Title: The World Before the Deluge

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Release date: May 18, 2012 [EBook #39723]

Language: English

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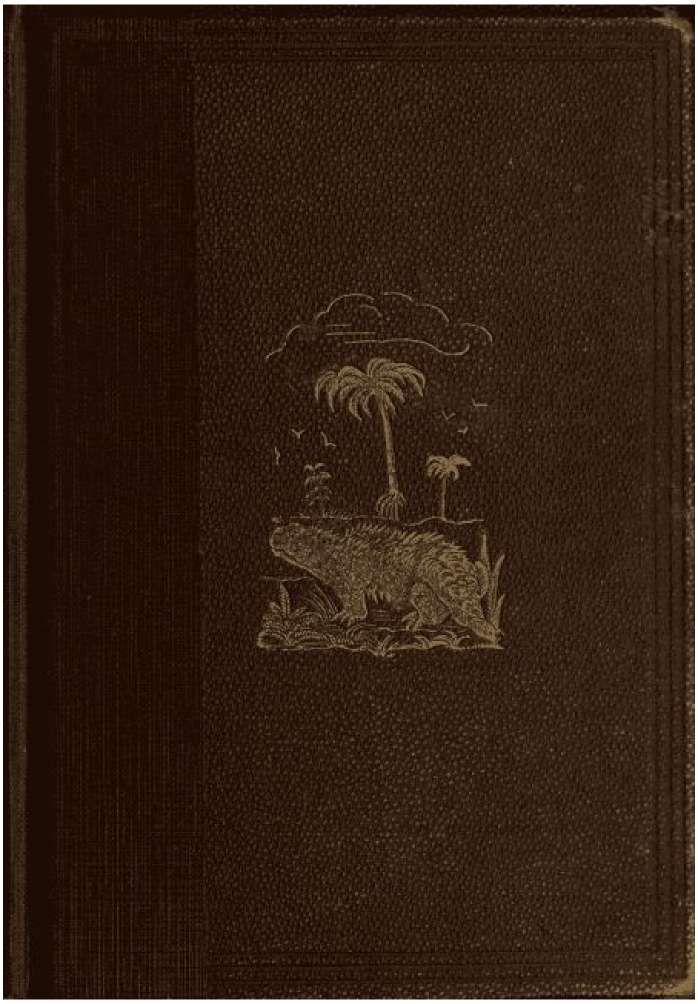

THE FIRST MAN.

THE
World before the Deluge.

BY

LOUIS FIGUIER.

NEWLY EDITED AND REVISED
BY

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With 235 Illustrations.

CASSELL, PETTER, & GALPIN,
LONDON, PARIS, AND NEW YORK.

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PREFACE. [iii]

The object of "The World before the Deluge" is to trace the progressive steps by which the earth has reached its present state, from that condition of chaos when it "was without form and void, and darkness was upon the face of the deep," and to describe the various convulsions and transformations through which it has successively passed. In the words of the poet—

> "Where rolls the deep, there grew the tree;
> O Earth, what changes hast thou seen!
> There, where the long street roars, hath been
> The silence of the central sea."

It has been thought desirable that the present edition of the work should undergo a thorough revision by a practical geologist, a task which Mr. H. W. Bristow has performed. Mr. Bristow has however confined himself to such alterations as were necessary to secure accuracy in the statement of facts, and such additions as were necessary to represent more precisely the existing state of scientific opinion. Many points which are more or less inferential and therefore matters [iv] of individual opinion, and especially those on which M. Figuier bases his speculations, have been left in their original form, in preference to making modifications which would wholly change the character of the book. In a work whose purpose is to give the general reader a summarised account of the results at which science has arrived, and of the method of reasoning regarding the facts on which these generalisations rest, it would be out of place, as well as ineffective, to obscure general statements with those limitations which caution imposes on the scientific investigator.

In the original work the Author had naturally enough drawn most of his facts from French localities; in the translation these are mostly preserved, but others drawn from British Geology have been added, either from the translator's own knowledge, or from the works of well-known British writers. It was considered desirable, for similar reasons, to enlarge upon the opinions of British geologists, to whom the French work scarcely does justice, considering the extent to which the science is indebted to them for its elucidation.

In the original work the chapter on Eruptive Rocks comes at the end of the work, but, as the work proceeded, so many unexplained allusions to that chapter were found that it seemed more logical, and more in accordance with chronological order, if the expression may be used, to place that chapter at the beginning.

A new edition of the French work having appeared in the early part of 1866, to which the Author contributed a chapter on Metamorphic Rocks, a translation of it is appended to the chapter on Eruptive Rocks. [v]

A chapter on the Rhætic (or Penarth) beds has been inserted (amongst much other original matter), the stratigraphical importance of that series having been recognised since the publication of the First Edition.

In the present Edition the text has been again thoroughly revised by Mr. Bristow, and many important additions made, the result of the recent investigations of himself and his colleagues of the Geological Survey.

THE WORLD BEFORE THE DELUGE. [1]

GENERAL CONSIDERATIONS.

The observer who glances over a rich and fertile plain, watered by rivers and streams which have, during a long series of ages, pursued the same uniform and tranquil course; the traveller who contemplates the walls and monuments of a great city, the first founding of which is lost in the night of ages, testifying, apparently, to the unchangeableness of things and places; the naturalist who examines a mountain or other locality, and finds the hills and valleys and other accidents of the soil in the very spot and condition in which they are described by history and tradition—none of these observers would at first suspect that any serious change had ever occurred to disturb the surface of the globe. Nevertheless, the earth has not always presented the calm aspect of stability which it now exhibits; it has had its convulsions, and its physical revolutions, whose story we are about to trace. The earth, like the body of an animal, is wasted, as the philosophical Hutton tells us, at the same time that it is repaired. It has a state of growth and augmentation; it has another state, which is that of diminution and decay: it is destroyed in one part to be renewed in another; and the operations by which the renewal is accomplished are as evident to the scientific eye as those by which it is destroyed. A thousand causes, aqueous, igneous, and atmospheric, are continually at work modifying the external form of the earth, wearing down the older portions of its surface, and reconstructing newer out of the older; so that in many parts of the world denudation has taken place to the extent of many thousand feet. Buried in the depths of the soil, for example, in one of those vast excavations which the intrepidity of the miner has dug in search of coal or other minerals, there are numerous phenomena which strike the mind of the inquirer, and carry their own conclusions with them. A striking increase of temperature in these subterranean places is one of the most remarkable of [2] these. It is found that the temperature of the earth rises one degree for every sixty or seventy feet of descent from its surface. Again: if the mine be examined vertically, it is found to consist of a series of layers or beds, sometimes horizontal, but more frequently inclined, upright, or contorted and undulating—even folded back upon themselves. Then, instances are numerous where horizontal and parallel beds have been penetrated, and traversed vertically or obliquely by veins of ores or minerals totally different in their appearance and nature from the surrounding rocks. All these undulations and varying inclinations of strata are indications that some powerful cause, some violent mechanical action, has intervened to produce them. Finally, if the interior of the beds be examined more minutely—if, armed with the miner’s pick and hammer, the rock is carefully broken up—it is not impossible that the very first efforts at mining may be rewarded by the discovery of some fossilised organic form no longer found in the living state. The remains of plants and animals belonging to the earlier ages of the world, are, in fact, very common; entire strata are sometimes formed of them; and in some localities the rocks can scarcely be disturbed without yielding fragments of bones and shells, or the impressions of fossilised animals and vegetables—the buried remains of extinct creations.

