upper Silurian formations. It is covered

[1] *Siluria*, p. 130. [2] *Siluria*, p. 133.

by a series of grits or sandstones which in some places are at least 3000 feet thick. These are covered by and pass laterally into hard shales, which are believed to represent parts of the true Wenlock group, perhaps even some portion of the Ludlow rocks. It is evident, however, that in spite of the wide extent over which these Silurian rocks of North Wales are spread, and the great thickness which they attain, they do not present an adequate stratigraphical equivalent for the complete succession in the original Silurian district. Instead of passing up conformably into the base of the Old Red Sandstone, as at Ludlow, they are covered by that formation unconformably. In fact they have been upturned, crumpled, faulted, and cleaved before the deposition of those portions of the Old Red Sandstone which lie upon them. These great physical changes took place in Denbighshire when, so far as the evidence goes, there was entire quiescence in the Shropshire district; yet the distance between the two areas was not more than about 60 miles. These subterranean movements were doubtless the precursors of those more widely extended upheavals which converted the floor of the Silurian sea into a series of isolated basins, in which the Old Red Sandstone was laid down.

In Westmoreland and Cumberland a vast mass of hard slates, grits, and flags was identified by Sedgwick as of Upper Silurian age. These form the varied ranges of hills in the southern part of the lake district from near Shap to Duddon mouth. The following are the local subdivisions with the conjectural equivalents in Siluria.[1]

Hay Fell and Kirkby Moor Flags	Flaggy beds, with lamelli-branchs abundant	(?) Tilestones.
	Massive greenish and grey sandstones, with bands of fossils, *Holopella* abundant	Upper Ludlow.
Bannisdale Slates	Calcareous beds, with *Rhynchonella navicula* abundant	Aymestry Limestone.
	Sandstone and shale, with star-fish	Lower Ludlow.
	Dark blue flags and grits of great thickness	Upper Wenlock.
Coniston Grits	Flags and greywacke (*Orthoceras subundulatum*, *O. angulatum*, *Graptolithus Flemingii*, *G. colonus*, *Ceratiocaris Murchisoni*), upwards of 4000 feet	Lower Wenlock.
Coniston Flags	Dark grey coarse flags (*Cardiola interrupta*, *Orthoceras subundulatum*), 1000 feet	
Coniston Limestone (Lower Silurian)		Caradoc or Bala.

In the northern part of the Lake district a great anticlinal fold takes place. The Skiddaw slates arch over and are succeeded by the base of the volcanic series above described. But before more than a small portion of that series has appeared the whole Silurian area is overlapped unconformably by the Carboniferous Limestone series. It is necessary to cross the broad plains of Cumberland and the south of Dumfriesshire before Silurian rocks are again met with. In this intervening tract a synclinal fold must lie, for along the southern base of the uplands of the south of Scotland a belt of Upper Silurian rocks, dipping on the whole to the south-east, can be traced from the heart of the Cheviot Hills to the headlands of Wigtownshire. These rocks must reach a thickness of several thousand feet, but their top is nowhere seen. They repose on some of the older parts of the Llandeilo series, with so close a coincidence of dip and strike that no decided unconformability has yet been traced between them. They consist essentially of shales, with a considerable proportion of greywacke bands towards the base. At different horizons they contain lenticular bands of a calcareous pebbly grit. But their most characteristic feature, and one which at once distinguishes them locally from the adjoining Lower Silurian rocks, is the occurrence of a nearly black, highly fissile shale, composed of layers in most cases as thin as ordinary writing paper and usually crowded with graptolites. These peculiar bands occur throughout the whole series of rocks from bottom to top. They are sometimes so thin that 20 or 30 seams or ribs, each finely fissile, may be seen intercalated within the space of an inch of the ordinary shale or greywacke. Occasionally they form zones 80 to 100 feet thick, consisting entirely of finely leaved graptolitic shales. As a whole these Upper Silurian strata resemble lithologically the corresponding series in Westmoreland, though here and there they assume the character of mudstones not unlike those of Shropshire. The abundant fossils in them are simple graptolites (*Graptolithus Sedgwickii*, *G. Becki*, *G. Flemingii*, *G. colonus*, *G. Griestonensis*, *Retiolites Geinitzianus*, &c.). Orthoceratites come next in point of numbers (*Orthoceras annulatum*, *O. tenuicinctum*, &c.). In some of the shales crustacean fragments are numerous. They include large pieces of the carapace of *Dictyocaris*, with remains of *Pterygotus* and *Ceratiocaris*. The pebbly grits contain *Petraia* and crinoid stems. In the south of Kirkcudbright certain limestones and conglomerates intercalated among these shales have yielded a more varied fauna, having on the whole a decidedly Wenlock character. It includes *Favosites*, *Catenipora*, *Beyrichia tuberculata*, *Phacops caudatus*, *Meristella*, *Leptæna sericea*, *Atrypa reticularis*, *Strophomena imbrex*, *Murchisonia*, *Orthoceras tenuicinctum*, &c.

