depths 40 feet below without altering the position of its body. It must have wandered far from land, and that many kinds of fishes formed its food is shown by the teeth and scales found in the position of its stomach" (Cope). But the real rulers of the American Cretaceous waters were the pythonomorphic saurians or sea-serpents. Some of them attained a length of 75 feet or more. They possessed a remarkable elongation of form, particularly in the tail; their heads were large, flat, and conic, with eyes directed partly upwards. They swam by means of two pairs of paddles, like the flippers of the whale, and the eel-like strokes of their flattened tail. Like snakes they had four rows of formidable teeth on the roof of the mouth, which served as weapons for seizing their prey. But the most remarkable feature in these creatures was the unique arrangement for permitting them to swallow their prey entire, in the manner of snakes. Each half of the lower jaw was articulated at a point nearly midway between the ear and the chin, so as greatly to widen the space between the jaws, and the throat must, consequently, have been loose and baggy like a pelican's. Nine species of birds have been obtained from the American Cretaceous rocks. Three of these belonged to the order of Natatores or swimmers, which includes our modern gulls, ducks, and geese; four were *Grallæ* or waders; while two belonged to a long extinct order, and united certain ichthyic and reptilian characters with those of birds. (See Cope, *Report of U.S. Geol. Surv. of Territories*, vol. ii., 1875; Marsh, *American Journ. Science*, 3d ser., i. to iv.; Leidy, *Smithsonian Contributions*, 1865, No. 192; Lesquereux, *Cretaceous Flora*, *Report of U.S. Geol. Surv. of Territories*, vol. vi.)

IV. TERTIARY OR CAINOZOIC.

The close of the Secondary periods was marked in the west of Europe by great geographical changes, during which the floor of the Cretaceous sea was raised partly into land and partly into shallow marine and estuarine waters. These events must have occupied a vast period of time, so that, when sedimentation once more began in the region, the organic remains of the Secondary ages had (save in a few low forms of life) entirely disappeared and given place to others of a distinctly more modern type. In England, the interval between the Cretaceous and the next geological period represented there by sedimentary formations is marked by the abrupt line which separates the top of the Chalk from all later accumulations, and by the evidence that the Chalk seems to have been in some places extensively denuded before even the oldest of what are called the Tertiary beds were deposited upon its surface. There is evidently here a considerable gap in the geological record. We have no data for ascertaining what was the general march of events in the south of England between the eras chronicled respectively by the Upper Chalk and the overlying Thanet beds.

Here and there on the Continent a few scraps of evidence are obtainable which help to fill up this gap. Thus, on the banks of the Meuse at Maestricht, a series of shelly and polyzoan limestones with a conglomeratic base (*Système Maestrichtien* of Dumont, who places it above his Senonian system in the Upper Cretaceous series) contains a mingling of true Cretaceous organisms with others which are characteristic of the older Tertiary formations. It contains, for example, the characteristic Upper Chalk crinoid, *Bourgeticrinus ellipticus*, in great numbers; also *Ostrea vesicularis*, *Baculites Faujasii*, *Belemnitella mucronata*, and the great reptile *Mosasaurus*; but with these occur such Tertiary genera as *Voluta*, *Fasciolaria*, and others. At Faxoe, on the Danish island of Seeland, the uppermost member of the Senonian series contains in like manner a blending of well-known Upper Chalk organisms with the Tertiary genera *Cypræa*, *Oliva*, and *Mitra*. In the neighbourhood of Paris also, and in scattered patches over the north of France, a formation known as the pisolitic limestone occurs, which was formerly classed with the Tertiary formations, seeing that its fossils had more affinities with later than with older rocks. But the discovery in it of numerous distinctively Upper Cretaceous forms has led to its being placed at the top of the Senonian series, from which, however, it is marked off by a decided unconformability, for it rests on a denuded surface of the White Chalk. These fragmentary formations are interesting, in so far as they help to show that, though in western Europe there is a tolerably abrupt separation between Cretaceous and Tertiary deposits, there was nevertheless no real break between the two periods. The one merged insensibly into the other; but the chronicles of the intervening ages have been in great measure destroyed.

In entering upon the Tertiary series of formations, we find ourselves upon the threshold of the modern type of life. The ages of lycopods, ferns, cycads, and yew-like conifers have passed away, and that of the dicotyledonous angiosperms—the hard-wood trees and evergreens of to-day—now succeeds them, but not by any sudden extinction and recreation, for, as we have seen (*ante*, p. 359), some of these trees had already begun to make their appearance even in Cretaceous times. The ammonites, baculites, and other cephalopods, which had played so large a part in the molluscan life of the Secondary periods, now cease. The great reptiles, too, which in such wonderful variety of type were the dominant animals of the earth's surface, alike on land and sea, ever since the commencement of the Lias, now wane before the increase of the mammalia, which advance in ever-augmenting diversity of type until man appears at their head.

The name Tertiary, given in the early days of geology before much was known regarding fossils and their history, has retained its hold on the literature of the science. It is sometimes replaced by the term Cainozoic (*recent life*), which expresses the great fact that it is in the series of strata comprised under this designation that most recent species and genera have their earliest representatives. Taking as the basis of classification the percentage of living species of mollusca found in the different groups of the Tertiary series, Lyell proposed a scheme of arrangement which has been generally adopted. The older Tertiary formations, in which the number of still living species of shells is very small, where, in fact, we seem to see as it were the first beginnings of the modern life, he named *Eocene* (*dawn of the recent*), including under that title those parts of the Tertiary series of the London and Paris basins wherein the proportion of existing species of shells was only 3½ per cent. The middle Tertiary beds in the valleys of the Loire, Garonne, and Dordogne, containing 17 per cent. of living species, were termed *Miocene* (*less recent*). The younger Tertiary formations of Italy were included under the designation *Pliocene* (*more recent*), because they contained a majority or from 35 to 95 per cent. of living species. This newest series, however, was further subdivided into Older Pliocene (35 to 50 per cent. of living species) and Newer Pliocene (90 to 95 per cent.). This classification, with various modifications and amplifications, has been adopted for the Tertiary group not of Europe only but of the whole globe.