These bones—these remains of animals or vegetables which the hammer of the geologist has torn from the rock—belong possibly to some organism which no longer any where exists: it may not be identical with any animal or plant living in our times: but it is evident that these beings, whose remains are now so deeply buried, have not always been so covered; they once lived on the surface of the earth as plants and animals do in our days, for their organisation is essentially the same. The beds in which they now repose must, then, in older times have formed the surface of the earth; and the presence of these fossils proves that the earth has suffered great mutations at some former period of its history.

Geology explains to us the various transformations which the earth has passed through before it arrived at its present condition. We can determine, with its help, the comparative epoch to which any beds belong, as well as the order in which others have been superimposed upon them. Considering that the stratigraphical crust of the earth with which the geologist has to deal may be some ten miles thick, and that it has been deposited in distinct layers in a definite order of succession, the dates or epochs of each formation may well be approached with hesitation and caution.

Dr. Hutton, the earliest of our philosophical geologists, eloquently observes, in his "Theory of the Earth," that the solid earth is everywhere wasted at the surface. The summits of the mountains are necessarily degraded. The solid and weighty materials of these mountains have everywhere been carried through the valleys by the force of running water. The soil which is produced in the destruction of the solid earth is gradually transported by the moving waters, and is as constantly supplying vegetation with its necessary aid. This drifted soil is at last deposited upon some coast, where it forms a fertile country. But the billows of the ocean again agitate the loose material upon the shore, wearing away the coast with endless repetitions of this act of power and imparted force; the solid portion of our earth, thus sapped to its foundations, is carried away into the deep and sunk again at the bottom of the sea whence it had originated, and from which sooner or later it will again make its appearance. We are thus led to see a circulation of destruction and renewal in the matter of which the globe is formed, and a system of beautiful economy in the works of Nature. Again, discriminating between the ordinary and scientific observer, the same writer remarks, that it is not given to common observation to see the operation of physical causes. The shepherd thinks the mountain on which he feeds his flock has always been there. The inhabitant of the valley cultivates the soil as his fathers did before him, and thinks the soil coeval with the valley or the mountain. But the scientific observer looks into the chain of physical events, sees the great changes that have been made, and foresees others that must follow from the continued operation of like natural causes. For, as Pythagoras taught 2,350 years ago, "the minerals and the rocks, the islands and the continents, the rivers and the seas, and all organic Nature, are perpetually changing; there is nothing stationary on earth." To note these changes—to decipher the records of this system of waste and reconstruction, to trace the physical history of the earth—is the province of Geology, which, the latest of all modern sciences, is that which has been modified most profoundly and most rapidly. In short, resting as it does on observation, it has been modified and transformed according to every series of facts recorded; but while many of the facts of geology admit of easy and obvious demonstration, it is far otherwise with the inferences which have been based upon them, which are mostly hypothetical, and in many instances from their very nature incapable of proof. Its applications are numerous and varied, projecting new and useful lights upon many other sciences. Here we ask of it the teachings which serve to explain the origin of the globe—the evidence it furnishes of the progressive formation of the different rocks and mineral masses of which the earth is composed—the description and restoration of the several species of animals and vegetables which have existed, have died and become extinct, and which form, in the language of naturalists, the *Fauna* and *Flora* of the ancient world.

In order to explain the origin of the earth, and the cause of its various revolutions, modern geologists invoke three orders of facts, or fundamental considerations:

I. The hypothesis of the original incandescence of the globe.

II. The consideration of fossils.

III. The successive deposition of the sedimentary rocks.

As a corollary to these, the hypothesis of the upheaval of the earth's crust follows—upheavals having produced local revolutions. The result of these upheavals has been to superimpose new materials upon the older rocks, introducing extraneous rocks called *Eruptive*, beneath, upon, and amongst preceding deposits, in such a manner as to change their nature in divers ways. Whence is derived a third class of rocks called *Metamorphic* or altered *rocks*, our knowledge of which is of comparatively recent date.

Fossils.

The name of *Fossil* (from *fossilis*, dug up) is given to all organised bodies, animal or vegetable, buried naturally in the terrestrial strata, and more or less petrified, that is, converted into stone. Fossils of the older formations are remains of organisms which, so far as species is concerned, are quite extinct; and only those of recent formations belong to genera living in our days. These fossil remains have neither the beauty nor the elegance of most living species, being mutilated, discoloured, and often almost shapeless; they are, therefore, interesting only in the eyes of the observer who would interrogate them, and who seeks to reconstruct, with their assistance, the Fauna and Flora of past ages. Nevertheless, the light they throw upon the past history of the earth is of the most satisfactory description, and the science of fossils, or palæontology, is now an important branch of geological inquiry. Fossil shells, in the more recent deposits, are found scarcely altered; in some cases only an impression of the external form is left—sometimes an entire cast of the shell, exterior and interior. In other cases the shell has left a perfect impression of its form in the surrounding mud, and has then been dissolved and washed away, leaving only its mould. This mould, again, has sometimes been filled up by calcareous spar, silica, or pyrites, [5] and an exact cast of the original shell has thus been obtained. Petrified wood is also of very common occurrence.

These remains of an earlier creation had long been known to the curious, and classed as *freaks of Nature*, for so we find them described in the works of the ancient philosophers who wrote on natural history, and in the few treatises on the subject which the Middle Ages have bequeathed to us. Fossil bones, especially those of elephants, were known to the ancients, giving rise to all sorts of legends and fabulous histories: the tradition which attributed to Achilles, to Ajax, and to other heroes of the Trojan war, a height of twenty feet, is attributable, no doubt, to the discovery of the bones of elephants near their tombs. In the time of Pericles we are assured that in the tomb of Ajax a *patella*, or knee-bone of that hero, was found, which was as large as a dinner-plate. This was probably only the patella of a fossil elephant.