It is impossible in the south of Scotland to separate the Upper Silurian rocks into Wenlock and Ludlow groups. On the whole these rocks seem to be representative mainly of the older half of the Upper Silurian formations. They are covered unconformably by Lower Old Red Sandstone and later formations. In the counties of Edinburgh and Lanark, however, the base of the Lower Old Red Sandstone is found to graduate downward into a thick series of brown, olive, and grey shales, sandstones, and grits, containing undoubted Ludlow fossils. It is deserving of remark also that the peculiar lithological type so characteristic of the strata in the original Silurian area reappears in the centre of Scotland, many of the concretionary brown shales and olive-coloured mudstones being undistinguishable from those in the typical sections at Ludlow. Some of these beds are crowded with fossils. Among the most characteristic are *Leptæna transversalis*, *Orthonota amygdalina*, *Platyschisma helicites*, *Beyrichia Klœdeni*, *Orthoceras Maclareni*, with many crustaceans of the genera *Ceratiocaris*, *Eurypterus*, *Pterygotus*, *Slimonia*, and *Stylonurus*. In the Pentland Hills these strata are estimated to attain a thickness of 3500 to 4000 feet, but their base is nowhere reached; in Lanarkshire they are at least as thick. Their lower portions may represent some of the higher parts of the Wenlock group.

Ireland furnishes some interesting evidence regarding the geographical changes in the west of Europe between the close of the Lower Silurian and the beginning of the Upper Silurian period. It has already been pointed out that the metamorphosed Lower Silurian rocks of the Scottish Highlands are prolonged into the north of Ireland, whence they range south-westwards to Galway Bay. In the picturesque tract between Loch Mask and the mouth of Killary harbour these metamorphosed rocks are unconformably overlaid by masses of sandstones, conglomerates, and shales more than 7000 feet thick, and containing Llandovery and Wenlock fossils with a mixture of Caradoc forms. In the midst

[1] The arrangement and thicknesses here given are those in the Kendal district as mapped by Mr Aveline and Mr Hughes in the course of the Geological Survey (*Sheet* 98, S.E., *Explanation*, pp. 6–13, 1872).

of the greatly metamorphosed Lower Silurian platform, portions are to be found still little altered and full of fossils. The overlying Upper Silurian strata have not been metamorphosed, but contain pebbles of the altered rocks on the upturned edges of which they lie. It is evident therefore, as Mr Hull has remarked, that the metamorphism must have occurred between the close of the Lower and the commencement of the Upper Silurian period.[1] In connexion with this question it should be remarked that abundant volcanic activity accompanied the deposit of these Upper Silurian rocks in the west of Ireland, successive sheets of lava (eurite) and beds of tuff forming conspicuous bands among the stratified rocks, and reaching a collective thickness of 800 feet and upwards. Between Brandon Head and Dingle Bay a thick mass of strata on the coast, must, from the comparatively few fossils obtained from it, be held to represent Upper Silurian formations.

CONTINENTAL EUROPE.—The broad hollow which, running from the mouth of the English Channel across the plains of northern Germany into the heart of Russia, divides the high grounds of the north and north-west of Europe from those of the centre and south, separates the European Silurian area into two distinct tracts. In the northern of these we find the Lower and Upper Silurian formations attaining an enormous development in Britain, but rapidly diminishing in thickness towards the north-east, until in the south of Scandinavia and the Gulf of Finland they reach only about $\frac{1}{20}$th of that depth. In these tracts, too, they have on the whole escaped so well from the dislocations, crumplings, and metamorphisms so conspicuous to the south-west, that to this day they remain over wide areas nearly as horizontal and soft as at first. In the southern tract Silurian rocks appear only here and there from amidst later formations, and almost everywhere present proofs of intense subterranean movement.

In the south of Scandinavia (Christiania, Mjösen See, Malmö, Gothland) the Lower and Upper Silurian rocks attain a united thickness of not more than about 1300 feet, yet are said to contain representatives of all the leading subdivisions of the British series. The following table exhibits the Silurian succession in the south of Norway and Sweden, with the supposed English equivalents:—