As the North American development of the Tertiary series differs in so many respects from that of Europe, it will be most conveniently considered by itself after the European classification has been described.

Eocene.

Great Britain.—The Eocene rocks of Britain are entirely confined to the south-east of the island, where they occupy two great depressions of the chalk, known respectively as the London and Hampshire basins. They have been arranged into the groups shown in the subjoined table.

Upper	Upper fresh-water and estuarine series	Hempstead beds	170 ft.
		Bembridge ,,	115 ,,
		Osborne ,,	70 ,,
		Headon ,,	200 ,,

Middle	Middle marine series	Upper Bagshot Sand	250 to 300 ft.
		Middle Bagshot beds, including Barton Clay (300 feet) and Bracklesham beds (100 feet).	
		Lower Bagshot beds	100 ,, 150 ,,
Lower	Lower fresh-water, estuarine, and marine series	London Clay	50 ,, 500 ,,
		Oldhaven beds	20 ,, 30 ,,
		Woolwich and Reading beds	15 ,, 163 ,,
		Thanet Sand	20 ,, 60 ,,

Grouped in relation to the physical changes which they record, these strata naturally stand in three divisions. At the base lies a series of beds laid down in fresh, estuarine, and sea-water, on an upraised denuded surface of Chalk. Then comes a central group bearing witness to the deepening of these shallow waters, and to the advance of the sea far up the former estuary. The upper group brings before us proof of the eventual retreat of the sea, and the conversion of the area once more into fresh-water lakes and rivers. This arrangement does not quite tally with that which is based on a comparison of the fossils with existing forms, and with those of other Tertiary districts, for it places the London Clay in the middle series, though the fossil evidence distinctly shows that formation to belong to the older Eocene groups.

Lower Eocene.—The Thanet Sand at the base of the London Tertiary basin consists of pale yellow and greenish sand, sometimes clayey, and containing at its bottom a layer of green-coated flints resting directly on the Chalk. According to Mr Whitaker, it is doubtful if any proof of actual erosion of the chalk can anywhere be seen under the Tertiary deposits in England, and he states that the Thanet Sands everywhere lie upon an even surface of chalk with no visible unconformability. Professor Philips, on the other hand, describes the chalk at Reading as having been "literally ground down to a plain or undulated surface, as it is this day on some parts of the Yorkshire coast," and having likewise been abundantly bored by lithodomous shells. The fossils of the Thanet Sand comprise about 70 known species (all marine, except a few fragments of terrestrial vegetation). Among them are several foraminifera, numerous lamellibranchs (*Astarte tenera*, *Cyprina Morrisii*, *Ostrea Bellovacina*, &c.), a few species of gasteropods (*Natica subdepressa*, *Aporrhais Sowerbii*, &c.), a nautilus, and the teeth or palatal bones of fishes (*Lamna*, *Pisodus*).

The Woolwich and Reading beds, or Plastic Clay of the older geologists, consist of lenticular sheets of plastic clay, loam, sand, and pebble beds. The organic remains show that the sea of the Thanet Sand era gradually shallowed into an estuary. They amount to more than 100 species, and include a few plants of terrestrial growth such as *Ficus Forbesi*, *Grevillea Heeri*, and *Laurus Hookeri*. The lamellibranchs are partly estuarine or fresh-water (*Cyclas*, *Cyrena*, *Dreissena*, *Unio*), partly marine. Of the latter a characteristic species is *Ostrea Bellovacina*, which forms a thick oyster bed at the base of the series. *Ostrea tenera* is likewise abundant. The gasteropods include a similar mixture of marine with fluviatile species (*Cerithium funatum*, *Melania inquinata*, *Natica subdepressa*, *Fusus latus*, *Paludina lenta*, &c.) The fish are chiefly sharks (*Lamna*). Bones of turtles and scutes of crocodiles have been found. The highest organisms are bones of mammalia, one of which, the *Coryphodon*, was allied to the modern tapir.

The Oldhaven beds forming the base of the London Clay, though of trifling thickness, have yielded upwards of 150 species of fossils. Traces of *Ficus*, *Cinnamomum*, and *Coniferæ* have been obtained from them; but the organisms are chiefly marine and partly estuarine shells, the gasteropods being particularly abundant. The London Clay, as its name implies, is a mass of clay, stiff, brown, or bluish-grey, with septarian nodules. It extends through both the London and Hampshire basins, attaining a maximum thickness in the south of Essex. It has yielded a long and varied suite of organic remains, from which we can see that it must have been laid down in the sea beyond the mouth of a large estuary, into which abundant relics of the vegetation, and even sometimes of the fauna of the adjacent land were swept. Its fossils are mainly marine mollusca, and, taken in connexion with the flora, indicate that the climate was somewhat tropical in character. The plants include the fruits or other remains of palms (*Nipadites*), custard-apple, acacia, gourds, melons, *Proteaceæ*, and *Coniferæ*. Crustacea abound (*Xanthopsis*, *Hoploparia*). Gasteropods are the prevalent mollusks, the common genera being *Pleurotoma* (45 species), *Fusus* (15 species), *Cypræa*, *Murex*, *Cassidaria*, *Pyrula*, and *Voluta*. The cephalopods are represented by 6 or more species of *Nautilus*, by *Belosepia sepioidea*, and *Beloptera Levesquei*. Nearly 100 species of fishes occur in this formation, the rays (*Myliobates*, 14 species) and sharks (*Lamna*, *Otodus*, &c.) being specially numerous. A sword-fish (*Tetrapterus priscus*), and a saw-fish (*Pristis bisulcatus*) about 10 feet long, have been described by Agassiz from the London Clay of Sheppey, whence almost the whole of the fish remains have been obtained. The reptiles were numerous, but markedly unlike, as a whole, to those of Secondary times. Among them are numerous turtles and tortoises, two species of crocodile, and a sea-snake (*Palæophis*), estimated to have been 13 feet long. Remains of birds have also been met with; one of these (*Lithornis vulturinus*) appears to have been allied to the vulture, another (*Halcyornis toliapicus*) to our modern king-fisher, besides waders and other types. The mammals numbered among their species a hog (*Hyracotherium*), several tapirs (*Coryphodon*, &c.), an opossum (*Didelphys*), and a bat. The carcases of these animals must have been borne seawards by the great river which transported so much of the vegetation of the neighbouring land.