The uses to which fossils are applied by the geologist are—First, to ascertain the relative age of the formations in which they occur; secondly, the conditions under which these were deposited. The age of the formation is determined by a comparison of the fossils it contains with others of ascertained date; the conditions under which the rocks were deposited, whether marine, lacustrine, or terrestrial, are readily inferred from the nature of the fossils. The great artist, Leonardo da Vinci, was the first to comprehend the real meaning of fossils, and Bernard Palissy had the glory of being the first modern writer to proclaim the true character of the fossilised remains which are met with, in such numbers, in certain formations, both in France and Italy, particularly in those of Touraine, where they had come more especially under his notice. In his work on "Waters and Fountains," published in 1580, he maintains that the *figured stones*, as fossils were then called, were the remains of organised beings preserved at the bottom of the sea. But the existence of marine shells upon the summits of mountains had already arrested the attention of ancient authors. Witness Ovid, who in Book XV. of the "Metamorphoses" tells us he had seen land formed at the expense of the sea, and marine shells lying dead far from the ocean; and more than that, an ancient anchor had been found on the very summit of a mountain.

> "Vidi factas ex æquore terras,
> Et procul a pelago conchæ jacuere marinæ,
> Et vetus inventa est in montibus anchora summis."
>
> Ov., *Met.*, Book xv.

The Danish geologist Steno, who published his principal works in Italy about the middle of the [6] seventeenth century, had deeply studied the fossil shells discovered in that country. The Italian painter Scilla produced in 1670 a Latin treatise on the fossils of Calabria, in which he established the organic nature of fossil shells.

The eighteenth century gave birth to two very opposite theories as to the origin of our globe—namely, the *Plutonian* or igneous, and the *Neptunian* or aqueous theory. The Italian geologists gave a marked impulse to the study of fossils, and the name of Vallisneri[1] may be cited as the author to whom science is indebted for the earliest account of the marine deposits of Italy, and of the most characteristic organic remains which they contain. Lazzaro Moro[2] continued the studies of Vallisneri, and the monk Gemerelli reduced to a complete system the ideas of these two geologists, endeavouring to explain all the phenomena as Vallisneri had wished, "without violence, without fiction, without miracles." Marselli and Donati both studied in a very scientific manner the fossil shells of Italy, and in particular those of the Adriatic, recognising the fact that they affected in their beds a regular and constant order of superposition.[3]

In France the celebrated Buffon gave, by his eloquent writings, great popularity to the notions of the Italian naturalists concerning the origin of fossil remains. In his admirable "Époques de la Nature" he sought to prove that the shells found in great quantities buried in the soil, and even on the tops of mountains, belonged, in reality, to species not living in our days. But this idea was too novel not to find objectors: it counted among its adversaries the bold philosopher who might have been expected to adopt it with most ardour. Voltaire attacked, with his jesting and biting criticism, the doctrines of the illustrious innovator. Buffon insisted, reasonably enough, that the presence of shells on the summit of the Alps was a proof that the sea had at one time occupied that position. But Voltaire asserted that the shells found on the Alps and Apennines had been thrown there by pilgrims returning from Rome. Buffon might have replied to his opponent, by pointing out whole mountains formed by the accumulation of these shells. He might have sent him to the Pyrenees, where shells of marine origin cover immense areas to a height of 6,600 feet [7] above the present sea-level. But his genius was averse to controversy; and the philosopher of Ferney himself put an end to a discussion in which, perhaps, he would not have had the best of the argument. "I have no wish," he wrote, "to embroil myself with Monsieur Buffon about shells."

It was reserved for the genius of George Cuvier to draw from the study of fossils the most wonderful results: it is the study of these remains, in short, which, in conjunction with mineralogy, constitutes in these days positive geology. "It is to fossils," says the great Cuvier, "that we owe the discovery of the true theory of the earth; without them we should not have dreamed, perhaps, that the globe was formed at successive epochs, and by a series of different operations. They alone, in short, tell us with certainty that the globe has not always had the same envelope; we cannot resist the conviction that they must have lived on the surface of the earth before being buried in its depths. It is only by analogy that we have extended to the primary formations the direct conclusions which fossils furnish us with in respect to the secondary formations; and if we had only unfossiliferous rocks to examine, no one could maintain that the earth was not formed all at once."[4]

The method adopted by Cuvier for the reconstruction and restoration of the fossil animals found in the plaster-quarries of Montmartre, at the gates of Paris, has served as a model for all succeeding naturalists; let us listen, then, to his exposition of the vast problem whose solution he proposed to himself. "In my work on fossil bones," he says, "I propose to ascertain to what animals the osseous fragments belong; it is seeking to traverse a road on which we have as yet only ventured a few steps. An antiquary of a new kind, it seemed to me necessary to learn both to restore these monuments of past revolutions, and to decipher their meaning. I had to gather and bring together in their primitive order the fragments of which they are composed; to reconstruct the ancient beings to which these fragments belonged; to reproduce them in their proportions and with their characteristics; to compare them, finally, with others now living on the surface of the globe: an art at present little known, and which supposes a science scarcely touched upon as yet, namely, that of the laws which preside over the co-existence of the forms of the several parts in organised beings. I must, then, prepare myself for these researches by others, still more extended, upon existing animals. A general review of actual creation could alone give a character of demonstration to my account of these ancient inhabitants of the world; but it ought, at the [8]
same time, to give me a great collection of laws, and of relations not less demonstrable, thus forming a body of new laws to which the whole animal kingdom could not fail to find itself subject."[5]

"When the sight of a few bones inspired me, more than twenty years ago, with the idea of applying the general laws of comparative anatomy to the reconstruction and determination of fossil species; when I began to perceive that these species were not quite perfectly represented by those of our days, which resembled them the most—I no longer doubted that I trod upon a soil filled with spoils more extraordinary than any I had yet seen, and that I was destined to bring to light entire races unknown to the present world, and which had been buried for incalculable ages at great depths in the earth.

