outpouring of great sheets of quartz-porphyry, granite-porphyry, porphyrite, and melaphyre, with abundant interstratifications of various tuffs, not infrequently enclosing organic remains. From the very nature of its component materials, the Rothliegende is comparatively barren of fossils, a few ferns, calamites, and remains of coniferous trees are found in it, particularly towards the base, where indeed they form, in the Mansfeld district, a coal-seam about 5 feet thick.

The plants, all of terrestrial growth, on the whole resemble generically the Carboniferous flora, but seem to be nearly all specifically distinct. They include forms of *Calamites* (*C. gigas*), *Asterophyllites*, and ferns of the genera *Sphenopteris*, *Alethopteris*, *Neuropteris*, *Odontopteris*, with well-preserved silicified stems of tree-ferns (*Psaronius*, *Tubicaulis*). The conifer *Walchia* (*W. piniformis*) is specially characteristic. Fish remains occur sparingly (*Amblypterus*, *Palæoniscus*, *Acanthodes*), and traces of labyrinthodonts (*Archegosaurus Decheni*) have been met with.

The Zechstein group is characterized by a suite of fossils like those of the Middle Permian of England. The Kupfer-schiefer contains numerous fish (*Palæoniscus Freieslebeni*, *Platysomus gibbosus*, &c.) and remains of plants (coniferous leaves and fruits and sea-weeds). This deposit is believed to have been laid down in some enclosed sea-basin, the waters of which, probably from the rise of mineral springs connected with some of the volcanic foci of the time, were so charged with metallic salts in solution as to become unfit for the continued existence of animal life. The dead fish, plants, &c., by their decay, gave rise to reduction and precipitation of these salts as sulphides, which thereupon enclosed and replaced the organic forms, and permeated the mud at the bottom. This old sea-floor is now the widely extended band of copper-slate which has so long and so extensively been worked along the flanks of the Harz. After the formation of the Kupfer-schiefer the area must have been once more covered by clearer water, for the Zechstein contains a number of organisms of which *Productus horridus*, *Spirifer undulatus*, *Strophalosia Goldfussi*, *Schizodus obscurus*, and *Fenestella retiformis* are common. Renewed unfavourable conditions are indicated by the dolomite, gypsum, and rock-salt which succeed. Professor Ramsay, reasoning upon such phenomena as developed in England, has connected them with the abundant labyrinthodont footprints and other evidences of shores and land, as well as the small number and dwarfed forms of the shells in the Magnesian Limestone, and has speculated on the occurrence of a long continental period in Europe, during one epoch of which a number of salt inland seas existed wherein the Permian rocks were accumulated. He compares these deposits to what may be supposed to be forming now in parts of the Caspian Sea.

North America.—The Permian system is hardly represented at all in this part of the globe. In Kansas certain red and green clays, sandstones, limestones, conglomerates, and beds of gypsum lie conformably on the Carboniferous syste , and contain a few genera and species of molluscs (*Bakewellia*, *Myalina*, &c,), which occur in the European Permian rocks.

III. SECONDARY OR MESOZOIC.

Triassic.

It has been already mentioned that the great mass of red rocks, which in England overlie the Carboniferous system, were formerly classed together as New Red Sandstone, but are now ranged in two systems. We have considered the lower of these under the name of Permian. The general facies of organic remains in that division is still decidedly Palæozoic. Its brachiopods and its plants connect it with the Carboniferous rocks below. Hence it is placed at the close of the long series of Palæozoic formations. When, however, we enter the upper division of the red rocks, though the general lithological characters remain very much as in the lower group, the fossils bring before us the advent of the great Mesozoic flora and fauna. This group therefore is put at the base of the Mesozoic or Secondary series. It is called Trias, because in Germany it consists of three well-marked subdivisions. But the old name, New Red Sandstone, is familiarly retained for it by many geologists in England. The term Trias, like Dyas, is unfortunately chosen, for it elevates a mere local character into an importance which it does not deserve. The threefold subdivision, though so distinct in Germany, disappears elsewhere.

Great Britain.—Triassic rocks occupy a large area of the low plains in the centre of England, ranging thence northwards along the flanks of the Carboniferous tracts to Lancaster Bay, and southwards by the head of the Bristol Channel to the south-east coast of Devonshire. They have been arranged in the following subdivisions:—

Rhætic	Penarth beds.—Red, green, and grey marls, and "White Lias."	
Upper Trias or Keuper.	New Red Marl.—Red and grey shales and marls, with beds of rock-salt and gypsum (*Estheria* and *Foraminifera*).	
	Lower Keuper Sandstone.—Thinly laminated micaceous sandstones and marls (waterstones) passing downwards into white, brown, or reddish sandstones, with a base of calcareous conglomerate or breccia.	
Middle	Wanting in England (Muschelkalk of Germany).	
Lower Trias or Bunter.	Upper Mottled Sandstone.—Soft bright-red and variegated sandstones, without pebbles.	
	Pebble beds.—Harder reddish-brown sandstones with quartzose pebbles, passing into conglomerate; with a base of calcareous breccia.	
	Lower Mottled Sandstone.—Soft bright-red and variegated sandstone, without pebbles.	

like the Permian red rocks below, the sandstones and marls of the Triassic series are almost barren of organic remains. Hence the subdivisions in the foregoing table are based on mineral characters, and could not therefore be relied on as a guide in districts outside of the English area. Indeed, extraordinary differences in the development of the different members of the series occur, even within that area, as may be seen from the subjoined table, which shows the variations in thickness from north-west to south-east:—

		Lancashire and W. Cheshire.	Stafford-shire.	Leicester-shire and Warwick-shire.
		Fct.	Feet.	Feet.
Keuper.	Red marl	3000	800	700
	Lower Keuper sandstone	450	200	150
Bunter.	Upper mottled sandstone	500	50–200	absent
	Pebble beds	500–750	100–300	0–100
	Lower mottled sandstone	200–500	0–100	absent

Hence we observe that, while towards the north-west the Triassic rocks attain a maximum depth of 5200 feet, they rapidly come down to a fifth or a sixth of that thickness as they pass towards the south-east. Recent borings in the south-eastern counties show that the Triassic rocks are there absent altogether. It is evident that the source of supply of the sediment lay towards the north. This is further borne out by the character of the pebble-beds. These are coarsest towards the north, and, besides local materials, contain abundant rolled pebbles of quartz which have evidently been derived from some previous conglomerate, probably from some of the Old Red Sandstone masses now removed or concealed The Trias everywhere rests unconformably on the rocks underneath it, so that, although the general physical conditions as regards climate, geography, and sedimentation, which prevailed in the Permian period still continued, great terrestrial movements had, in the meanwhile, taken place, whereby the Permian sediments were upraised and exposed to denudation. Hence the Trias rests now on Permian, now on Carboniferous, and sometimes even on Cambrian rocks. Moreover, the upper parts of the Triassic series overlap the lower, so that the Keuper groups come to rest directly on Permian or Carboniferous rocks.