Middle.—The Bagshot group consists of sand and bands of clay which, in the Hampshire basin, are tolerably fossiliferous. As developed in the Isle of Wight and at Bournemouth, their lower members have yielded a large number of terrestrial plants, among which the *Proteaceæ* are still numerous, together with species of fig, cinnamon, fan-palm (*Sabal*), oak, yew, cypress, laurel, lime, senna, and many more. Crocodilian forms still haunted the waters, and have left their bones with those of sea-snakes and turtles and of the tapirs and other denizens of the land, which still, as in the time of the London Clay, continued to be washed out to sea. Among these strata we now find one of the most typical organisms of the Eocene rocks of the Mediterranean basin, a foraminifer termed *Nummulites* (*N. lævigata*, *N. scabra*, *N. variolaria*). Characteristic fossils are *Voluta athleta*, *V. luctatrix*, *Murex asper*, *Fusus longævus*, *Cardita planicosta*, and *Chama squamosa*.

Upper.—The strata of this division of the English Eocene formations are entirely confined to Hampshire and the Isle of Wight. They consist of sands, clays, marls, and limestones, in thin-bedded alternations. These strata were accumulated partly in the sea, partly in brackish, and partly in fresh water. They were hence named by Edward Forbes the fluvio-marine series. Among the marine fossils are—*Fusus porrectus*, *Oliva Branderi*, *Natica labellata*, *Ostrea callifera*, and *Nummulites lævigata*. The genera *Cerithium*, *Potamomya*, *Paludina*, *Planorbis*, *Limnæa*, and *Cyclas* are abundant, showing the brackish and fresh-water conditions in which many of the strata were deposited. Remains of turtles, snakes, crocodiles, and alligators continue to occur in these Upper Eocene beds. With these are found the bones of several very characteristic mammals also met with in the Paris basin,—the three-toed *Palæotherium*, resembling the living tapir; *Anoplotherium*, a more graceful

animal with long tail, and two-toed feet, forming a kind of intermediate type between a hog and a deer or antelope; *Dichobune*, allied to the last named; also *Dichodon*, *Hyopotamus*, *Chœropotamus*, *Hyœmodon*, &c. The top of the Eocene series in the Isle of Wight has been removed by denudation, so that we have no evidence in Britain of what took place after the close of the Eocene period.

CONTINENTAL EUROPE.—Geologists on the continent of Europe, finding it impossible to carry out the principle of percentage of recent species, as originally formulated by Lyell in his terminology of the Tertiary series, have made various modifications of this nomenclature. By some the three terms Eocene, Miocène, and Pliocene are retained, but, following Beyrich, they subdivide the Miocene into two, keeping that term for the upper half and calling the lower Oligocene, which corresponds with Lyell's Lower Miocene. Others would consider the whole Tertiary and post-Tertiary series as divisible into three groups, the Eocene or Older Tertiary, corresponding pretty closely to the Lyellian use of the term, the Neogene or Younger Tertiary, embracing both Miocene and Pliocene, and the Diluvial and Alluvial.

In the Paris basin the Eocene formations assume a somewhat different type from that which they present in England, though the occurrence of a number of the same species of fossils in both allows of their being paralleled in a general way. The lower Eocene consists there of sand and clay answering in lithological character to the Thanet Sand and Plastic Clay of the London basin. The common species in that basin (*Ostrea Bellovacina*) occurs there in great numbers, while the brackish water-beds contain some of the common species at Woolwich, such as *Cyrena cuneiformis* and *Melania inquinata*. Beds of lignite occur in this division, likewise bones of *Coryphodon Eocænus*, *Viverra gigantea*, and the bird *Gastornis*. The Middle Eocene is made up of the characteristic "Calcaire grossier"—a mass of limestone, sometimes tender and crumbling, in other places so compact as to be largely quarried as a building stone. Some portions are entirely composed of minute foraminifera (miliolitic limestone). Among the characteristic fossils of this division are *Nummulites*, *Cerithium giganteum*, with bones of *Dichobune*, *Lophiodon*, *Paloplotherium*, &c. The Upper Eocene consists of sand (Sables moyens) overlaid by the great gypsum and gypseous marl group of Montmartre. This is the deposit from which so many of the mammals of the Eocene period have been recovered. It is divided into three zones, and among its fossils are upwards of 50 species of quadrupeds, including many Palæotheres, Anoplotheres, Paloplotheres, with *Xiphodon*, *Dichobune*, *Adapis*, *Chœropotamus*, *Myacus*, *Canis Parisiensis*, *Viverra Parisiensis*, *Vespertilio*, *Didelphys Cuvieri*, and about 17 species of birds.