"I had not yet given any attention to the published notices of these bones, by naturalists who made no pretension to the recognition of their species. To M. Vaurin, however, I owe the first intimation of the existence of these bones, with which the gypsum-quarries swarm. Some specimens which he brought me one day struck me with astonishment; I learned, with all the interest the discovery could inspire me with, that this industrious and zealous collector had already furnished some of them to other collectors. Received by these amateurs with politeness, I found in their collections much to confirm my hopes and heighten my curiosity. From that time I searched in all the quarries with great care for other bones, offering such rewards to the workmen as might awaken their attention. I soon got together more than had ever been previously collected, and after a few years I had nothing to desire in the shape of materials. But it was otherwise with their arrangement, and with the reconstruction of the skeleton, which could alone lead to any just idea of the species.

"From the first moment of discovery I perceived that, in these remains, the species were numerous. Soon afterwards I saw that they belonged to many genera, and that the species of the different genera were nearly the same size, so that size was likely rather to hinder than aid me. Mine was the case of a man to whom had been given at random the mutilated and imperfect remains of some hundreds of skeletons belonging to twenty sorts of animals; it was necessary that each bone should find itself alongside that to which it ought to be connected: it was almost like a small resurrection, and I had not at my disposal the all-powerful trumpet; but I had the [9]
immutable laws prescribed to living beings as my guide; and at the voice of the anatomist each bone and each part of a bone took its place. I have not expressions with which to describe the pleasure I experienced in finding that, as soon as I discovered the character of a bone, all the consequences of the character, more or less foreseen, developed themselves in succession: the feet were found conformable to what the teeth announced; the teeth to that announced by the feet; the bones of the legs, of the thighs, all those which ought to reunite these two extreme parts, were found to agree as I expected; in a word, each species was reproduced, so to speak, from only one of its elements."[6]

While the Baron Cuvier was thus zealously prosecuting his inquiries in France, assisted by many eminent fellow-labourers, what was the state of geological science in the British Islands? About that same time, Dr. William Smith, better known as "the father of English geology," was preparing, unaided, the first geological map of this country. Dr. Smith was a native of Wiltshire, and a canal engineer in Somersetshire; his pursuits, therefore, brought him in the midst of these hieroglyphics of Nature. It was his practice, when travelling professionally, during many years to consult masons, miners, wagoners, and agriculturists. He examined the soil; and in the course of his inquiries he came to the conclusion that the earth was not all of the same age; that the rocks were arranged in layers, or strata, superimposed on each other in a certain definite order, and that the strata, when of the same age, could be identified by means of their organic remains. In 1794 he formed the plan of his geological map, showing the superposition of the various beds; for a quarter of a century did he pursue his self-allotted task, which was at last completed, and in 1801 was published, being the first attempt to construct a stratigraphical map.

Taking the men in the order of the objects of their investigation, rather than in chronological order, brings before us the patient and sagacious investigator to whom we are indebted for our knowledge of the Silurian system. For many years a vast assemblage of broken and contorted beds had been observed on the borders of North Wales, stretching away to the east as far as Worcestershire, and to the south into Gloucester, now rising into mountains, now sinking into valleys. The ablest geologists considered them as a mere labyrinth of ruins, whose order of succession and distinctive organic remains were entirely unknown, “But a man came,” as M. [10] Esquiros eloquently writes, “who threw light upon this sublime confusion of elements.” Sir Roderick Impey Murchison, then a young President of the Geological Society, had his attention directed, as he himself informs us, to some of these beds on the banks of the Wye. After seven years of unremitting labour, he was rewarded by success. He established the fact that these sedimentary rocks, penetrated here and there by eruptive masses of igneous origin, formed a unique system, to which he gave the name of *Silurian*, because the rocks which he considered the most typical of the whole were most fully developed, charged with peculiar organic remains, in the land of the ancient Silures, who so bravely opposed the Roman invaders of their country. Many investigators have followed in Sir Roderick’s steps, but few men have so nobly earned the honours and fame with which his name is associated.

The success which attended Sir R. Murchison’s investigations soon attracted the attention of other geologists. Professor Sedgwick examined the older slaty strata, and succeeded in proving the position of the Cambrian rocks to be at the base of the Silurian. Still it was reserved for Sir William Logan, the Director of the Canadian Geological Survey, to establish the fact that immense masses of gneissic formation lay at the base of the Cambrian; and, by subsequent investigations, Sir Roderick Murchison satisfied himself that this formation was not confined to Canada, but was identical with the rocks termed by him Fundamental Gneiss, which exist in enormous masses on the west coast of Scotland, and which he proved to be the oldest stratified rocks in the British Isles. Subsequently he demonstrated the existence of these same Laurentian rocks in Bohemia and Bavaria, far beneath the Silurian rocks of Barrande.

While Murchison and Sedgwick were prosecuting their inquiries into the Silurian rocks, Hugh Miller and many others had their attention occupied with the Old Red Sandstone—the Devonian of Sedgwick and Murchison—which immediately overlies them. After a youth passed in wandering among the woods and rocks of his native Cromarty, the day came when Miller found himself twenty years of age, and, for the time, a workman in a quarry. A hard fate he thought it at the time, but to him it was the road to fame and success in life. The quarry in which he laboured was at the bottom of a bay formed by the mouth of a river opening to the south, a clear current of water on one side, as he vividly described it, and a thick wood on the other. In this silent spot, in the remote Highlands, a curious fossil fish of the Old Red Sandstone was revealed to him; its appearance struck him with astonishment; a fellow-workman named a spot where many such [11] monuments of a former world were scattered about; he visited the place, and became a geologist and the historian of the “Old Red.” And what strange fantastic forms did it afterwards fall to his lot to describe! “The figures on a China vase or Egyptian obelisk,” he says, “differ less from the real representation of the objects than the fossil fishes of the ‘Old Red’ differ from the living forms which now swim in our seas.”

The *Carboniferous Limestone*, which underlies the coal, the *Coal-measures* themselves, the *New Red Sandstone*, the *Lias*, and the *Chalk*, have in their turn found their historians; but it would be foreign to our object to dwell further here on these particular branches of the subject.

Some few of the fossilised beings referred to resemble species still found living, but the greater part belong to species which have become altogether extinct. These fossil remains may constitute natural families, none of the genera of which have survived. Such is the *Pterodactyle* among Pterosaurian reptiles; the *Ammonite* among Mollusca; the *Ichthyosaurus* and the *Plesiosaurus* among the Enaliosaurian reptiles. At other times there are only extinct genera, belonging to families of which there are still some genera now living, as the genus *Palæoniscus* among fishes. Finally, in Tertiary deposits, we meet with some extinct species belonging to genera of our existing fauna: the *Mammoth*, for example, of the youngest Tertiary deposits, is an extinct species of the genus elephant.