One of the most interesting features in the English Trias is the occurrence of beds of rock-salt which have long been profitably worked. The uppermost subdivision of the Keuper, consisting of red marls, has a wide distribution, for it can be traced from the coast of Lancashire to the Bristol Channel, and covers a larger area of surface in the central counties than the rest of the Trias and the whole of the Permian sandstones combined. Even as far south as the

coast of Devonshire, it contains casts of the cubical spaces once occupied by crystals of common salt. But in Cheshire the salt occurs in two or more beds, of which the lower is sometimes upwards of 100 feet thick. It is a crystalline substance, usually tinged yellow or red from intermixture of clay and peroxide of iron, but is tolerably pure in the best part of the beds, where the proportion of chloride of sodium is as much as 98 per cent. Through the bright red marls with which the salt is interstratified there run bands of gypsum, somewhat irregular in their mode of occurrence, sometimes reaching a thickness of 40 feet and upwards. Thin seams of rock-salt likewise occur among the red marls. These facts point to the concentration and evaporation of salt lakes or inland seas.

The organic remains of the Trias are comparatively few, as the conditions for at least animal life must have been extremely unfavourable in the waters of the ancient Dead Sea wherein these red rocks were accumulated. The land possessed a vegetation which, from the few fragments yet known, seems to have consisted in large measure of cypress-like coniferous trees (*Voltzia*, *Walchia*), with calamites on the lower more marshy grounds. The red marl group contains in some of its layers numerous valves of the little crustacean *Estheria minuta*, and a solitary species of lamellibranch, *Pullastra arenicola*. A number of teeth, spines, and sometimes entire skeletons of fish have been obtained (*Dipteronotus cyphus*, *Palæoniscus superstes*, *Hybodus Keuperi*, *Acrodus minimus*, *Sphenonchus minimus*, *Lophodus*, &c.). The bones, and still more frequently the footprints, of labyrinthodont and even of saurian reptiles occur in the Keuper beds—*Labyrinthodon* (4 species), *Cladyodon Lloydii*, *Hyperodapedon*, *Palæosaurus*, *Teratosaurus*, *Thecodontosaurus*, *Rhyncosaurus*, and footprints of *Cheirotherium*. The remains of a small marsupial (*Microlestes*) have likewise been discovered.

Rhætic.—At the top of the Red Marl certain thin-bedded strata form a gradation upwards into the base of the Jurassic system. As their colours are grey and blue, and contrast with the red marls on which they repose conformably, they were formerly classed without hesitation in the Jurassic series. Egerton, however, showed that, from the character of their included fish remains, they had more palæontological affinity with the Trias than with the Lias. Subsequent research, particularly among the Rhætic Alps and elsewhere on the Continent, brought to light a great series of strata of intermediate characters between the Trias and Lias. These results led to renewed examination of the so-called beds of passage in England, which were found to be truly representative of the massive formations of the Tyrolese and Swiss Alps. They are therefore now classed as Rhætic, and considered as the uppermost member of the Trias, but offering evidence of the gradual approach of the physical geography and characteristic fauna and flora of the Jurassic period.

The Rhætic beds extend as a continuous though very thin band at the top of the Trias, from the coast of Yorkshire across England to Lyme Regis on the Dorsetshire shores. They occur in scattered patches even up as far as Carlisle, and westwards on both sides of the Bristol Channel. Their thickness, on the average, is probably not more than 50 feet, though it rarely increases to 150 feet. They consist of thin-bedded grey and dark shales and clays, with bands of light-coloured limestone. One of their most important subdivisions is the so-called Bone-bed—a pyritous, micaceous, and occasionally rippled sandstone, sometimes in several bands, abounding in fish bones, teeth, coprolites, and other organic remains. The grey marly beds in the lower portion of the series have yielded remains of the *Microlestes Rhæticus*. Among the reptilian fossils are some precursors of the great forms which distinguished the Jurassic period (*Ichthyosaurus* and *Plesiosaurus*). The fishes include *Acrodus minimus*, *Ceratodus altus*, *Hybodus minor*, *Nemacanthus monilifer*, &c. Some of the lamellibranchs are specially characteristic; such are *Cardium Rhæticum*, *Avicula contorta*, *Pecten Valoniensis*, and *Pullastra arenicola*.

Professor Ramsay has drawn attention to the probable geographical changes recorded by the Triassic rocks of England. Connecting them with the earlier and similar Permian sandstones and marls he points out that the great Continental period which began with the Old Red Sandstone closed with the New Red Marl, and was characterized by the existence of great lakes, many of which must have been salt, and by the abundance of labyrinthodont life. The Triassic rocks were, doubtless, laid down in one of these salt lakes round the margins of which the labyrinthodonts left their footprints on the soft sand. In the Rhætic series we see how these inland basins were gradually invaded by the sea, which brought into the region of Britain the rich fauna of the Jurassic period.