The Eocene formations of the north-west of Europe occupy but a few detached basins, and consist for the most part of soft clays, sands, marls, and thin limestones. They were laid down partly in estuaries, rivers, or lakes, partly in shallow seas near land. They contain abundantly the vegetation, with some remains of the quadrupeds and birds, of that land, and show that still in older Tertiary times, as during the long Palæozoic and Secondary ages, the chief area of land lay to the north-west. But when we turn to the corresponding formations in central and southern Europe, they present us with the idea of their antiquity, for they consist chiefly of massive, hard, crystalline, and sometimes even marble-like limestones, which suggest some of the Palæozoic rocks rather than those of so modern a date as the London Clay and Calcaire Grossier. Again, instead of being confined to a few local basins, they cover an enormous geographical area and play a notable part in the structure of some of the great mountain chains of the globe. Crowded as they are with nummulites, they must have been deposited not in estuaries and shallow bays but in a wide and clear sea, which, traced by the area of these limestones, must have ranged across the whole of the south of Europe and north of Africa, through Greece, Turkey, Asia Minor, and the heart of Asia, to the far shores of China and Japan. Since the time when this wide channel connected the Atlantic and the Pacific across the heart of the Old World, the great mountain ranges of the Pyrenees, Alps, Apennines, Carpathians, and of Central Asia, have been upheaved to their present altitude. Some of the prominent peaks along their flanks consist of the hardened and crumpled calcareous mud of the Eocene sea.

In the northern and southern Alps the Eocene formations consist of nummulitic limestone—a grey, yellow, sometimes reddish compact rock, usually containing and often made up of nummulites; Nummulite sandstone; Vienna sandstone—an enormous mass of arenaceous rock almost destitute of organic remains, and referred partly to the Cretaceous and partly to the Eocene series; and Flysch—a massive development of dark shales or schists, sandstones, and argillaceous limestone, sometimes charged with the remains of fucoids and (at Matt, Glarus) of fish. The nummulitic series of southern Europe is divided into zones characterized by fossils, and brought into a kind of broad parallelism with the subdivisions of the English and French Eocene basins. In the eastern Alps, near Vienna and elsewhere, some of the nummulitic sandstones contain enormous blocks of granite, gneiss, and other crystalline rocks, which are believed to have been ice-borne, and therefore to prove the existence of Alpine glaciers even in Eocene times. These mountains already existed, as it were, in embryo, even far back in the Secondary and Palæozoic ages. During the later part of the Eocene period they seem to have been clothed with an abundant flora, among which the fan-palm, *Banksia*, *Dryandria*, and other plants remind one of the living vegetation of tropical America, the East Indies, and Australia. Out of these plants the important coal-seams of Häring in Tyrol were formed.

MIOCENE.

According to the original nomenclature proposed by Lyell, this subdivision of the Tertiary series was meant to include those strata in which 17 per cent. or thereabouts of the shells belong to still living species. As the system of nomenclature was adopted at a time when our knowledge both of living and fossil species was still very defective, it could not but require modification with the progress of science. Some strata, classed at one time as Miocene from their proportion of recent forms, might, on more extended research, prove to contain a much larger percentage, and therefore to be referable to a later part of the Tertiary series. The term, however, is used as a convenient and long-established designation for a series of strata younger than the Eocene, which they seem to have succeeded, though in some parts of the European area after enormous geographical changes.

GREAT BRITAIN.—Miocene formations, in the ordinary sense of the term, are almost entirely absent from the British Islands. In Devonshire, at Bovey Tracey, a small but interesting group of sand, clay, and lignite beds, from 200 to 300 feet thick, lies between the granite of Dartmoor and the Greensand hills, in what was evidently the hollow of a Miocene lake. From these beds Heer of Zurich, who has thrown so much light on the Miocene flora of both the Old World and the New, has described about 50 species of plants, which, he says, place this Devonshire group of strata on the same geological horizon with some part of the Lower Miocene formations of Switzerland. Among the species are a number of ferns (*Lastrœa stiriaca*, *Pecopteris lignitum*, &c.); some conifers, particularly a *Wellingtonia* called the *Sequoia Couttsiæ*, the debris of which forms one of the lignite beds; a few grasses, water-lilies, and a palm. Leaves of oaks, figs, laurels, willows, and seeds of grapes have also been detected—the whole vegetation implying a subtropical climate. In the north of Ireland lies a great plateau of basalt, presenting along the coast of Antrim a magnificent range of mural escarpments. The basalt-beds mark successive outpourings of lava, which took place on a prodigious scale from the Antrim region northwards through the Western Islands and the Faroe Islands into Iceland, and even far up into Arctic Greenland. In Ireland the basalts attain a maximum thickness of 900 feet; in Mull about 3000 feet. They are associated with tuffs, pitchstones, trachytes, and granitoid rocks, which mark the position of the main vents of eruption. It is evident that long-continued and vigorous volcanic action took place in these north-western regions. The geological date of this activity can be approximately fixed by the fossil plants here and there to be found in leaf-beds between the sheets of basalt. They agree generally with species found in the Older Miocene beds of Switzerland; and hence the date of this marked volcanic era in the north-west of Europe and in Greenland is placed in the older part of the Miocene period. With these exceptions there are no Miocene rocks in Britain.

CONTINENTAL EUROPE.—The records of the Miocene period in Europe bring before us a scene very different from that which the region presented during the Eocene ages. The least amount of change took place in the north-west and north. It consisted chiefly in the upraising of the floor of the shallow sea which had stretched eastwards across the north of France, and the formation of numerous fresh-water lakes, lagoons, and morasses. But over the Alpine region a vast revolution took place. The Eocene sea had its bed elevated, and the Alps rose many thousand feet above their previous height, carrying up on their flanks the hardened, upturned, crumpled, and crystallized nummulite limestone. These vast corrugations of the earth's crust were general over the whole globe about the same geological period. Subterranean movements appear to have continued during Miocene times in the Alpine area; large lake-basins were formed over a great part of what is now Switzerland, and in these the deposits of the period took place. Hence the Miocene formations of Europe are in great measure of lacustrine and terrestrial formation. The sea, however, was allowed to pass across the south of France between the central axis and the Pyrenees. It likewise covered a wide area in eastern Europe, sweeping far up into the Vienna basin and the foot of the Austrian Alps. Traces of the occasional presence of the sea can likewise be followed across Belgium and North Germany, and even on the south side of the Eifel and Westphalian high grounds in the basin of Mainz.