Some fossils are terrestrial, like the gigantic Irish stag, *Cervus Megaceros*, the snail or *Helix*; fluviatile or lacustrine, like the *Planorbis*, the *Lymnæa*, the *Physa*, and the *Unio*; marine, or inhabiting the sea exclusively, as the Cowry (*Cypræa*), and the Oyster, (*Ostrea*).

Fossils are sometimes preserved in their natural state, or are but very slightly changed. Such is the state of some of the bones extracted from the more recent caves; such, also, is the condition of the insects found enclosed in the fossil resins in which they have been preserved from decomposition; and certain shells, found in recent and even in old formations, such as the Jurassic and Cretaceous strata—in some of which the shells retain their colours, as well as their brilliant pearly lustre or nacre. At Trouville, in Normandy, in the Kimeridge strata, magnificent *Ammonites* are found in the clay and marl, all brilliant with the colours of mother-of-pearl. In the Cretaceous beds at Machéroménil, some species of *Ancyloceras* and *Hamites* are found still covered with a nacre, displaying brilliant reflections of blue, green, and red, and retaining an [12] admirable lustre. At Glos, near Liseaux, in the Coral Rag, not only the *Ammonites*, but the *Trigoniæ* and *Aviculæ* have preserved all their brilliant nacre. Sometimes these remains are much changed, the organic matter having entirely disappeared; it sometimes happens also, though rarely, that they become petrified, that is to say, the external form is preserved, but the original organic elements have wholly disappeared, and have been replaced by foreign mineral substances—generally by silica or by carbonate of lime.

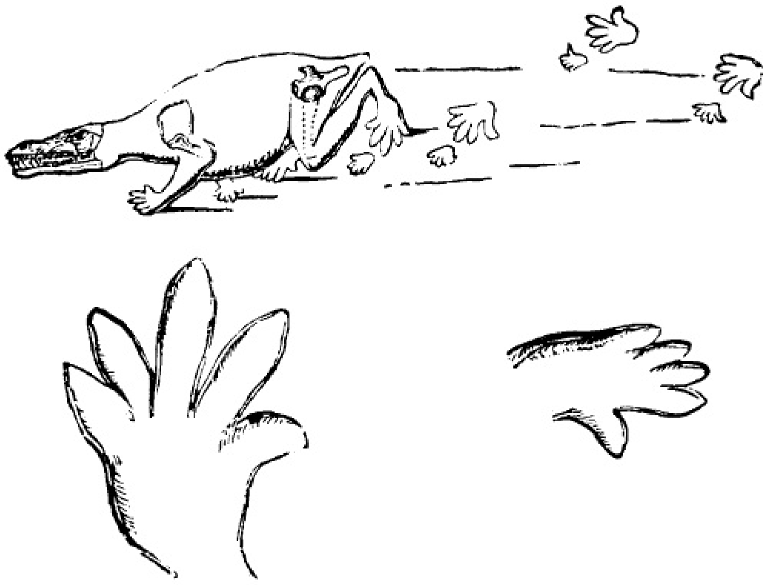

Fig. 1.—Labyrinthodon pachygnathus and footmarks.

Geology also enables us to draw very important conclusions from certain fossil remains whose true nature was long misunderstood, and which, under the name of *coprolites*, had given rise to much controversial discussion. Coprolites are the petrified excrements of extinct fossil animals. The study of these singular remains has thrown unexpected light on the habits and physiological organisation of some of the great antediluvian animals. Their examination has revealed the scales and teeth of fishes, thus enabling us to determine the kind of food in which the animals of the ancient world indulged: for example, the coprolites of the great marine reptile which bears the name of *Ichthyosaurus* contain the bones of other animals, together with the remains of the vertebræ, or of the phalanges (paddle-bones) of other Ichthyosauri; showing that this animal [13]
habitually fed on the flesh of its own species, as many fishes, especially the more voracious ones, do in our days.

The imprints left upon mud or sand, which time has hardened and transformed into sandstone, furnish to the geologist another series of valuable indications. The reptiles of the ancient world, the turtles in particular, have left upon the sands, which time has transformed into blocks of stone, impressions which evidently represent the exact moulds of the feet of those animals. These impressions have, sometimes, been sufficient for naturalists to determine to what species the animal belonged which thus left its impress on the wet ground. Some of these exhibit tracks to which we shall have occasion to refer; others present traces of the footprints of the great reptile known as the *Labyrinthodon* or *Cheirotherium*, whose footmarks slightly resemble the impression made by the human hand (Fig. 1). Another well-known impression, which has been left upon the sandstone of Corncockle Moor, in Dumfriesshire, is supposed to be the impress of the foot of some great fossil Turtle.

We may be permitted to offer a short remark on this subject. The historian and antiquary may traverse the battle-fields of the Greeks and Romans, and search in vain for traces of those conquerors, whose armies ravaged the world. Time, which has overthrown the monuments of their victories, has also effaced the marks of their footsteps; and of the many millions of men whose invasions have spread desolation throughout Europe, not even a trace of a footprint is left. Those reptiles, on the other hand, which crawled thousands of ages ago on the surface of our planet when it was still in its infancy, have impressed on the soil indelible proofs of their existence. Hannibal and his legions, the barbarians and their savage hordes, have passed over the land without leaving a material mark of their passage; while the poor turtle, which dragged itself along the silent shores of the primitive seas, has bequeathed to learned posterity the image and impression of a part of its body. These imprints may be perceived as distinctly on the rocks, as the traces left on moist sand or in newly-fallen snow by some animal walking under our own eyes. What grave reflections should be awakened within us at the sight of these blocks of hardened earth, which thus carry back our thoughts to the early ages of the world! and how insignificant seem the discoveries of the archæologist who throws himself into ecstacies before some piece of Greek or Etruscan pottery, when compared with these veritable antiquities of the earth!

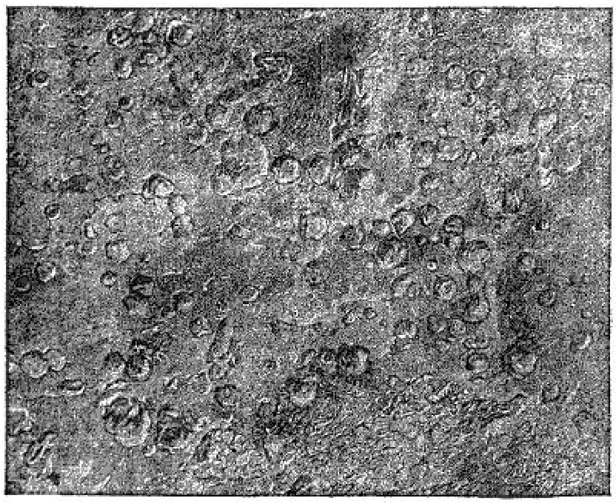

Fig. 2.—Impressions of rain-drops.