Continental Europe.—The Trias is the most compactly distributed of all the geological formations of Europe. Its main area extends as a great basin from Basel down to the plains of Hanover, traversed along its centre by the course of the Rhine, and stretching from the flanks of the old high grounds of Saxony and Bohemia on the east across the Vosges mountains into France. This must have been a great inland sea, out of which the Harz mountains, and the high grounds of the Eifel, Hundsruck, and Taunus probably rose as islands. It may have extended up to the base of the Alps, for enormous masses of Triassic rocks now form part of these mountains. Traces of what were probably other basins occur eastward in the Carpathian district, along the southern front of the Alps, in the west and south of France, and over the eastern half of the Spanish peninsula. But these areas have been considerably obscured, sometimes by dislocation and denudation, sometimes by the overlap of more recent formations.

In the great German Triassic basin the deposits are as shown in the subjoined table.

Keuper.	Upper or Rhætic.—Grey sandy clays and fine-grained sandstones, containing *Equisetum*, *Asplenites*, and cycads (*Zamites*, *Pterophyllum*), sometimes forming thin seams of coal—*Cardium Rhæticum*, *Avicula contorta*, *Estheria minuta*, *Nothosaurus*, *Termatosaurus*, *Belodon*, and *Microlestes antiquus*.	
	Middle (Bunte Keupermergel, Gypskeuper).—Bright red and mottled marls, with beds of gypsum and rock-salt. In some places where sandstones appear they contain numerous plants (*Equisetum columnare*, *Taniopteris vittata*, *Pterophyllum*, &c.), and labyrinthodont and fish remains. 300 to 1000 feet.	
	Lower (Lettenkohle, Kohlenkeuper).—Grey sandstones and dark marls and clays, with abundant plants, sometimes forming thin seams of an earthy hardly workable coal (Lettenkohle). The plants include, besides those above mentioned, the conifers *Araucarozylon Thuringicum*, *Voltzia heterophylla*, &c Some of the shales are crowded with small ostracod crustacea (*Estheria minuta*). Remains of fish (*Ceratodus*) and of the *Mastodonsaurus Jægeri* have been obtained. About 230 feet.	
Muschelkalk.	Upper Limestone in thick beds with argillaceous partings.—It abounds in organic remains among which *Ceratites nodosus*, *Nautilus bidorsatus*, *Lima striata*, *Myophoria vulgaris*, *Trigonodus Sandbergeri*, *Terebratula vulgaris*, and *Encrinus liliiformis* are specially characteristic. It is a thoroughly marine formation, sometimes almost wholly made up of crinoid stems. 200 to 400 feet.	
	Middle Limestone and Anhydrite, consisting of dolomites with anhydrite, gypsum, and rock-salt. Nearly devoid of organic remains, though bones and teeth of saurians have been found. 200 to 400 feet.	
	Lower Limestone, consisting of limestones and dolomites, but on the whole poor in fossils, save in the limestone bands, some of which are full of *Terebratula vulgaris* and *Encrinus liliiformis*. 160 to 500 feet.	
Bunter.	Upper (Röth).—Red and green marls, with gypsum in the lower part. 250 to 300 feet.	
	Middle.—Coarse-grained sandstones, sometimes incoherent, with waxboards of *Estheria* shale.	
	Lower.—Fine reddish argillaceous sandstone, often micaceous and fissile, with occasional interstratifications of dolomite and of the marly oolitic limestone called "Rogenstein."	
	The Bunter division is usually barren of organic remains. The plants already known include *Equisetum arenaceum*, one or two ferns, and a few conifers (*Albertia* and *Voltzia*). The lamellibranch *Myophoria costata* is found in the upper division all over Germany. Numerous footprints occur on the sandstones, and the bones of labyrinthodonts as well as of fish have been obtained.	

The Trias attains an enormous development in the eastern Alps, where it bears evidence of having been accumulated under very different conditions from those of the Trias in Germany. The great thickness of its limestones, and their unequivocally marine organisms, show that it must have accumulated in opener water, which remained clear and comparatively free from inroads of sandy and muddy sediment. It possesses, moreover, a high interest as being a massive formation of marine origin formed between Permian

and Jurassic times, and containing a remarkable blending of true Palæozoic organisms with others as characteristically Mesozoic. It is divided into two great series:—(1) Lower Trias, consisting of (*a*) Werfen Shales and Guttenstein Limestone, and (*b*) Virgloria Limestone or alpine Muschelkalk; and (2) Upper Trias,—a varied series of strata in three leading groups, having a united thickness sometimes of thousands of feet.

North America.—Rocks which are regarded as equivalent to the European Trias cover a large area in North America. On the Atlantic coast they are found on Prince Edward's Island, New Brunswick, and Nova Scotia, in Connecticut, New York, Pennsylvania, and North Carolina. Spreading over an enormous extent of the western territories, they cross the Rocky Mountains into California and British Columbia. They consist mainly of red sandstones, passing sometimes into conglomerates, and often including shales and impure limestones. On the Pacific slope they contain distinctly marine organisms, which include a mingling of such Palæozoic genera as *Spirifer*, *Orthoceras*, and *Goniatites*, with the characteristically Secondary genus *Ammonites*. In the centre and east of the continent they are marked by the occurrence of terrestrial plants, and in Connecticut by abundant footprints of land animals. The fossil plants present a general facies like that of the European Triassic flora, among them cycads, including some of the European species of *Pterophyllum*. Ferns (*Pecopteris*, *Neuropteris*, *Clathropteris*), calamites, and conifers are the predominant forms. The fauna is remarkable chiefly for the number and variety of its vertebrates. The labyrinthodonts are represented by footprints, from which upwards of fifty species have been described. Saurian footprints have likewise been recognized, but in a few cases their bones also have been found. These saurians had some bird-like characteristics, among others that of three-toed hind feet, which produced impressions exactly like those of birds. It is by no means certain, therefore, that what have been described as ornithichnites were not really made by dinosaurs. A small insectivorous marsupial (*Dromatherium*), found in the Trias of North Carolina, is the oldest American mammal yet known.

Jurassic.

The next great period of geological time is termed the Jurassic, from the Jura Mountains, where the deposits of that age are well developed. It was in England, however, that they were first studied by William Smith, in whose hands they were made to lay the foundations of stratigraphical geology. The names adopted by him for the subdivisions he traced across the country have passed into universal use, and though some of them are uncouth English provincial names, they are as familiar to the geologists of France, Switzerland, and Germany as to those of England.