Sandy beds, with *Pterinea retroflexa, Rhynchonella nucula, Orthonota retusa, Beyrichia tuberculata.* S. Gothland	= Upper Ludlow.
Upper Malmö limestone	= Lower Ludlow.
Upper Graptolite marls, with *Graptolithus priodon* (*Ludense*) abundant	
Lower Malmö or upper Orthoceratite limestone, with large *Orthocerata* having central siphuncles	
Encrinital schists with orthoceratites and *Gomphoceras pyriforme*	= Wenlock.
Coral limestone (*Omphyma turbinatum* and other Wenlock corals)	
Pentamerus limestone, *Pentamerus oblongus, P. galeatus, Strickiandinia lens, Leptæna transversalis, Encrinurus punctatus*, &c.	= Llandovery.
Lower argillaceous schists	
Calcareous sandstones (containing a mixture of Llandovery forms, as *Meristella angustifrons*, and many large smooth *Pentameri*)	= Caradoc.
Calcareous and argillaceous flagstones, *Orthis calligramma, O. testudinaria, O. pecten, Leptæna sericea, Comularia quadrisulcata, Asaphus expansus, Trinucleus concentricus*, &c.	
Orthoceratite limestone and lower Encrinital schists	
Upper Graptolite schists, with *Diplograptus pristis, D. folium, D. teretiusculus*, and forms of *Asaphus, Ogygia, Trinucleus*, &c.	= Llandeilo.
Lower Orthoceratite limestone, with *Orthoceras duplex, O. annulatum, Lituites cornu-arietis, Orthis calligramma, O. elegantula, Bellerophon bilobatus*, &c.	
Lower Graptolite schists (with numerous graptolites)	= Arenig in part.
Alum schists, 150 feet (= Regiones A and B of Angelin), containing the fossils enumerated on p. 331	= Cambrian.
Quartzite (Fucoids)	

[1] *Physical Geology of Ireland*, p. 22; Kinahan's *Geology of Ireland*, chap. iii.; *Geological Survey of Ireland, Explanation of Sheets* (76, 77, 83, and 84).

Though the general resemblance of the succession of fossils in Scandinavia and in Britain is singularly close, there are, as might have been anticipated, differences in the range of species, some forms having appeared earlier or having survived later in the one region than in the other. Thus the *Pentamerus oblongus* ascends in Scandinavia into rocks full of Wenlock corals, but does not occur in the Wenlock group of Britain. On the other hand, among Scandinavian strata containing such characteristically Lower Silurian genera of trilobites as *Asaphus, Trinucleus*, and *Ogygia*, there occur organisms which in Britain are typically Upper Silurian, such as *Orthoceras dimidiatum* and *O. distans*, two fossils of the Ludlow rocks. This is a point of considerable importance in its bearing upon the value of palæontological evidence in correlating the formations of different countries. It shows that the order of succession found to hold good in one region cannot be rigidly applied to others, and that in such cases it is not from individual species so much as from the general facies of the fossils that we must draw geological parallels. The first appearance and duration of a species have doubtless greatly varied in different regions.

In Russia Silurian rocks must occupy the whole vast breadth of territory between the Baltic and the flanks of the Ural Mountains, beyond which they spread eastwards into Asia. Throughout most of this extensive area they lie in horizontal undisturbed beds, covered over and concealed from view by later formations. Along the flanks of the Urals they have been upheaved, and placed on end or at a high angle against the central portions of that chain, and have been partially metamorphosed into chlorite-schist, micaschist, quartz-rock, and other crystalline masses. But along the southern margin of the Gulf of Finland they appear at the surface as soft clays, sands, and unaltered strata, which, so far as their lithological characters go, might be supposed to be of late Tertiary date, so little have they been changed during the enormous lapse of ages since Lower Palæozoic time. The great plains between the Ural chain on the east and the rising grounds of Germany on the south-west have thus from a remote geological antiquity been exempted from the terrestrial corrugations which have affected so much of the rest of Europe. They have been alternately, but gently, depressed as a sea-floor, and elevated into steppes or plains. The following subdivisions have been established by F. Schmidt among the Silurian rocks of north-west Russia:—[2]

I. *Upper Silurian*—	
Sandy variable limestone, with marly layers passing into sandstone (*Beyrichia tuberculata, Grammysia cingulata, Chonetes striatella*, and numerous fish remains, *Onchus*, &c.)	= Tilestones.
Upper Oesel group, yellow marly and sometimes dolomitic strata (*Rhynchonella Wilsoni, Chonetes striatella, Platyschisma helicites, Eurypterus remipes*, and fish remains, &c.)	= Ludlow.
Lower Oesel group, dolomite, with marl and limestone below (*Propora tubulata, Halysites distans, Beyrichia Klödeni, Encrinurus punctatus, Proëtus concinnus, Meristella lumida, Spirifer crispus, Leptæna transversalis, Enomphalus funatus, Orthoceras annulatum*, &c.)	= Wenlock.
II. *Middle Silurian*—	
Pentamerus band, with *P. ehstonus (oblongus), Atvcolites Labechei, Bellerophon dilatatus, Brunteus signatus (laticauda)*	= Llandovery.
Compact limestone and dolomite with siliceous nodules (*Heliolites interstinctus, Ptilodictya scalpellum, Strophomena pecten, Orthis hybrida, Pentamerus linguifer, Leperditia marginata*)	
Pentamerus band, limestone, and dolomite, with *Pentamerus borealis*, &c.	

[2] *Untersuchungen über die Silurische Formation von Estland, Nord-Livland, and Oesel*, Dorpat, 1858.