The palæontologist (from παλαιος "ancient," οντος "being," λογος "discourse"), who occupies [14]
himself with the study of animated beings which have lived on the earth, takes careful account also of the sort of moulds left by organised bodies in the fine sediment which has enveloped them after death. Many organic beings have left no trace of their existence in Nature, except their impressions, which we find perfectly preserved in the sandstone and limestone, in marl or clay, and in the coal-measures; and these moulds are sufficient to tell us the kind to which the living animals belonged. We shall, no doubt, astonish our readers when we tell them that there are blocks of sandstone with distinct impressions of drops of rain which had fallen upon sea-shores of the ancient world. The impressions of these rain-drops, made upon the sands, were preserved by desiccation; and these same sands, being transformed by subsequent hardening into solid and coherent sandstones, their impressions have been thus preserved to the present day. Fig. 2 [15]
represents impressions of this kind upon the sandstone of Connecticut river in America, which have been reproduced from the block itself by photography. In a depression of the granitic rocks of Massachusetts and Connecticut, the red sandstone occupies an area of a hundred and fifty miles in length from north to south, and from five to ten miles in breadth. "On some shales of the finest texture," says Sir Charles Lyell, "impressions of rain-drops may be seen, and casts of them in the argillaceous sandstones." The same impressions occur in the recent red mud of the Bay of Fundy. In addition to these, the undulations left by the passage of the waters of the sea, over the sands of the primitive world, are preserved by the same physical agency. Traces of undulations of this kind have been found in the neighbourhood of Boulogne-sur-Mer, and elsewhere. Similar phenomena occur in a still more striking manner in some sandstone-quarries worked at Chalindrey (Haute-Marne). The strata there present traces of the same kind over a large area, and along with them impressions of the excrements of marine worms. One may almost imagine oneself to be standing on the sea-shore while the tide is ebbing.

Chemical and Nebular Hypotheses of the Globe.

Among the innumerable hypotheses which human ingenuity has framed to explain the phenomena which surround the globe, the two which have found most ready acceptance have been termed respectively the Chemical, and the Nebular or mechanical hypothesis. By the first the solid crust is supposed to have contained abundance of potassium, sodium, calcium, magnesium, and other metallic elements. The percolating waters, coming in contact with these substances, produce combinations resulting in the conversion of the metals into their oxides—potash, soda, lime, and magnesia—all of which enter largely into the composition of volcanic rocks. The second hypothesis involves the idea of an original incandescent mass of vapour, succeeded by a great and still existing central fire.

This idea of a great central fire is a very ancient hypothesis: admitted by Descartes, developed by Leibnitz, and advocated by Buffon, it is supposed to account for many phenomena otherwise inexplicable; and it is confirmed by a crowd of facts, and adopted, or at least not opposed, by the leading authorities of the age. Dr. Buckland makes it the basis of his Bridgewater treatise. Herschel, Hind, Murchison, Lyell, Phillips, and other leading English astronomers and geologists give a cautious adhesion to the doctrine. The following are some of the principal arguments [16]
adduced in support of the hypothesis, for, in the nature of the proofs it admits of, it can be no more.

When we descend into the interior of a mine, it is found that the temperature rises in an appreciable manner, and that it increases with the depth below the surface.

The high temperature of the waters in Artesian wells when these are very deep, testifies to a great heat of the interior of the earth.

The thermal waters which issue from the earth—of which the temperature sometimes rises to 100° Centigrade and upwards—as, for instance, the Geysers of Iceland—furnish another proof in support of the hypothesis.

Modern volcanoes are said to be a visible demonstration of the existence of central heat. The heated gases, the liquid lava, the flames which escape from their craters, all tend to prove sufficiently that the interior of the globe has a temperature prodigiously elevated as compared with that at its surface.

The disengagement of gases and burning vapours through the accidental fissures in the crust, which accompany earthquakes, still further tends to establish the existence of a great heat in the interior of the globe.

We have already said that the temperature of the globe increases about one degree for every sixty or seventy feet of depth beneath its surface. The correctness of this observation has been verified in a great number of instances—indeed, to the greatest depth to which man has penetrated, and been able to make use of the thermometer. Now, as we know exactly the length of the radius of the terrestrial sphere, it has been calculated from this progression of temperature, supposing it to be regular and uniform, that the centre of the globe ought to have at the present time a mean temperature of 195,000° Centigrade. No matter could preserve its solid state at this excessive temperature; it follows, then, that the centre of the globe, and all parts near the centre, must be in a permanent state of fluidity.

The works of Werner, of Hutton, of Leopold von Buch, of Humboldt, of Cordier, W. Hopkins, Buckland, and some other English philosophers, have reduced this hypothesis to a theory, on which has been based, to a considerable extent, the whole science of modern geology; although, properly speaking, and in the popular acceptation of the term, that science only deals with the solid crust of the earth.

The nebular theory thus embraces the whole solar system, and, by analogy, the universe. It [17] assumes that the SUN was originally a mass of incandescent matter, that vast body being brought into a state of evolution by the action of laws to which the Creator, in His divine wisdom, has subjected all matter. In consequence of its immense expansion and attenuation, the exterior zone of vapour, expanding beyond the sphere of attraction, is supposed to have been thrown off by centrifugal force. This zone of vapour, which may be supposed at one time to have resembled the rings of Saturn, would in time break up into several masses, and these masses coalescing into globes, would (by the greater power of attraction which they would assume as consolidated bodies) revolve round the sun, and, from mechanical considerations, would also revolve with a rotary motion on their own axes.

This doctrine is applied to all the planets, and assumes each to have been in a state of incandescent vapour, with a central incandescent nucleus. As the cooling went on, each of these bodies may be supposed to have thrown off similar masses of vapour, which, by the operation of the same laws, would assume the rotary state, and, as satellites, revolve round the parent planet. Such, in brief, was the grand conception of Laplace; and surely it detracts nothing from our notions of the omnipotence of the Creator that it initiates the creation step by step, and under the laws to which matter is subjected, rather than by the direct fiat of the Almighty. The hypothesis assumes that as the vaporous mass cooled by the radiation of heat into space, the particles of matter would approximate and solidify.