The Jurassic formations stretch across England in a varying band from the mouth of the Tees to the coast of Dorsetshire. They consist of harder sandstones and limestones interstratified with softer clays and shales. Hence they give rise to a characteristic type of scenery,—the more durable beds standing out as long ridges, sometimes even with low cliffs, while the clays underlie the level spaces between. Arranged in descending order, the following subdivisions of the English Jurassic system are recognized:—

			Maximum thicknesses. Feet.
Upper or Portland Oolites.	Purbeck.	Upper fresh-water beds ...	360
		Middle marine beds	
		Lower fresh-water beds ..	
	Portland.	Portland Stone	70
		Portland Sands	150
		Kimeridge Clay	600
Middle or Oxford Oolites.	Coralline Oolite.	Coral Rag and Calcareous Grit	250
	Oxford clay.	Oxford Clay and Kellaways Rock	600
Lower or Bath Oolites.	Great Oolite.	Cornbrash, Bradford Clay	40
		and Forest Marble (in Dorsetshire 450 ft.)	30
		Great or Bath Oolite with Stonesfield slate (part of Northampton Sand)	130
	Fuller's Earth.	Fuller's Earth group	150
	Inferior Oolite.	Cheltenham beds	270
		Midford Sands (and perhaps part of Northampton Sands), "Dogger" of Yorkshire	160
Lias.		Upper Lias	400
		Marlstone	200
		Lower Lias	900

Although these names appear in tabular order as expressive of what is the predominant or normal succession of the beds, considerable differences occur when the rocks are traced across the country. Thus the Forest Marble attains a thickness of 450 feet in Dorsetshire, but dwindles down to only 15 feet at Blenheim Park. The Inferior Oolite consists of marine limestones and shales in Gloucestershire, but chiefly of massive estuarine sandstones and shales in Yorkshire. These differences help to bring before us some of the geographical features of the British area during the Jurassic period.

The Lias consists of three formations, well marked by physical and palæontological characters. In the lower member numerous thin blue and brown limestones with partings of dark shale are surmounted by similar shales with occasional nodular limestone bands, the whole being divided into seven zones, each characterized by the presence of one or more distinctive species of ammonite. From this point of the geological series up to the close of the Mesozoic formations, the ammonites play a chief part among the mollusks. The Middle Lias, consisting of argillaceous limestones (marlstones) with micaceous sands and clays, is divided into five ammonite zones. In its Yorkshire development this subdivision is remarkable for containing a bed of earthy carbonate of iron 15 to 20 feet thick, which has been extensively worked in the Cleveland district. The upper division is composed chiefly of clays and shales with nodules of limestones, among which three ammonite zones have been noted in Yorkshire.

The organic remains of the Lias comprise leaves and other remains of cycads (*Palæozamia*), conifers (*Pinites*, *Cupressus*, *Feuce*), ferns (*Otopteris*, *Alethopteris*, &c.), and reeds (*Equisetites*). These fossils serve to indicate the general character of the flora, which seems now to have been mainly cycadaceous and coniferous, and to have presented a great contrast to the lycopodiaceous vegetation of Palæozoic times. The occurrence of land-plants dispersedly throughout the English Lias shows also that the strata, though chiefly marine were deposited within such short distance from shore, as to receive from time to time leaves, seeds, fruits, twigs, and stems from the land. Further evidence in the same direction is supplied by the numerous insect remains, which have been obtained principally from the Lower Lias. These were, no doubt, blown off the land and fell into shallow water, where they were preserved in the silt on the bottom. The *Neuroptera* are numerous, and include several species of *Libellula*. The coleopterous forms comprise a number of beetles. There were likewise representatives of the orthopterous, hemipterous, and dipterous orders. These relics of insect-life are so abundant in some of the calcareous bands that the latter are known as insect-beds. With them are associated remains of terrestrial plants, cyprids, and mollusks, sometimes marine, sometimes apparently brackish-water. The marine life of the period has been abundantly preserved, so far at least as regards the comparatively shallow and juxta-littoral waters in which the Liassic strata were accumulated. Corals, though on the whole scarce, abound on some horizons (*Isastræa*, *Montlivaltia*, *Septastræa*, &c.). The crinoids were represented by thick growths of *Extracrinus* and *Pentacrinus*. There were several kinds of star-fishes, and also of sea-urchins (*Cidaris*, *Diadema*, *Acrosalenia*)—all generically distinct from those of the Palæozoic periods. The contrast between the Liassic crustacea and those of the older systems, as Phillips has pointed out, is very decided, the ancient trilobites having entirely disappeared, and having been succeeded by tribes of long-tailed ten-footed lobsters and prawns. There is a similar striking difference between the mollusks of the Lias and those of the Palæozoic rocks, bearing witness to the great biological