In France, on the north side of the axis of old rocks, the upper parts of the Eocene series are covered by certain marls, clays, and limestones, containing *Ostrea cyathula*, and passing up into the thick sandstone of Fontainebleau, well known for its picturesque scenery. These are considered as the base of the Miocene (or Oligocene) series. They contain *Fusus elongatus*, *Aporrhais speciosa*, *Pecunculus obovatus*, *Cyrena semistriata*, *Cerithium plicatum*, &c. They are succeeded by some fresh-water limestones (Calcaire de Beauce) full of *Paludina*, *Planorbis*, *Limnæa*, and *Helix*. These strata show very instructively the gradual shallowing of the sea in the north of France, and its conversion into fresh-water lakes and land. Further to the south a subsequent depression took place, in which the shelly sands and marls (faluns) of Touraine were accumulated. These strata lie in scattered patches, and seldom exceed 50 feet in thickness. They contain chiefly marine shells (*Cypræa*, *Oliva*, *Mitra*, *Terebra*, *Fusciolaria*, *Conus*, &c.), also remains of the *Dichobune* and *Chœropotamus*, with some of the huge early pachyderms,—*Mastodon*, *Dinotherium*, rhinoceros, hippopotamus, and species of dolphin, morse, &c.

In North Germany the older Miocene rocks are marine where they pass westwards into the Belgian area, but as they are followed southwards they bear evidence of increasing proximity to land, till at last they contain abundant seams of lignite, and hence have been termed the Brown-coal series. They appear to underlie most of the great north Germanic plain, on the south side of which they rise up into the Rhine valley, Thuringia, Saxony, and Silesia. The Brown-coal series consists of sandstones, conglomerates, and clays, with leaf-beds and seams of lignite. The last, which have been largely worked as fuel, are mainly composed of remains of conifers, (*Taxites*, *Taxaxylon*, *Cupressinoxylon*, *Sequoia*), but with them are associated, in the neighbouring strata, leaves and other fragments of oak, beech, maple, fig, laurel, cinnamomum, magnolia, sassafras, palmacites, &c. These strata are overlaid by marine beds containing *Ostrea*, *Cardita*, *Pleurotoma*, *Voluta*, and numerous corals. The subterranean movements above referred to as having long affected the Alpine region were felt likewise in North Germany, for we find these marine beds succeeded by a second lignitic formation, seen at Grosser Hubenecken, on the eastern horn of the Gulf of Dantzic. But this could only have been a local uplift, for marine sands and clays are next found with a wide diffusion over the plains of northern Germany.

Nowhere in Europe do the Miocene formations play so important a part in the scenery of the land, or present on the whole so interesting and full a picture of the state of Europe when they were deposited, as in Switzerland. Rising into massive mountains, as in the well-known Righi and Rossberg, they attain a thickness of more than 6000 feet. While they include indications of the presence of the sea, they have preserved with marvellous perfection a large number of the plants which clothed the Alps, and of the insects which flitted through the woodlands. They are termed "Molasse" by the Swiss geologists, and have been divided into the following groups:—

Upper fresh-water Molasse and brown-coal, consisting of sandstones, marls, and limestones, with a few lignite-seams and fresh-water shells, and including the remarkable group of plant and insect-bearing beds of Oeningen.

Upper marine Molasse (Helvetian stage)—sandstones and calcareous conglomerates, with 37 per cent. of shells, which are to be found living partly in the Mediterranean, and partly in tropical seas.

Lower fresh-water Molasse (Mainz stage)—sandstones with abundant remains of terrestrial vegetation, and containing also an intercalated marine band with *Cerithium*, *Venus*, &c.

Lower brown-coal or red Molasse (Aquitanian stage)—the most massive member of the whole series, consisting of red sandstones, marls, and conglomerates (Nagelfluh), resting upon variegated red marls. It contains seams of lignite, and a vast abundance of the remains of terrestrial vegetation.

Lower marine Molasse (Tongrian stage)—sandstone containing marine and brackish-water shells, among which is the *Ostrea cyathula*, above mentioned as a characteristic shell, at the base of the Miocene series in the north of France.

By far the larger portion of these strata is of lacustrine origin. They must have been formed in a large lake, the area of which probably underwent gradual subsidence during the period of deposition, so that the sea gained occasional admission into it. We may form some idea of the importance of the lake from the fact already stated, that the deposits formed in its waters are upwards of 6000 feet thick. Thanks to the untiring labours of Professor Heer, we know more of the vegetation of the mountains round that lake than we do of that of any other ancient geological period. The woods were marked by the predominance of an arborescent vegetation, among which evergreen forms were conspicuous, the whole having a decidedly American aspect. Among the plants were palms of American type, the Californian coniferous genus *Sequoia*, a great variety of maples, oaks, hornbeams, poplars, planes, willows, laurels, evergreen oaks, with vines, clematis, cypresses, and many more. In the Oeningen beds, so gently have the leaves, flowers, and fruits fallen, and so well have they been preserved, that we may actually trace the alternation of the seasons by the succession of different conditions of the plants. Selecting 482 of those plants which admit of comparison, Heer remarks that 101 might be referred to a temperate, 266 to a sub-tropical, and 85 to a tropical zone. American types are most frequent among them; European types stand next in number, followed in order of abundance by Asiatic, African, and Australian. Great numbers of insects (between 800 and 900 species) have been obtained from Oeningen. Judging from the proportions of species found there, the total insect fauna may be presumed to have been then richer in some respects than it now is in any part of Europe. The wood-beetles were specially numerous and large. Nor did the large animals of the land escape preservation in the silt of the lake. We know, from bones found in the Molasse, that among the inhabitants of that land were species of tapir, mastodon, rhinoceros, and deer. The woods were haunted by musk-deer, apes, opossums, three-toed horses, and some of the strange, long-extinct Tertiary ruminants, akin to those of Eocene times. There were also frogs, toads, lizards, snakes, squirrels, hares, beavers, and a number of small carnivores. On the lake the huge *Dinotherium* floated, mooring himself perhaps to its banks by the two strong tusks in his under jaws. The waters were likewise tenanted by numerous fishes (of which 32 species have been described, all save one referable to existing genera), crocodiles, and chelonians.