That the figure of the earth is such as a very large mass of matter in a state of fluidity would assume from a state of rotation, seems to be admitted, thus corroborating the speculations of Leibnitz, that the earth is to be looked on as a heated fluid globe, cooled, and still cooling at the surface, by radiation of its superfluous heat into space. Mr. W. Hopkins[7] has put forth some strong but simple reasons in support of a different theory; although he does not attempt to solve the problem, but leaves the reader to form his own conclusions. As far as we have been able to follow his reasoning we gather from it that:—

If the earth were a fluid mass cooled by radiation, the cooled parts would, by the laws of circulating fluids, descend towards the centre, and be replaced on the surface by matter at a higher temperature.

The consolidation of such a mass would, therefore, be accompanied by a struggle for superiority [18] between pressure and temperature, both of which would be at their maximum at the centre of the mass.

At the surface, it would be a question of rapidity of cooling, by radiation, as compared with the internal condition—for comparing which relations we are without data; but on the result of which depends whether such a body would most rapidly solidify at the surface by radiation, or at the centre by pressure.

The effect of the first would be solidification at the surface, followed by condensation at the centre through pressure. There would thus be two masses, a spherical fluid nucleus, and a spherical shell or envelope, with a large zone of semi-fluid, pasty matter between, continually changing its temperature as its outer or inner surface became converted to the solid state.

If pressure, on the other hand, gained the victory, the centre would solidify before the circulation of the heated matter had ceased; and the solidifying process would proceed through a large portion of the globe, and even approach the surface before that would become solid. In other words, solidification would proceed from the centre until the diminishing power of pressure was balanced by radiation, when the gradual abstraction of heat would allow the particles to approximate and become solid.

The terrestrial sphere may thus be a solid indurated mass at the centre, with a solid stony crust at the surface, and a shifting viscous, but daily-decreasing, mass between the two; a supposition which the diminished and diminishing frequency and magnitude of volcanic and other eruptive convulsions seem to render not improbable.

It is not to be supposed that amongst the various hypotheses of which the cosmogony of the world has been the object, a literal acceptation of the scriptural account finds no defenders among men of science. “Why,” asks one of these writers,[8] after some scornful remarks upon the geologists and their science—“why an omnipotent Creator should have called into being a gaseous-granite nebulous world, only to have to cool it down again, consisting as it does of an endless variety of substances, should even have been supposed to be originally constituted of the matter of granite alone, for nothing else was provided by the theory, nobody can rationally explain. How the earth’s centre now could be liquid fire with its surface solid and cold and its seas not boiling caldrons, has never been attempted to be accounted for. How educated gentlemen, engaged in scientific investigations, ever came to accept such a monstrously stupid [19] mass of absurdities as deductions of ‘science,’ and put them in comparison with the rational account of the creation given by Moses, is more difficult to understand than even this vague theory itself, which it is impossible to describe.

“Of the first creation of the chaotic world,” the same writer goes on to say, “or the material elements, before they were shaped into their present forms, we can scarce have the most vague conception. All our experience relates to their existing conditions. But knowing somewhat of the variety of the constituent elements and their distinct properties, by which they manifest their existence to us, we cannot conceive of their creation without presupposing a Divine wisdom, and —if I may say so, with all reverence, and only to suit our human notions—a Divine ingenuity,” and he follows for six days the operations as described by Moses, with a running comment. When light is created, the conception of the work becomes simpler to our minds. Its least manifestation would suffice at once to dispel darkness, and yet how marvellous is the light! In the second day’s work the firmament of heaven is opened; the expanse of the air between the heavens and the earth, dividing the waters above from the waters below, is the work recorded as performed. Not till the third day commence the first geological operations. The waters of the earth are gathered together into seas, and the dry land is made to appear. It is now that we can imagine that the formation of the primary strata commenced, while by some of the internal forces of matter the earth was elevated and stood above the waters.

Immediately the dry land is raised above and separated from the waters the fiat goes forth, “Let the earth *bring forth* grass, and herb and tree;” vegetable life begins to exist, and the world is first decorated with its beauteous flora, with all its exquisite variety of forms and brilliancy of colouring, with which not even Solomon in all his glory can compare. In like manner, on the sixth day the earth is commanded to bring forth land-animals—the living creature “after his kind,” cattle and creeping thing, and beast of the earth, “after his kind;” and last of all, but on the same day, man is created, and made the chief and monarch of God’s other living creatures—for that is “man’s place in Nature.” “Let us now see,” he continues, “how this history came to be discredited by the opposition of a falsely so-called ‘science’ of geology, that, while spared by our theologians, has since pulled itself to pieces. The first step in the false inductions geology made arose from the rash deduction, that the order in which the fossil remains of organic being were found deposited in the various strata necessarily determined the order of their creation; and the next [20] error arose from blindly rushing to rash conclusions, and hasty generalisation from a very limited number of facts, and the most imperfect investigations. There were also (and, indeed, are still) some wild dogmatisms as to the time necessary to produce certain geologic formations; but the absurdities of science culminated when it adopted from Laplace the irrational and unintelligible theory of a *natural* origin for the world from a nebula of gaseous granite, intensely hot, and supposed to be gradually cooled while gyrating senselessly in space.”

In this paper the writer does not attempt to deal with the various phenomena of volcanoes, earthquakes, hot springs, and other matters which are usually considered as proofs of great internal heat. Mr. Evan Hopkins, C.E., F.G.S., is more precise if less eloquent. He shows that, in tropical countries, plains of gravel may in a day be converted into lagoons and marshes; that by the fall of an avalanche rivers have been blocked up, which, bursting their banks, have covered many square miles of fertile country with several feet of mud, sand, and gravel. “Two thousand four hundred years ago,” he says, “Nineveh flourished in all its grandeur, yet it is now buried in oblivion, and its site overwhelmed with sand. Look at old Tyre, once the queen of cities and mistress of the sea. She was in all her pride two thousand four hundred and forty years ago. We now see but a bare rock in the sea, on which fishermen spread their nets! A thousand years ago, according to Icelandic histories, Greenland was a fertile land in the south, and supported a large population. Iceland at that period was covered with forests of birch and fir, and the inhabitants cultivated barley and other grain. We may, therefore, conclude, with these facts before us, that there is no necessity to assign myriads of ages to terrestrial changes, as assumed by geologists, as they can be accounted for by means of alterations effected during a few thousand years, for the surface of the earth is ever changing.