III. *Lower Silurian*—

(*c*) Borkholm limestones and marls (*Halysites labyrinthica, Heliolites megastoma, Syringophyllum organum, Lichas margaritifer, Pleurorhynchus dipterus, Orthoceras calamiteum*, &c.)	= Caradoc.
(*b*) Lyckholm, yellow or grey compact limestone and marls (*Orthis flabellulum, O. Actonia, O. insularis*, &c.)	
(*a*) Wesenberg limestone and marl (*Orthis testudinaria, Encrinurus multisegmentatus, Lichas Eichwaldi*, &c.)	
(*c*) Limestone usually somewhat bituminous, with partings of reddish yellow and brown very bituminous marl (*Beyrichia complicata, Asaphus acuminatus, Orthis calligramma, Leptæna sericea*, &c.)	= Llandeilo
(*b*) Orthoceratite limestone and marl bands, **15 to 40 feet thick** (*Monticulipora petropolitana, Echinosphærites aurantium, Asaphus expansus, Orthis calligramma, Orthoceras vaginatum*, &c.)	
(*a*) Limestone, full of glauconite grains, especially towards the bottom (*Orthis calligramma, O. extensa*, abundant fragments of *Illænus* and *Asaphus*, &c.)	
(*d*) Glauconite sand (6 feet), with numerous Foraminifera in the glauconite grains (*Panderella, Cymbulia, Tiedemannia*, &c.) and the "Conodonts" of Pander	= Arenig.
(*c*) Alum-slate (10 feet), highly carbonaceous, with pyrite-nodules and abundant graptolites (*Dictyonema Hisingeri, Obolus*, &c.)	
(*b*) Ungulite sandstone (120 feet), yellow to white, with (in the upper part) abundant shells of *Obolus Apollinis* ("Ungulites" of Pander)	
(*a*) Blue clay, with sandstone bands, sparingly fossiliferous; bored at Revel to a depth of 800 feet without its bottom being reached	

In the centre and south of Europe by far the most important Silurian area is the basin of Bohemia, so admirably worked out by M. Barrande in his great work already cited (p. 323), wherein the formations are grouped as in the subjoined table:—

Upper Silurian.	3d Fauna.	Etage H Shales with coaly layers and beds of quartzite (*Phacops fecundus, Tentaculites elegans*) with species of *Leptæna, Orthoceras, Lituites, Goniatites*, &c.	850 ft.
		,, G Argillaceous limestones with chert, shales, and calcareous nodules	1000 ,,
		Numerous trilobites of the genera *Dalmanites, Brontеus, Phacops, Proëtus Harpes*, and *Calymene*; *Atrypa reticularis, Pentamerus linguifer.*	
		,, F Pale and dark limestone with chert. *Harpes, Lichas, Phacops, Atrypa reticularis, Pentamerus galeatus, Favosites Gothlandica, F. fibrosa, Tentaculites.*	
		,, E Shales with calcareous nodules, and shales resting on sheets of igneous rock (300 ft.)	450–900 ,,
		A very rich Upper Silurian fauna, abundant cephalopods, trilobites, &c.; *Halysites catenularius*, graptolites many species.	
Lower Silurian.	2d Fauna.	,, D Yellow, grey, and black shales, with quartzite and conglomerate at base	3000 ,,
		Abundant trilobites of genera *Trinucleus, Ogygia, Asaphus, Illænus, Remopleurides*, &c.	
Azoic. Cambrian.	Primordial Fauna.	,, C Shales or "schists," sometimes with porphyries and conglomerates	900–1200 ,,
		Paradoxides, Ellipsocephalus, Agnostus, and other genera of trilobites referred to above (*ante*, p. 330).	
		,, B Schists wholly unfossiliferous resting	
		,, A on bottom gneiss.	

The lower two *étages* (A, B) correspond probably to some of the older parts of the British Cambrian series, and perhaps in part to still older rocks. Étage C, or the Primordial Zone, is the equivalent of the Upper Cambrian rocks of Wales, possibly also partly of the Arenig series. Étage D, subdivided into five groups (*d*1, *d*2, *d*3, *d*4, and *d*5), appears to be, on the whole, representative of the Lower Silurian formations of the British area, though it is impossible to make the minor subdivisions in the two countries agree. The remaining four formations answer to the English and Welsh Upper Silurian series,—the highest zone of all (H) indicating by its organic remains the approach of the Devonian series.