changes which had taken place in the long interval. The brachiopods are chiefly species of *Rhynchonella* and *Terebratula*—genera which, though occurring in Palæozoic rocks, play there a comparatively subordinate part. They include the last *Spiriferi* and *Leptænæ*. Of the lamellibranchs, a few of the most characteristic genera are *Gryphæa*, *Lima*, *Pecten*, *Monotis*, *Cardinia*, *Hippopodium*, *Myacites*, and *Pholadomya*. Gasteropods, though usually rare in such muddy strata as the greater part of the Lias, occasionally occur, but most frequently in the calcareous zones. Altogether 89 species are at present known, the chief genera being *Pleurotomaria*, *Turbo*, *Eucyclus*, *Cerithium*, and *Chemnitzia*. The cephalopods, however, are the most abundant and characteristic shells of the Lias; the family of the ammonites numbers in Yorkshire at least 113 species. As already stated, some species are so distinctive of special horizons that the whole of the Lias has been subdivided into zones, each denoted by the name of its characteristic ammonite. In ascending order, these zones are named as follows:—In the Lower Lias,—1st, *Ammonites planorbis*; 2d, *A. angulatus*; 3d, *A. Bucklandi*; 4th, *A. tuberculatus*; 5th, *A. obtusus*; 6th, *A. oxynotus*; 7th, *A. raricostatus*. In the Middle Lias,—1st, *A. Jamesoni* and *armatus*; 2d, *A. capricornus*; 3d, *A. margaritatus*; 4th, *A. spinatus*; 5th, *A. annulatus*. In the Upper Lias,—1st, *A. serpentinus*; 2d, *A. communis*; 3d, *A. jurensis*. The genus *Nautilus* is also present. The dibranchiate cephalopods are represented by upwards of 40 species of the genus *Belemnites*. Numerous species of fishes have been obtained from the Lias. Some of these are placoids, known only by their teeth (*Acrodus*, *Ceratodus*), others only by their spines (*Nemacanthus*), and some by both teeth and spines (*Hybodus*). The ganoids are frequently found entire, the genera *Dapedius*, *Pholidophorus*, *Æchmodus*, *Lepidotus*, *Pachycormus*, and *Leptolepis* being among the most frequent. But undoubtedly the most important palæontological feature of the Lias is the number and extraordinary interest of its reptilian remains. These include the extinct order of enaliosaurs or sea-lizards, uniting characters which are not found together in any living forms. Among these are the genus *Ichthyosaurus*, a creature with a fish-like body, two pairs of strong swimming paddles, and probably a vertical tail-fin. The head, joined to the body without any distinct neck, was furnished with two large eyes, having a ring of bony plates round the eyeball, and with teeth that had no distinct sockets. Some of the skeletons of this creature exceed 24 feet in length. Contemporaneous with it was the *Plesiosaurus*, distinguished by its long neck, the larger size of its paddles, the smaller size of its head, and the insertion of its teeth in special sockets, as in the higher saurians. These creatures seem to have haunted the shallow seas of the Liassic time. There were also huge winged bat-like reptiles (*Dimorphodon*), with large heads, having teeth in distinct sockets, eyes like the *Ichthyosaurus*, and one finger of each fore foot prolonged to a great length, for the purpose of supporting a membrane for flight. The bones, like those of birds, were hollow and air-filled. Gigantic deinosaurs were likewise among the inhabitants of Britain during Liassic time. These were true reptiles, yet with peculiarities of structure, particularly in the hinder part of the skeleton, linking them with birds like the ostrich. To this order belongs the *Megalosaurus* from the Lias of Lyme Regis. Lastly, the true crocodiles had representatives in the Liassic waters and shores, in the genera *Teleosaurus* and *Steneosaurus*.

The Lower or Bath Oolites lie conformably upon the top of the Lias, with which they are connected by a general similarity of organic remains. Out of the 312 known species in the Upper Lias, about 39 or 40 pass up into the overlying formation. The lowest of the three subdivisions of the English Oolites consists in the south-west and centre of England of shelly marine limestones, with clays and sandstones; but, as these strata are traced northwards into Northampton, Rutland, and Lincolnshire, they pass into a series of strata indicative of deposit in the estuary of some river descending from the north, for, instead of the abundant cephalopods of the truly marine and typical series, we meet with fresh-water genera such as *Cyrena* and *Unio*, with marine forms such as *Ostrea* and *Modiola*, thin seams of lignite, and remains of terrestrial plants. These indications of the proximity of land become still more marked in Yorkshire, where the strata (800 feet thick) consist chiefly of sandstones, shales with seams of ironstone and coal, and occasional horizons containing marine shells. It is deserving of notice that the Cornbrash, which forms the top of the Lower Oolite in the typical Gloucestershire district, occurs likewise in the same position in Yorkshire. Though rarely more than 8 feet thick, it runs across the country from Devonshire to Yorkshire. Thus a distinctly defined series of beds of an estuarine character, exactly representative of the marine formations of the south-west, shows us that at the close of the Lower Oolitic period the estuary of the northern tract was submerged, and a continuous sea-floor stretched across the whole of the south-east of England.

Thanks to the deposits of the Yorkshire estuarine series our knowledge of the Oolitic is much more ample than of the Liassic flora. With the exception of a few littoral fucoids all the plants are of terrestrial forms. They comprise about 60 species of ferns, among which the genera *Pecopteris*, *Sphenopteris*, *Phlebopteris*, and *Taniopteris* are characteristic. Next in abundance come the cycads, of which more than 20 species are known, belonging to the genera *Otozamites*, *Zamites*, *Pterophyllum*, and *Cycadites*. Coniferous remains are not infrequent in the form of stems or fragments of wood, as well as in occasional twigs with attached leaves; the genera *Araucarites*, *Brachyphyllum*, *Thuytes*, *Feuce*, *Walchia*, *Cryptomerites*, and *Taxites* have been recognized. The Inferior Oolite presents a tolerably copious suite of invertebrate remains, which resemble generically those of the Lias. The predominance of *Rhynchonella* and *Terebratula* over the rest of the brachiopods becomes still more marked. *Gryphæa*, *Lima*, *Pecten*, *Cardium*, *Myacites*, *Mytilus*, *Pholadomya*, *Trigonia* are frequent shells, while ammonites and belemnites also occur, though much more sparingly than in the Lias below, and in some of the later subdivisions of the Oolitic series. The Fuller's Earth, though well-marked in the Bath district, where it is about 200 feet thick, dies out in Oxfordshire, and contains only a few distinctive fossils, most of its forms being also found in the Inferior Oolite.

The Great or Bath Oolite consists, in Gloucestershire and Oxfordshire, of three groups of strata. At the base comes a series of thin-bedded limestones with sands, known as the Stonesfield Slate; in the centre lies a mass of shelly and yellow or cream-coloured often Oolitic limestones, with partings of marl or clay—the Great Oolite; while at the top lies a set of clays and shelly limestones, including the Bradford Clay, Forest Marble, and Cornbrash. The Stonesfield Slate, the lowest of these three zones, is a local but exceedingly important subdivision, which has furnished a large number of reptilian and some mammalian remains. It must have been deposited in shallow water close to thickly wooded shores.