Contemporaneously with the existence of the great Swiss Miocene lake, one or more large sheets of fresh water lay in the heart of France. In these basins a series of marls and limestones (1500 feet thick) accumulated, from which have been obtained the remains of nearly 100 species of mammals, including some palæotheres, like those of the Paris Eocene basin, a few genera found also in the Lower Miocene beds of Mainz, crocodiles, snakes, and birds. This water basin appears to have been destroyed by volcanic explosions, which afterwards poured out the great sheets of lava, and formed the numerous cones and *puys* so conspicuous on the plateau of Auvergne.

The sea which during the later part of the Miocene period stretched across the south of France ran also up the present valley of the Danube to the foot of the Alps and the high grounds of Bohemia and Moravia. In this wide eastern bay or Vienna basin a series of deposits was laid down, which have been grouped in four divisions,—the two lower classed as Miocene, and the two upper as Pliocene. The lowest group (Mediterranean stage or Marine Tegel) has yielded more than 1000 species of mollusca (*Conus*, *Ancillaria*, *Turrula*, *Murex*, *Cardium*, &c.), with remains of *Mastodon*, *Dino-*

Dinotherium, and other mammals. The second group (Sarmatian stage) consists of brackish-water beds showing the partial uprise of the bottom of the Vienna basin. It contains *Cerithium*, *Paludina*, *Rissoa*, with bones of dolphins, seals, turtles, and fish. The two uppermost divisions (Congeria stage and Belvedere stage), referred to the Pliocene series, are fresh-water formations, showing the final freshening and disappearance of the Miocene sea in the south-east of Europe.

In Styria and Carinthia the lower Aquitanian or Mediterranean stage bears witness in its plants and lignites to the proximity of land during its formation, while its shells are of fresh and brackish water genera. It has subsequently been upheaved, and the later Miocene strata lie unconformably on its edges. The subterranean movements east of the Alps culminated in the outpouring of enormous sheets of trachyte, andesite, propylite, and basalt in Hungary and along the flanks of the Carpathian chain into Transylvania. In Croatia the older Miocene marls, with their abundant land-plants, insects, &c., contain two beds of sulphur (the upper 4 to 16 inches thick, the under 10 to 15 inches), which have been worked at Radoboj. At Hrastreigg, Buchberg, and elsewhere, coal is worked in the Aquitanian stage in a bed sometimes 65 feet thick. In Transylvania, and along the base of the Carpathian mountains, extensive masses of rock-salt and gypsum are interstratified in the Tertiary formations. The largest of these, that of Parajd, has a maximum length of about 2500 yards, a breadth of 1800 yards, and a depth nearly 200 yards, and is estimated to contain 3500 millions of cubic feet of salt.

GREENLAND.—One of the most remarkable geological discoveries of recent times has been that of Miocene plant beds in North Greenland. Heer has described a flora extending at least up to 70° N. lat., containing 137 species, of which 46 are found also in the central European Miocene basins. More than half of the plants are trees, including 30 species of conifers (*Sequoia*, *Thujopsis*, *Salisburia*, &c.), besides beeches, oaks, planes, poplars, maples, walnuts, limes, magnolias, and many more. These plants grew on the spot, for their fruits in various stages of growth have been obtained from the beds. From Spitzbergen (78° 56′ N. lat.) 136 species of fossil plants have been named by Heer. But the latest English Arctic expedition brought to light a bed of coal, black and lustrous like one of the Palæozoic fuels, from 81° 45′ lat. It is from 25 to 30 feet thick, and is covered by black shales and sandstones full of land-plants. Heer notices 26 species, 18 of which had already been found in the Arctic Miocene zone. As in Spitzbergen, the conifers are most numerous (pines, firs, spruces, and cypresses), but there occur also the arctic poplar, two species of birch, two of hazel, an elm, and a viburnum. In addition to these terrestrial trees and shrubs the stagnant waters of the time bore water-lilies, while their banks were clothed with reeds and sedges. When we remember that this vegetation grew luxuriantly within 8° 15′ of the North Pole, in a region which is now in darkness for half of the year, and is almost continuously buried under snow and ice, we can realize the difficulty of the problem in the distribution of climate which these facts present to the geologist.

PLIOCENE.

GREAT BRITAIN.—The Miocene period seems to have passed away without any notable portion of the British Islands being depressed under the sea. Save the great outpouring of lava in the north-west, and the rise of hundreds of "dykes" of basalt along cracks of the crust in the north of England and throughout Scotland, the area of Britain seems to have remained as a part of the mainland of Europe, little affected by the subterranean movements which, as we have seen, were so potent among the Alps and in eastern Europe. At length the south-eastern counties began to subside, and on their submerged surface some sand-banks and shelly deposits were laid down, very much as similar accumulations now take place at the bottom of the North Sea. These formations are termed the Crag, and are subdivided, according to their proportion of living species of shells, into the following groups :—

Chillesford beds	Chillesford Clay	1 to 8 ft.
	Chillesford Sand with shells	5 „ 8 „
Norwich (fluvio-marine, mammaliferous) Crag		5 „ 10 „
Red Crag		25 „
White (Suffolk, coralline) Crag		40 „ 60 „