Small though the area of the Silurian basin of Bohemia is (for it measures only 100 miles in extreme length by 44 miles in its greatest breadth), it has proved extraordinarily rich in organic remains. M. Barrande has named and described above 2000 species from that basin alone, the greater number being peculiar to it. Some aspects of its organic facies are truly remarkable. One of these is the extraordinary variety and abundance of its straight and curved cephalopods. M. Barrande has determined 18 genera and 2 sub-genera, comprising in all no fewer than 1127 distinct species. The genus *Orthoceras* alone contains 554 species, and *Cyrtoceras* has 330.[1] The trilobites likewise appear in great numbers, the same indefatigable explorer having detected as many as 42 distinct genera, comprising 350 species. Of these the most prolific genus is *Brontеus*, which includes 46 species entirely confined to the 2d fauna or Upper Silurian; *Acidaspis* has 40 species, of which 6 occur in the 2d and 34 in the 3d fauna. *Proëtus* also numbers 40 species, which all belong to the 3d fauna, save 2 found in the 2d. Other less prolific but still abundant genera are *Dalmanites, Phacops*, and *Illænus*. The 2d fauna, or Lower Silurian rocks, contain in all 32 genera and 127 species of trilobites, while the 3d fauna, or Upper Silurian formations, contain 17 genera and 205 species, so that generic types are more abundant in the earlier and specific varieties in the later rocks.[2]

In Germany Silurian rocks appear in a few detached areas, but present a great contrast to those of Bohemia in their comparatively unfossiliferous character, and the absence of any one continuous succession of the whole Silurian system. They occur in the Thuringer Wald, where a series of fucoidal-schists (perhaps Cambrian) passes up into slates, greywackes, &c., with *Lingula, Discina, Calymene*, numerous graptolites, and other fossils. These strata (from 1600 to 2000 feet thick) may represent the Lower Silurian formations. They are covered by some graptolitic alum-slates, shales, flinty slates, and limestones (*Favosites Gothlandica*, &c.), which no doubt represent the Upper Silurian, and pass into the base of the Devonian formations. Among the Harz Mountains certain greywackes and shales containing land-plants (lycopods, &c.), trilobites (*Dalmanites*, &c.), graptolites, &c., are regarded as of intermediate age between true Upper Silurian and Lower Devonian rocks. In the north-west of France an impoverished series of sandstones and slates represents the succession of formations up to the top of the Silurian or base of the Devonian system, and contains a suite of trilobites which indicate more analogy with the Silurian fauna of Bohemia and of Spain than with that of the British Islands. In the western half of the Spanish peninsula Silurian rocks are found flanking the older schists and crystalline masses, and spreading over a vast area of the tableland. They appear to belong chiefly if not wholly to the lower division of the system, and they include representatives of Barrande's primordial zone, containing 19 species of organisms, of which 9 are primordial trilobites.

NORTH AMERICA.—In the United States and Canada the Silurian formations spread continuously over a vast territory, from the mouth of the St Lawrence south-westwards into Alabama and westwards by the great lakes. They almost encircle and certainly underlie all the later Palæozoic deposits of the great interior basin. The rocks are most typically developed in the state of New York, where they have been arranged as in the subjoined table.

B. Upper Silurian.

IV. Oriskany Formation.	Oriskany sandstone (*Spirifer arenosus*).	
III. Lower Helderberg Formation.	(4) Upper Pentamerus limestone (*Pentamerus pseudogaleatus*)	Ludlow.
	(3) Delthyris limestone (*Meristella lævis*)	
	(2) Lower Pentamerus limestone (*Pentamerus galeatus*)	
	(1) Water-lime (*Tentaculites, Eurypterus*, and *Pterygotus*)	
II. Salina Formation.	Onondago salt group, nearly barren of fossils	
I. Niagara Formation.	(3) Niagara shale and limestone (*Halysites, Favosites, Calymene Blumenbachii, Honalonotus delphinocephalus, Leptæna transversalis*, &c.)	Wenlock.
	(2) Clinton group (*Pentamerus oblongus, Atrypa reticularis*, &c.)	Upper Llandovery.
	(1) Medina group with Oneida conglomerate (*Modiolopsis orthonota*)	

[1] *Syst. Silur.*, vol. ii. suppt., p. 266, 1877.

[2] Barrande, *Syst. Silur.*, vol. i. suppt., "Trilobites." 1871.

A. Lower Silurian.

II. Trenton Formation.
- (3) Cincinnati (Hudson River) group (*Syringopora, Halysites, Diplograptus pristis, Pterinea demissa, Leptæna sericea*).
- (2) Utica group—Utica shale.
- (1) Trenton group:
  - Trenton limestone.
  - Black River limestone.
  - Birdseye limestone.

  Graptolithus amplexicaulis, Trinucleus concentricus, Orthis testudinaria, Murchisonia, Conularia, Orthoceras, Cyrtoceras, &c.

I. Canadian Formation.
- (3) Chazy group—Chazy limestone (*Maclurea magna, M. Logani, Orthoceras, Illænus, Asaphus*).
- (2) Quebec group (upwards of 100 species of trilobites of genera *Agnostus, Ampyx, Amphion, Conocoryphe, Dikelocephalus, Illænus, Asaphus*, &c., more than 50 species of graptolites).
- (1) Calciferous group (graptolites, *Lingulella acuminata, Leptæna, Conocardium, Ophileta compacta, Orthoceras primigenium*, 14 species of trilobites of the genera *Amphion, Bathyurus, Asaphus, Conocoryphe*).