About a dozen species of ferns have been found in the Stonesfield Slate, the genera *Pecopteris*, *Sphenopteris*, and *Taniopteris* being still the prevalent forms. The cycads are chiefly species of *Palæozamia*, the conifers of *Thuytes*. With these drifted fragments of a terrestrial vegetation there occur remains of beetles, dragon-flies, and other insects which had been blown or washed off the land. The waters were tenanted by a few brachiopods (*Rhynchonella* and *Terebratula*), by lamellibranchs (*Gervillia*, *Lima*, *Ostrea*, *Pecten*, *Astarte*, *Modiola*, *Trigonia*, &c.), by gasteropods (*Natica*, *Nerita*, *Pileolus*, *Trochus*, &c.), by a few ammonites and belemnites, and by placoid and ganoid fishes, of which about 50 species are known. The reptiles comprise representatives of turtles, with peculiar species of *Ichthyosaurus* and *Plesiosaurus*. The genus *Teleosaurus*, which occurs in the Yorkshire Lias, is among the organisms of the Stonesfield Slate. It was a true carnivorous crocodile, measuring about 18 feet in length, and is judged by Phillips to have been in the habit of venturing more freely to sea than the gavial of the Ganges and the crocodile of the Nile. The huge deinosaur *Megalosaurus* frequented the shores of the Stonesfield lagoons, walking probably on its massive hind legs, and feeding on the mollusks, fishes, and perhaps the small mammals of the district. It is estimated to have had a length of 25 feet, and to have weighed 2 or 3 tons. The flying reptiles were likewise represented by the *Rhamphorynchus*,—a harpy-like creature which was able to fly, to shuffle on land, or perch on rocks, perhaps even to dive in search of its prey. But the most important organic remains of the Stonesfield Slate are undoubtedly its mammalia, of which three genera *Amphitherium*, *Phascolotherium*, and *Stereognathus* have been determined. Only portions of lower jaws have yet been found, pointing doubtless to the fact that, as the animals were drifted from land, the lower jaws, unprotected by outer skin, were separated in decomposition from the rest of the body. These interesting relics were the first traces of mammalian life found in strata of such high antiquity. They are regarded as having belonged to small marsupial animals, to which living analogues exist in Australia. In the Great Oolite the remains of a gigantic saurian *Cetiosaurus* have been found. According to Phillips it was probably, when standing, not less than 10 feet in height and 50 feet in length, a marsh-loving or river-side animal, living on the ferns, cycads, and conifers among which it dwelt.

In the MIDDLE OR OXFORD OOLITES, the Oxford Clay, so called from the name of the county through which it passes in its course from the coast of Dorsetshire to that of Yorkshire, consists mainly of layers of stiff blue and brown clay. In its lower portion lies a marked zone of calcareous abundantly fossiliferous sandstone, known, from a place in Wiltshire, as the Kelaways Rock, which, after dying out in the midland counties, reappears on the Yorkshire coast. This zone contains about 150 species of fossils, of which nearly a half are found in lower parts of the Jurassic series, and about the same number pass upward into higher zones.

Among its characteristic forms is *Ammonites Calloviensis*. The Oxford clay, from the nature of its material and the conditions of its deposit, is deficient in some forms of life which were no doubt abundant in neighbouring areas of clearer water. Thus there are hardly any corals, few echinoderms, polyzoa, or brachiopods. Some lamellibranchs are abundant, particularly *Gryphæa* and *Ostrea* (both forming sometimes wide oyster-beds), *Lima*, *Avicula*, *Pecten*, *Astarte*, *Trigonia*—the whole having a great similarity to the assemblages in the Lower Oolite formations. The gasteropods are not so numerous as in the calcareous beds below, but belong mostly to the same genera. The ammonites are numerous,—*A. Duncani*, *A. Jason*, *A. Lamberti*, and *A. oculatus* being characteristic. Of the belemnites, which also are frequent, *B. hastatus* is found all the way from Dorsetshire to Yorkshire. Spines and teeth of placoid fishes and entire specimens of *Lepidotus* are occasionally to be met with. The reptiles, besides *Ichthyosaurus*, *Megalosaurus*, *Plesiosaurus* (4 species), *Steneosaurus*, and *Rhamphorhynchus*, comprise also *Pleiosaurus*—a marine saurian with large head, short neck, paddles similar to those of Plesiosaurus, approaching the type of the ichthyosaurians, but even surpassing them in size.

The Coralline Oolite can likewise be traced, with local modifications and partial interruptions, across England from Yorkshire to Dorsetshire. It is named from its beds full of masses of coral. It consists of three zones,—a lower calcareous grit, a central rubbly limestone with corals (the true "coral rag" of William Smith), and an upper calcareous grit, which, though feebly represented further south, attains importance in Yorkshire. It is frequently entirely made up of comminuted shells, urchins, corals, and other marine organisms. The corals include the genera *Isastræa*, *Thamnastræa*, and *Thecosmilia*. The urchins belong to *Cidaris*, *Hemicidaris*, *Pigurus*, *Pigaster*, and other genera. There are likewise *Ammonites*, *Belemnites*, and *Nautili*.

The UPPER OR PORTLAND OOLITES bring before us the closing epochs of the long Jurassic period in England, with the records of some of the physical revolutions which led to this change. At their base lies the Kimeridge Clay, so named from the locality on the coast of Dorsetshire where it is so well exhibited, and whence it is traceable continuously, save where covered by the Chalk, into Yorkshire. Like the Oxford Clay below, it is distinguished by its thickness, persistence, and peculiar organic remains.

Mollusca appear in greatly diminished variety; *Gryphæa virgula*, *Ostræa deltoidea*, *Astarte Hartwellensis*, and *Cardium striatulum* are characteristic species. The reptiles are the most important of the palæontological contents of this zone. They include remains of turtles, 5 species of *Ichthyosaurus*, 5 of *Pleiosaurus*, 8 of *Plesiosaurus*, *Cetiosaurus*, *Megalosaurus*, and the crocodilians *Steneosaurus*, *Teleosaurus*, and *Goniopholis*.

The Portland beds are so named from the isle of Portland, where they directly succeed the Kimeridge Clay. A feeble representative of them is believed to overlie that clay on the Yorkshire coast, but it is in the southern counties that they attain their chief development. They consist, at Portland, of a lower sandy set of beds about 150 feet thick, and of an upper calcareous zone (containing the well-known limestone so largely used for building purposes under the name of Portland stone) about 70 feet thick.