The White Crag consists of shelly sands and marls. It contains 316 species of shells, of which 84 per cent. are still living. Among these are *Terebratula grandis*, *Lingula Dumortieri*, *Pecten operacularis*, *Pholadomya histerna*, *Pyrula reticulata*. The name coralline was given to the formation from the immense number of coral-like polyzoa which it contains, no fewer than 130 species having been described. The Red Crag is also a thin and local formation, consisting of a dark-red or brown ferruginous shelly sand. Of its mollusks, 92 per cent are believed to be still living species, and, out of 25 species of corals, 14 are still natives of British seas. Some of the typical shells of this subdivision are *Trophon antiquum* (*Fusus contrarius*), *Voluta Lamberti*, *Purpura tetragona*, *Pecten operacularis*, *Pectunculus glycimeris*, and *Cyprina rustica*. Numerous mammalian remains have been obtained from these sands, including bones of *Mastodon Arvernensis* and *M. tapiroides*, *Elephas meridionalis*, *Rhinoceros Schleiermacheri*, *Tapirus priscus*, *Sus antiquus*, *Equus plicideus*, *Hipparion*, *Hyæna antiqua*, *Felis pardoides*, and *Cervus anoceros*. The Norwich or Fluvio-marine or Mammaliferous Crag consists of a few feet of shelly sand and gravel, containing, so far as known, 139 species of shells, of which 93 per cent. are still living. About 20 of the species are land or fresh-water shells. The name of mammaliferous was given from the large number of bones, chiefly of extinct species of elephant, recovered from this deposit. These fossils comprise *Mastodon Arvernensis*, *Elephas meridionalis*, *E. antiquus*, a hippopotamus, horse, and deer, likewise the living species of otter and beaver. One interesting feature in this formation is the decided mixture in it of *northern* species of shells, such as *Rhynchonella psittacea*, *Scalaria Grœnlandica*, and *Astarte borealis*. These may be regarded as the forerunners of the great invasion of Arctic plants and animals which, in the beginning of the Quaternary ages, came southward into Europe, together with the severe climate of the north. The Chillesford beds occur likewise as a thin local deposit in Suffolk and Norfolk. Of the shells which they contain, about two-thirds still live in Arctic waters. It is evident that, in these fragmentary accumulations of the Crag series, we have merely the remnants of some thin sheets of shelly sands and gravels laid down in the shallow waters of the North Sea, while that great lowering of the European climate was beginning which culminated in the succeeding or Glacial period.

CONTINENTAL EUROPE.—Marine strata, sometimes of considerable thickness, were laid down over different portions of the European area during the Pliocene period. The most extensive of these occur in Italy and Sicily; in the latter island they have since been upheaved to a height of 3000 feet above the sea. They have likewise been raised into the chain of heights flanking the Apennine Mountains, where they are known as the Subapennine series. In the shore waters and estuaries of that ancient Italy some of the same huge mammals lived as were contemporaneously denizens of England,—the Auvergne-mastodon. *Rhinoceros Etruscus Elephas meridionalis*. *Hippopotamus major*, with bears and hyænas.

Eastwards we obtain evidence of the gradual exclusion of the sea from the areas of the European continent which it had covered during the Miocene period. The Congeria stage (above referred to) of the Vienna basin brings before us the picture of an isolated gulf gradually freshening by the inpouring of rivers like the modern Caspian, but with bays nearly cut off from the main body of water, and undergoing so copious an evaporation without counterbalancing inflow that their salt was deposited over the bottom as in the Karaboghaz of the Caspian (*ante*, p. 279).

TERTIARY SERIES OF NORTH AMERICA.

Tertiary formations of marine origin extend in a strip of low land along the Atlantic border of the United States.

from the coast of New Jersey southward round the margin of the Gulf of Mexico, whence they run up the valley of the Mississippi to beyond the mouth of the Ohio. On the western sea-board they also occur in the coast ranges of California and Oregon, where they sometimes have a thickness of 3000 or 4000 feet, and reach a height of 3000 feet above the sea. Over the Rocky Mountain region Tertiary strata cover an extensive area, but are chiefly of fresh-water origin, though containing marine interstratifications. The following are the subdivisions into which they have been grouped, together with their supposed European equivalents :—

4. Sumter series = Pliocene.
3. Yorktown „ = Miocene, with perhaps part of Pliocene.
2. Alabama „ = Middle and Upper Eocene.
1. Lignitic „ = Lower Eocene.

1. *Lignitic.*—As already mentioned, it is still matter of dispute whether this formation should not be included wholly or in large measure in the Cretaceous system below. It consists mainly of laoustrine strata, with occasional brackish water and marine bands. Its name is derived from the beds of fossil fuel which it contains. The mollusca in some of the shell-bearing beds comprise species of *Inoceramus*; *Anchura*, *Gyrodes*, *Cardium*, *Cyrena*, *Melampus*, *Ostrea*, and *Anomia*. Other strata contain the modern lacustrine and fluviatile genera *Physa*, *Valvata*, *Cyrena*, *Corbula*, and *Unio*. An abundant terrestrial flora has been disinterred from the Lignitic strata. It resembles in many respects the present flora of North America, comprising as it does species of oak, poplar, maple, elm, dogwood, beech, hickory, ilex, plane, fig, cinnamon, laurel, magnolia, smilax, thuja, sequoia, and several palms. A few of the species are common to the Middle Tertiary flora of Europe, and a number of them have been met with in the Tertiary beds of the Arctic regions. Some of the seams of vegetable matter are true bituminous coals and even anthracites.

It was stated in the account of the North American Cretaceous rocks that considerable difference of opinion exists as to the line to be drawn between these rocks and those of Tertiary age. According to Cope, the Vertebrate remains of the Lignitic series bind it indissolubly to the Mesozoic formations. Lesquereux, on the other hand, insists that the vegetation is unequivocally Tertiary. The former writer, admitting the force of the evidence furnished by the fossil plants, concludes, that "there is no alternative but to accept the result that a Tertiary flora was contemporaneous with a Cretaceous fauna, establishing an uninterrupted succession of life across what is generally regarded as one of the greatest breaks in geologic time." The Lignitic series was disturbed along the Rocky Mountain region before the deposition of the succeeding Tertiary formations, for these lie unconformably upon it. So great have been the changes in some regions that the strata have assumed the character of hard slates like those of Palæozoic date, if indeed they have not become in California thoroughly crystalline masses.