Potsdam formation, representing Cambrian (see *ante*, p. 331).

The most recent researches of Mr Selwyn and his colleagues of the Geological Survey of Canada have shown that in the so-called Quebec group have been included a number of formations of very different stratigraphical positions. He recognizes in it three distinct groups:—(1) at the base a group of crystalline schists; (2) a group of sandstones and slates with abundant volcanic rocks, probably Cambrian; and (3) Lower Silurian slates, shales, limestones, quartzites, sandstones, and conglomerates. He objects to the introduction of new names to denote systems of rocks, and thinks that Laurentian, Huronian, Cambrian, and Silurian meet all present requirements.

Devonian and Old Red Sandstone.

In Wales and the adjoining counties of England, where so full a development of the Silurian system was originally discovered and worked out by Murchison, the abundant marine fauna comes to an abrupt close when the red rocks set in at the top of the Ludlow group. From that horizon upwards in the geological series we have to pass through some 10,000 feet or more of barren red sandstones and marls, until we again encounter a copious marine fauna in the Carboniferous Limestone. It is evident that between the disappearance of the Silurian and the arrival of the Carboniferous fauna very great geographical changes must have occurred over the area of Wales and the west of England. The sea must have been excluded from the area, or at least must have been rendered unfit for the existence and development of marine life over the area in question. From the striking contrast between the general facies of life in the Silurian and that in the Carboniferous system it is manifest that the interval between them must have been of long duration.

The geological records of this vast interval are still only very partially unravelled and interpreted. At present the general belief among geologists is that, while in the west and north-west of Europe the Silurian sea-bed was upraised into land in such a way as to enclose large inland basins, in the centre and south-west the geographical changes did not suffice to exclude the sea, which continued to cover more or less completely that region. In the isolated basins of the north-west a peculiar type of deposits termed the Old Red Sandstone is believed to have accumulated, while in the shallow seas to the south and east a series of marine sediments and limestones was formed to which the name of Devonian has been given. It is thus supposed that the Old Red Sandstone and the Devonian represent different geographical areas, with different phases of sedimentation and of life, during the long lapse of time between the Silurian and Carboniferous periods.

That the Old Red Sandstone does really represent this prolonged interval can be demonstrated by innumerable sections in Britain, where its lowest strata are found graduating downward into the top of the Ludlow group and its highest beds are seen to pass up into the base of the Carboniferous system. But the evidence is not everywhere so clear in regard to the true position of the Devonian rocks. That these rocks lie between Silurian and Carboniferous formations is indeed sufficiently clear. But it is a curious fact that where the Lower Devonian beds are best developed the Upper Silurian formations are scarcely to be recognized, or if they occur, they can hardly be separated from the so-called Devonian rocks. It is therefore quite possible that the lower portions of what has been termed the Devonian series may in certain regions to some extent represent what are elsewhere recognized as undoubted Ludlow or even perhaps Wenlock rocks. We cannot suppose that the rich Silurian fauna died out abruptly at the close of the Ludlow epoch. We should be prepared for the discovery of younger Silurian rocks than the latest of those in Britain, such as M. Barrande has shown to exist in his Étage H. The rocks termed Lower Devonian may partly represent some of these later phases of Silurian life, if they do not also mark peculiar geographical conditions of a still older period in Upper Silurian time. On the other hand, the upper parts of the Devonian system might in several respects be claimed as fairly belonging to the Carboniferous system above.

The late Mr Jukes proposed a solution of the Devonian problem, the effect of which would be to turn the whole of the Devonian rocks into Lower Carboniferous, and to place them above the Old Red Sandstone, which would thus become the sole representative in Europe of the interval between Silurian and Carboniferous time.[1] In the following descriptions an account will first be given of the Devonian type and then of the Old Red Sandstone.

A. Devonian.

This name was first applied by Sedgwick and Murchison to the rocks of North and South Devon and Cornwall, whence a suite of fossils was obtained which Lonsdale pronounced to be intermediate in character between Silurian and Carboniferous. The relations of these strata to Silurian rocks cannot be determined from any section. They pass upward into Carboniferous strata. They have been arranged into three divisions, as in the subjoined table.

- Upper....
  - Pilton and Pickwell-Down Group.—Grey slate with courses of impure limestone (Pilton) passing down into yellow, brown, and red sandstones (Baggy Point, Marwood), and a series of hard grey and red sandstones and micaceous flagstones at the base (Pickwell-Down, Dulverton, Morte Bay).
- Middle..
  - Ilfracombe Group.—Grey unfossiliferous slates (Morte Hoe, Woolacombe, and Lee Bay) passing down into calcareous fossiliferous slates and limestones (Ilfracombe, Combe Martin, Torquay, Plymouth) resting on hard green, grey, and red grits, sandstones, and conglomerates (Hangman Hill).
- Lower....
  - Lynton Group.—Soft slates with thin limestone and sandstone bands (Lynton) resting on lowest schists and red and grey micaceous sandstones (Lynton, Lynmouth, Foreland, &c.).