The fossils, which very commonly occur as mere empty casts, include as characteristic species *Isastræa oblonga*, *Cardium dissimile*, *Trigonia gibbosa*, and *Terebra Portlandica*. There occur also remains of some of the great Oolitic saurians.

The Purbeck beds, so named from the Isle of Purbeck, where they are best developed, are usually connected with the foregoing formations as the highest zone of the Jurassic series of England. But they are certainly separated from the rest of that series by many peculiarities, which show that they were accumulated at a time when the physical geography and the animal and vegetable life of the region were undergoing a remarkable change.

They have been arranged in three groups. The lowest consists of fresh-water limestones and clays, with layers of ancient soil containing stumps of the trees which grew in them. The middle group comprises about 130 feet of strata with marine fossils, while the highest division shows a return of fresh-water conditions. Among the indications of the presence of the sea is an oyster bed (*Ostrea distorta*) 12 feet thick, with *Pecten*, *Modiola*, *Avicula*, *Thracia*, &c. The fresh-water bands contain still living genera of lacustrine and fluviatile shells—*Paludina*, *Limnæa*, *Planorbis*, *Physa*, *Valvata*, *Unio*, and *Cyclas*. Numerous fishes, both placoid and ganoid, haunted these Purbeck waters. Many insects, blown off from the adjacent land, sank and were entombed and preserved in the calcareous mud. These include coleopterous, orthopterous, hemipterous, neuropterous, and dipterous forms. Remains of several reptiles, chiefly chelonian, but including the Jurassic crocodile *Goniopholis*, have also been discovered. But the most remarkable organic remains of the Purbeck beds are those of 10 genera and 25 species of marsupial mammals, from the size of a mole to that of a polecat. They are believed to have been mostly insectivorous. One of them (*Triconodon major*) is regarded by Owen as carnivorous, and probably about the size of the existing *Dasyurus maugei* of Australia. These mammalian remains occur, almost wholly as lower jaws, in a stratum about 5 inches thick lying near the base of the Middle Purbeck group.

CONTINENTAL EUROPE.—Jurassic rocks cover a vast area in central Europe. They rise from under the Cretaceous formations in the north-east of France, whence they range southwards down the valleys of the Saone and Rhone to the Mediterranean. They appear as a broken border round the old crystalline nucleus of Auvergne. Eastwards they range through the Jura Mountains up to the high grounds of Bohemia. They appear in the outer chains of the Alps on both sides, and on the south they rise along the centre of the Apennines, and here and there over the Spanish peninsula. Covered by more recent formations they underlie the great plain of northern Germany, whence they range eastwards and occupy large tracts in central and eastern Russia. According to Neumayr, three distinct geographical regions of deposit can be made out among the Jurassic rocks of Europe. (1.) The Mediterranean province, embracing the Pyrenees, Alps, and Carpathians, with all the tracts lying to the south. One of the biological characters of this area was the great abundance of ammonites belonging to the groups of *Heterophylli* (*Phylloceras*) and *Fimbriati* (*Lytoceras*). (2.) The central European province, comprising the tracts lying to the north of the Alpine ridge, and marked by the comparative rarity of the ammonites just mentioned, which are replaced by others of the groups *Inflati* (*Aspidoceras*) and *Oppellia*, and by abundant reefs and masses of coral. (3.) The boreal or Russian province, comprising the middle and north of Russia, Spitzbergen, and Greenland. The life in this area was much less varied than in the others, showing that in Jurassic times there was a perceptible diminution of temperature towards the north. The ammonites of the more southern tracts here disappear, together with the corals.

In France the following arrangement has been made of the Jurassic rocks, the subdivisions nearly corresponding to those first proposed in England:—

(Purbeck beds not recognized.)
Terrain Portlandien (Calcaire tacheté de Boulogne).
,, Kimeridgien (Argile de Honfleur).
,, Corallien (Calcaire Corallien).
,, Oxfordien (Oolithe de Trouville).
,, Callovien (Argiles de Dives = Kelaways Rock).
,, Bathonien (Oolithe de Caen = Cornbrash, Terre à foulon).
,, Bajocien ou Oolithe Inférieure (Oolithe de Bayeux).
,, Toarcien (Marnes Liasiques supérieure = Upper Lias).
,, Liasien (Marnes et calcaires à Belemnites = Middle Lias).
,, Sinémurien (Calcaire à Gryphées = Lower Lias)

In north-western Germany the subjoined classification has been adopted.

Upper or White Jura (Malm).	Purbeck group (Serpulit, Münder Mergel, and Eimbeckhäuser Plattenkalk).	
	Kimeridge group (Upper, with *Ammonites gigas* and *Exogyra virgula*; Lower or Nerinæen-Schichten).	
	Oxford group (Upper, with *Cidaris florigemma*: Lower, with *Gryphæa dilatata*).	
Middle or Brown Jura (Dogger).	Upper	Clays with *Ammonites ornatus*.
		Shales with *Amm. macrocephalus*.
		Cornbrash with *Avicula echinata*, *Amm. posterus*.
	Middle	Shales with *Ostrea Knorri*, *Amm. ferrugineus*.
		Zone of *Amm. Parkinsoni*.
		Coronaten-Schichten, clays with *Belemnites giganteus*, *Amm. Humphresianus*, *Amm. Braikenridgi*.
	Lower	Shales with *Inoceramus polyplocus*, *Amm. Murchisonæ*.
		Clays and limestones with *Amm. opalinus*.
Lower or Black Jura (Lias).	Upper	Grey marls with *Ammonites jurensis*.
		Bituminous shales (Posidonien-schiefer) with *Amm. lythensis*, *A. communis*, *A. bifrons*, *Posidonia Bronni*.
	Middle	Clays with *Amm. amalthea*.
		Marls and limestones with *Amm. capricornus*.
		Dark clays and ferruginous marls with *Amm. brevispina*.
	Lower	Clays with *Amm. planicosta*.
		Blue grey clays with *Amm. Bucklandi* (Arietenschichten).
		Dark clays with *Amm. angulatus*.
		Dark clays and sandy layers with *Amm. planorbis* (*psilonotus*).