2. *Alabama Group.*—The strata included in this group are believed to represent the Middle and Upper Eocene of Europe. As their name implies, they are well developed in the State of Alabama, where they consist of two sub-groups,—(1) the Clayborne beds—clays, marls, limestones, lignite, and sands, and (2) the Vicksburg beds—lignitic clays, limestones, and marls,—the whole attaining a thickness of nearly 250 feet. But the strata thicken into South Carolina. Towards the west the marine fossils give place to leaf-beds and lignites. In the Green River basin the strata attain a thickness of more than 2000 feet, lying on the disturbed Lignitic group, and containing beds of coal, with remains of fish and of tapiroid pachyderms. The fossils of the Alabama group in the eastern States comprise numerous sharks, some of which are specifically, and more are generically, the same as some of the English Eocene forms, such as *Lamna elegans*, and *Carcharodon megalodon*; also bones of several crocodiles and snakes. In the lacustrine and fluviatile deposits of the west there have been found also the remains of several birds, and a large number of mammals, including marsupials, numerous representatives of the tapirs, with double pairs of nasal horns, an early form of horse (*Orohippus*) not larger than a fox, and with four toes in the fore foot, rodents, insectivores, bats, carnivores, and a number of forms allied to the living lemurs and marmosets. The richness of this fauna is remarkable, particularly in the mammals.

3. *Yorktown Group.*—Under this name are classed strata of sand and clay, which extend over a large area in the seaward part of the eastern States. Their organic remains (comprising mollusks, with remains of sharks, seals, walruses, whales, &c.) show them to have been chiefly laid down in a shallow sea in Miocene time. Westward, in the Upper Missouri region, and across the Rocky Mountains into California and Oregon, strata assigned to the same geological period were laid down in great lakes, and attain thicknesses of 1000 to 4000 or 5000 feet. The organic remains of these ancient lakes embrace examples of three-toed horses (*Anchitherium*), of horned tapir-like animals (*Titanotherium*), of forms related to the hog, rhinoceros, camel, lama, deer, musk-ox, hare, squirrel, beaver, hyæna, wolf, panther, and tiger. The intermediate types indicated by Cuvier among the Paris Tertiary beds have been greatly increased from the American Tertiary groups by the researches of Marsh and Leidy.

4. *Sumter Group* or *Pliocene.*—In the Carolina States beds of loam, clay, or sand, lying in hollows of the older Tertiary deposits, and containing from 40 to 60 per cent. of living marine shells, are referred to the Pliocene age. In the Upper Missouri region, the Yorktown group is overlaid by other fresh-water beds, which are believed to be Pliocene. These strata contain land and fresh-water shells, probably of existing species. But their most remarkable organic remains are the mammalia, which continue the wonderful series in the strata underneath. Dana thus summarizes the facts :—"Leidy has determined a large number of Pliocene mammals, all now extinct. They include three species of camel (*Procamelus*); a rhinoceros as large as the Indian species; a mastodon smaller than *M. Americanus*, L., of the Quaternary; an elephant (*E. Americanus*), occurring also in the Quaternary; four or five species of the horse family, one of which was closely like the modern horse; a species of deer (*Cervus Warreni*, L.); others near the musk-deer of Asia; species of *Merychyus*, allied to *Oreodon* (a genius intermediate between deer, camel, and hog); a wolf larger than any living species; a small fox; a tiger (*Felis augustus*, L.) as large as the Bengal tiger, besides other carnivores; a small beaver; a porcupine. The collection of animals has a strikingly Oriental character, except in the preponderance of herbivores."

V. POST-TERTIARY OR QUATERNARY.

Under this division are included the various superficial deposits in which all the mollusca are of still living species. It is usually subdivided into two series—(1) an older group of deposits in which many of the mammals are of extinct species,—to this group the names of Pleistocene, Post-Pliocene, or Diluvial have been given; and (2) a later series, wherein the mammals are all of still living species, to which the name of Recent or Alluvial has been assigned. These subdivisions, however, are confessedly very artificial, and it is often exceedingly difficult to draw any line between them.

In Europe and North America a tolerably sharp demarcation can usually be made between the Pliocene formations and those now to be described. The Crag deposits of the south-east of England show traces of a gradual lowering of the temperature during later Pliocene times. This change of climate continued to augment until at last thoroughly arctic conditions prevailed, under which the oldest of the Post-Tertiary or Pleistocene deposits were accumulated.

It is hardly possible to arrange these deposits in a strict chronological order, because we have no means of deciding, in many cases, their relative antiquity. The following table is rather an enumeration of the more important of them than an arrangement in their exact sequence :—

Recent.....	River alluvia, peat mosses, lake deposits, blown sand, marine deposits, raised beaches.
Pleistocene or Glacial.	Brick-earth, valley-gravels, old marine terraces, cavern-deposits.
	Moraine-stuff, Kame or Esker series, Clyde-beds, Upper Boulder clays, Interglacial beds, Lower Till, ice-worn rock-surfaces.
	Pre-glacial forests and land surfac

PLEISTOCENE OR GLACIAL.

Under the name of the Glacial Period or Ice Age, a remarkable geological episode in the history of the northern hemisphere is denoted. We have seen in the foregoing section on the Crag deposits that there is evidence of a gradual refrigeration of the climate at the close of the Tertiary ages. This change of temperature affected the higher latitudes alike of the Old and the New World. It reached such a height that the whole of the north of Europe was buried under snow and ice, extending southwards even as far as Saxony. The Alps and Pyrenees were loaded with vast snow-fields, from which enormous glaciers descended into the plains, overriding ranges of minor hills on their way. The greater portion of Britain was similarly ice-covered.