The total fauna of the British Devonian rocks numbers about 400 species. The middle group is the chief repository of fossils.

Lower.—Among the lower gritty slates and limestone bands of North Devon there are found, according to the detailed census compiled by Mr Etheridge, 18 species of fossils, comprising *Favosites cervicornis, Fenestella antiqua, Orthis arenata, Spirifer canaliferus, S. lævicostus*, &c. Of these organisms 7 species are also found among the Devonian rocks of the Rhine, Belgium, or France. Mr Etheridge remarks that it is singular that the British Lower Devonian rocks should only have yielded 1 gasteropod (*Pleurotomaria aspera*), 4 lamellibranchs, 1 cephalopod (*Orthoceras gracile*), and 1 nucleobranch (*Bellerophon bisulcatus*). They have furnished only 10 brachiopods. Traces of fish remains have been obtained among them in the form of bones and coprolitic debris. So far as observation has gone not a single Silurian species has been certainly detected in the Devonian rocks of Britain, with, according to Mr Etheridge, the sole exception of the long-lived and universally diffused *Atrypa reticularis*, which occurs in the Ilfracombe group. There can be no doubt, however, from the meagre list of fossils from the Lower Devonian rocks of Devon and Cornwall, that either the conditions for the existence or those for the fossilization of the early Devonian fauna must have been singularly unfavourable in the south-west of England. It would be exceedingly rash to argue as to the extinction of the Silurian fauna from the unsatisfactory evidence of these rocks.

[1] See his papers in *Journ. Roy. Geol. Soc. Ireland* (1865), i. pt. 1, new ser., and *Quart. Journ. Geol. Soc.*, xxii. (1866), and his pamphlet on *Additional Notes on Rocks of North Devon*, &c., 1867.

Middle.—As above remarked, this is the great storehouse of Devonian fossils in the south-west of England. In this fauna, as tabulated by Mr Etheridge, there are 8 amorphozoans, including 5 species of *Stromatopora*; 23 genera and 50 species of cœlenterates, among which the corals *Acervularia, Alveolites, Cyathophyllum, Favosites, Pleurodictyum*, and *Petraia* are conspicuous; 4 genera and 8 species of crinoids (*Hexacrinus, Cyathocrinus*, &c.); 1 annelide (*Tentaculites annulatus*); 5 genera and 13 species of crustaceans, which are all trilobites (*Phacops granulatus, P. latifrons, P. punctatus, Bronteus flabellifer, Cheirurus articulatus, Harpes macrocephalus*, &c.); and 12 species of polyzoans. The brachiopods are abundant; 68 species have been yielded by the rocks of South Devon, including *Athyris concentrica, A. lachryma, Atrypa reticularis, A. desquamata, Camarophoria rhomboidea, Cyrtina Lemarlii, Orthis striatula, Rhynchonella acuminata, R. pugnus, Pentamerus brevirostris, Spirifer disjunctus, Stringocephalus Burtini, Uncites gryphus*, &c. The lamellibranchs are poorly represented, 11 genera only occurring, and many of them represented by only 1 species. The gasteropods are likewise present in but small numbers and variety; 12 genera and 36 species have been enumerated. Of these species, 4 (*Acroculia vetusta, Euomphalus lævis, Macrocheilus imbricatus*, and *Murchisonia spinosa*) survived into the Carboniferous period. The cephalopods are represented by 5 genera, the most abundant specifically being *Cyrtoceras* and *Orthoceras*; *Goniatites, Clymenia*, and *Nautilus* also occur. Of the total list of fossils a large proportion is found in the Middle Devonian rocks of the continent of Europe. Very few species agree with those of the Silurian or with those of the Carboniferous system.

Upper.—From the calcareous portions of the Petherwin and Pilton beds of Cornwall and Devon a considerable number of fossils has been obtained. Among the more characteristic of these we find 11 species of the coiled cephalopod *Clymenia* (*C. undulata, C. lævigata, C. striata*), the trilobites *Phacops granulatus* and *P. latifrons*, the small ostracod *Cypridina serrato-striata*, the brachiopods *Spirifer disjunctus* or *Verneuilli, Strophomena rhomboidalis, Chonetes Hardrensis, Productus subaculeatus*, and the lamellibranch *Cucullæa Hardingii*. The Marwood and Baggy Point beds have also yielded traces of land plants, such as *Knorria dichotoma* and *Adiantites Hibernicus*, the latter fern being common in some parts of the Upper Old Red Sandstone of Ireland.