NORTH AMERICA.—So far as yet known rocks of Jurassic age play but a very subordinate part in North American geology. Perhaps some of the red strata of the Trias belong to this division, for it is difficult, owing to paucity of fossil evidence, to draw a satisfactory line between the two systems. Strata containing fossils believed to represent those of the European Jurassic series have been met with in recent years during the explorations in the western domains of the United States. They occur among some of the eastern ranges of the Rocky Mountains, as well as on the western side of the watershed. They have been recognized also far to the north beyond the great region of Azoic and Palæozoic rocks in the arctic portion of the continent. They consist of limestones and marls, which appear seldom to exceed a few hundred feet in thickness. The fossils include species of *Pentacrinus*, *Monotis*, *Trigonia*, *Lima*, *Ammonites*, and *Belemnites*.

CRETACEOUS.

The next great series of geological formations is termed the Cretaceous system, from the fact that in England and western Europe one of its most important members is a thick band of white chalk (*creta*).

BRITAIN.—The Purbeck beds bring before us evidence of a great change in the geography of England towards the close of the Jurassic period. They show how the floor of the sea in which the thick and varied formations of that period were deposited came to be gradually elevated, and how into pools of fresh and brackish water the leaves, insects, and small marsupials of the adjacent land were washed down.

These evidences of terrestrial conditions are followed in the same region by a vast delta-formation, that of the Weald, which accumulated over the south of England, while the older parts of the Cretaceous system were being deposited in the north. Hence there are two types of that system, one where the strata are fluviatile or estuarine, termed the Wealden type, the other where they are marine, known as the Neocomian type. Arranged in descending order the following are the subdivisions of the English Cretaceous rocks:—

Upper Cretaceous.	Chalk	Upper Chalk with flints ...	.....600 to 1200 ft.
		Lower Chalk without flints	
		Chalk Marl (Grey Chalk)	
		Chloritic Marl	
	Upper Greensand	Greenish-grey sandstones and sands	40 ,, 150 ,,
	Gault	Stiff blue clay with calcareous and pyritous nodules.....	100 ,, 150 ,,

Fluviatile Type.		*Marine Type.*		
Lower Cretaceous or Neocomian.	Weald Clay, 1000 ft.	Lower. Upper.	Lower Greensand.	Folkstone beds . 70 to 100 ft
				Sandgate beds .. 75 ,, 100 ,,
				Hythe beds..... 80 ,, 300 ,,
				Atherfield clay . 20 ,, 60 ,,
				Upper part of Speeton Clay..... 150 ,,
	Hastings beds consisting of— Tunbridge Wells Sand (140-380 ft); Wadhurst Clay (120-180 ft); Ashdown Sand (400 or 500 ft).	Lower. Middle.		Punfield beds, Tealby beds, and middle part of Speeton Clay..... ..... 150 ,,
				Lower part of Speeton Clay..... 200 ,,

Lower Cretaceous or Neocomian.—The fluviatile development of this series in the south of England consists of a great depth of sands and clays known generally as the Wealden series, from the Weald of Sussex and Kent, where they are best displayed.

They precisely resemble the deposits of a delta, and this is borne out by their organic remains, which consist partly of terrestrial plants (*Equisetum*, *Sphenopteris*, *Alethopteris*, *Thuytes*, cycads, and conifers), and fresh-water shells (*Unio*, 10 species; *Cyrena*, 5 species; with *Cyclas*, *Paludina*, *Melania*, &c.), with a few estuarine or marine forms as *Ostrea* and *Mytilus*, and ganoid fishes (*Lepidotus*) like the gar of American rivers. Among the spoils of the land floated down by this river were the carcases of huge deinosaurian reptiles (*Iguanodon*, *Hylæosaurus*, *Megalosaurus*), of the long necked plesiosaurs, and of winged pterodactyles. The deltoid formation in which these remains occur extends in an east and west direction for at least 200 miles, and from north to south for at least 100. Hence the delta must have been not less than 20,000 square miles in area. It has been compared with that of the Quorra; in reality, however, its extent must have been greater than its present visible area, for it has suffered from denudation, and is to a large extent concealed under more recent formations. The river probably descended from the north-west, draining a vast area, of which the existing mountain groups of Britain are perhaps merely fragments.

The marine type of the Lower Cretaceous rocks is now commonly termed Neocomian, from Neufchâtel (*Neocomum*), where it is well developed. In the south of England only the upper division appears, overlying conformably the Wealden series, and showing the gradual depression of the old delta and the advance of the sea. In Yorkshire, however, a thick deposit known as the Speeton Clay has been ascertained by Mr Judd to pass down into the Jurassic system, and to contain a representation of the upper parts of the Neocomian of the Continent.

The lower division of the Speeton Clay contains, among other fossils, *Ammonites Noricus*. The central zone is marked by *Pecten cinctus*, *Ancyloceras Duvallii*, and *Meyeria ornata*. The upper division is characterized by *Perna Mulleti*, *Ammonites Deshayesii*, *Pecten orbicularis*. It is the fossils of this upper division which occur in the Lower Greensand of Kent. They amount to about 300 species, of which only 18 or 20 per cent. pass up into the Upper Cretaceous. This marked palæontological break, taken in connexion with traces of unconformability between the Lower Greensand and the Gault, shows that a definite geological boundary-line can be drawn between the lower and upper parts of the Cretaceous system.

Upper Cretaceous.—At the base of this series lies the Gault—a dark blue stiff clay or marl, sometimes sandy and calcareous. It overlaps the older parts of the Cretaceous series, and in Wiltshire lies on Kimeridge Clay. Among the characteristics fossils of this division are *Cyclocythus Fittoni*, *Caryophilia Bowerbankii*, *Nucula pectinata*, *Inoceramus sulcatus*, *Natica Gaultina*, *Rostellaria carinata*, *Ammonites dentatus*, and *Hamites attenuatus*. In all, about 200 species of fossils occur, of which about 46 per cent. pass into up into the Upper Greensand.