The higher red and yellow sandy portions of the Upper Devonian rocks shade up insensibly at Barnstaple in North Devon into strata which by their fossils are placed at the base of the Carboniferous Limestone series. But in no other series save the south-western district of Britain can such a passage be observed. In all other places the Carboniferous system, where its true base can be seen, passes down into the red sandy and marly strata of the Upper Old Red Sandstone without marine fossils.

Continental Europe.—Devonian rocks occupy a large area in the centre of Europe, extending from the Ardennes through the south of Belgium across Rhenish Prussia to Darmstadt. They are best known from the picturesque gorges which have been cut through them by the Rhine below Bingen and by the Moselle below Treves. They have been arranged into the following groups in the Eifel region, where their true geological position was first indicated by Sedgwick and Murchison.

III. *Upper Devonian*—
- (*c*) Cypridina shales (*Cypridina serrato-striata*).
- (*b*) Goniatite shales (*Goniatites retrorsus, G. primordialis, Orthoceras subflexuosum, Cardiola retrostriata*, &c.).
- (*a*) Nodular crumbling limestone (Kramenzelkalk), dolomitic marl, and shaly limestone (*Spirifer disjunctus* or *Verneuilli, Atrypa reticularis, Rhynchonella cuboides, Productus subaculeatus*, &c.).

II. *Middle Devonian*—
- (*b*) Stringocephalus group, consisting of the great Eifel limestone with underlying crinoidal beds (*Stringocephalus Burtini, Spirifer undatus, Productus subaculeatus, Pentamerus galeatus, Atrypa reticularis, Calceola sandalina*, and many corals and crinoids).
- (*a*) Calceola group,—marly limestones full of *Calceola sandalina, Spirifer concentricus, Camarophoria microrhyncha*, &c., esting upon impure shaly ferruginous limestone and greywacke, marked by an abundance of *Spirifer cultrijugatus, Rhynchonella Orbignyana Atrypa reticularis, Phacops latifrons*, &c.

I. *Lower Devonian*—
- (*c*) Upper greywacke and shale (Vichter-Schichten), with a mixture of Lower and Middle Devonian fossils.
- (*b*) Ahr group,—greywacke-shales with *Chonetes sarcinulata, C. dilatata, Rhynchonella Livonica, Spirifer paradoxus, S. speciosus*, many species of *Pterinea, Pleurotomaria*, and *Murchisonia*.
- (*a*) Coblentz group, greywacke and clay-slate (*Leptæna laticosta, Chonetes sarcinulata, Rhynchonella Livonica, Pleurodictyum problematicum*, &c.).

This threefold subdivision, with a central mass of calcareous strata, is traceable westwards through Belgium (where the Calcaire de Givet represents the Stringocephalus limestone of the Eifel) and eastwards into the Harz. The rocks reappear with local petrographical modifications, but with a remarkable persistence of general palæontological characters, in Eastern Thuringia, Franconia, Saxony, Silesia, the north of Moravia, and East Galicia. Devonian rocks have been detected among the crumpled rocks of the Styrian Alps by means of the evidence of abundant corals, clymenias, gasteropods, lamellibranchs, and other organic remains. Perhaps in other tracts of the Alps, as well as in the Carpathian range, similar shales, limestones, and dolomites, though as yet unfossiliferous, but containing ores of silver, lead, mercury, zinc, cobalt, and other metals, may be referable to the Devonian system.

In the centre of Europe, therefore, the Devonian rocks consist of a vast thickness of dark-grey sandy and shaly rocks, with occasional seams of limestone, and in particular with one thick central calcareous zone. These rocks are characterized in the lower zones by numerous broad-winged spirifers and by peculiar trilobites (*Phacops, Homalonotus*, &c.), which, though generically like those of the Silurian system, are specifically distinct. The central calcareous zone abounds in corals and crinoids as well as in numerous brachiopods. In the highest bands a profusion of coiled cephalopods (*Clymenia*) occurs in some of the limestones, while the shales are crowded with a small but characteristic ostracod crustacean (*Cypridina*). Here and there traces of fishes have been found, more especially in the Eifel, but seldom in such a state of preservation as to warrant their being assigned to any definite place in the zoological scale. More recently, however, E. Beyrich has described from Gerolstein in the Eifel an undoubted species of *Pterichthys*, which, as it cannot be certainly identified with any known form, he names *P. Rhenanus*. A *Coccosteus* has been described by F. A. Roemer from the Harz, and more recently one has been cited from Bicken near Herborn by V. Koenen; but, as Beyrich points out, there may be some doubt as to whether the latter is not a *Pterichthys*.[1] A *Ctenacanthus*, seemingly undistinguishable from the *C. Bohemicus* of Barrande's Étage G, has also been obtained from the Lower Devonian "Nereitenschichten" of

[1] *Zeitschrift der Deutsch. Geol. Gesell.*, xxix. 751.