“Grant geological speculators,” Mr. Hopkins continues, “a few millions of centuries, with a command over the agencies of Nature to be brought into operation when and how they please, and they think they can form a world with every variety of rock and vegetation, and even transform a worm into a man! Yet the wisest of our philosophers would be puzzled if called upon to explain why fluids become spheres, as dew-drops; why carbonate of lime acquires in solidifying from a liquid the figure of an obtuse rhomboihedron, silica of a six-sided prism; and why oxygen and hydrogen gases produce both *fire* and *water*. And what do they gain," he proceeds to ask, "by carrying back the history of the world to these myriads of centuries? Do they, by the extension of [21] the period to infinity, explain how the '*Original*' materials were created? But," he adds, "geologists are by no means agreed in their assumed geological periods! The so-called glacial period has been computed by some to be equal to about eighty-three thousand years, and by others at even as much as twelve hundred and eighty millions of years! Were we to ask for a *demonstrative proof* of any given deposit being more than four or five thousand years old, they could not give it. Where is Babylon, the glory of the kingdoms? Look at Thebes, and behold its colossal columns, statues, temples, obelisks, and palaces desolated; and yet those great cities flourished within the last three thousand years. Even Pompeii and Herculaneum were all but lost to history! What," he asks after these brief allusions to the past—"what, as a matter of fact, have geologists discovered, as regards the great terrestrial changes, more than was known to Pythagoras and the ancient philosophers who taught, two thousand three hundred and fifty years ago, 'that the surface of the earth was ever changing—solid land converted into sea, sea changed into dry land, marine shells lying far distant from the deep, valleys excavated by running water, and floods washing down hills into the sea?'"

In reference to the argument of the vast antiquity of the earth, founded on elevation of coasts at a given rate of upheaval, he adduces many facts to show that upheavals of equal extent have occurred almost within the memory of man. Two hundred and fifty years ago Sir Francis Drake, with his fleet, sailed into Albemarle Sound through Roanoke Outlet, which is now a sand-bank above the reach of the highest tides. Only seventy years ago it was navigable by vessels drawing twelve feet of water. The whole American coast, both on the Atlantic and Pacific, have undergone great changes within the last hundred years. The coast of South America has, in some places, been upheaved twenty feet in the last century; in others, a few hundred miles distant, it has been depressed to an equal extent. A transverse section from Rio Santa Cruz to the base of the Cordilleras, and another in the Rio Negro, in Patagonia, showed that the whole sedimentary series is of recent origin. Scattered over the whole at various heights above the sea, from thirteen hundred feet downwards, are found recent shells of *littoral* species of the neighbouring coast—denoting upheavals which might have been effected during the last three thousand years.

Coming nearer home, he shows that in 1538 the whole coast of Pozzuoli, near Naples, was raised twenty feet in a single night. Then, with regard to more compact crystalline or semi-crystalline [22] rocks, no reliable opinion can be formed on mere inspection. Two blocks of marble may appear precisely alike, though formed at different periods. A crystal of carbonate of lime, formed in a few years, would be found quite perfect, and as compact as a crystal formed during many centuries. Nothing can be deduced from the process of petrifaction and crystallisation, unless they enclose relics of a known period. At San Filippo, a solid mass of limestone thirty feet thick has been formed in about twenty years. A hard stratum of travertine a foot thick is obtained, from these thermal springs, in the course of four months. Nor can geologists demonstrate that the Amiens deposits, in which the flint-implements occur, are more than three or four thousand years old.

The causes of these changes and mutations are referred by some persons to floods, or to pre-Adamite convulsions, whereas the cause is in constant operation; they are due to an invisible and subtle power which pervades the air, the ocean, and the rocks below—in which all are wrapped and permeated—which is universally present, namely, magnetism—a power always in operation, always in a state of activity and tension. It has an attractive power towards the surface of the earth, as well as a directive action from pole to pole. "It is, indeed," he adds, emphatically, "the *terrestrial gravitation*. Magnetic needles freely suspended show its meridional or directive polar force, and that the force converges at two opposite parts, which are bounded by the Antarctic and Arctic circles."

This polar force, like a stream, is constantly moving from pole to pole; and experiment proves that this movement is from the South Pole to the North. "Hence the various terrestrial substances, solids and fluids, through which this subtle and universal power permeates, are controlled, propelled, and modified over the entire surface of our globe, commencing at the south and dissolving at the north. Thus, all terrestrial matter moves towards the Arctic region, and finally disappears by dissolution and absorption, to be renewed again and again in the Antarctic Sea to the end of time."

In order to prove that the north polar basin is the receptacle of the final dissolution of all terrestrial substances, Mr. Hopkins quotes the Gulf Stream. Bottles, tropical plants, and wrecks cast into the sea in the South Atlantic, are carried to Greenland in a comparatively short time. The great *tidal* waves commence at the fountain-head in the Antarctic circle, impinge against the south coast of Tierra del Fuego, New Zealand, and Tasmania, and are then propelled northward in a series of undulations. The South Atlantic stream, after doubling the Cape of Good Hope, moves towards the Guinea coast, bends towards the Caribbean Sea, producing the trade winds; [23] again leaves Florida as the Gulf Stream, and washes the coasts of Greenland and Norway, and finally reaches the north polar basin.

Again the great polar force shows itself in the arrangement of the mineral structure below. In all the primary rocks in every quarter of the globe where they have been examined, its action is recognised in giving to the crystalline masses—granites and their laminated elongations—a polar grain and vertical cleavage. "Had it been possible to see our globe stripped of its sedimentary deposits and its oceanic covering, we should see it like a gigantic melon, with a uniform grain extending from pole to pole." This structure appears to give polarity to earthquakes—thermal waters and earthquakes—which are all traceable in the direction of the polar grain or cleavage from north to south.

In England, for instance, thermal and saline springs are traceable from Bath, through Cheltenham, to Dudley. In Central France, mineral springs occur in lines, more or less, north and south. All the known salt-springs in South America occur in meridional bands. Springs of chloride of sodium in the Eastern Cordilleras stretch from Pinceima to the Llanoes de Meta, a distance of 200 miles. The most productive metalliferous deposits are found in meridional bands. The watery volcanoes in South America are generally situated along the lines of the meridional splits and the secondary eruptive pores on the transverse fractures. The sudden ruptures arising locally from increasing tension of the polar force, and the rapid expansion of the generated gases, produce a vibratory jar in the rocky structure below, which being propagated along the planes of the polar cleavage, gives rise to great superficial oscillations, and thus causes earthquakes and subterranean thunder for thousands of miles, from south to north.

In 1797, the district round the volcano of Tunguraqua in Quito, during one of the great meridional shocks, experienced an undulating movement, which lasted upwards of four minutes, and this was propagated to the shores of the Caribbean Sea.

All these movements demonstrated, according to Mr. Hopkins, that the land as well as the ocean moves from the south pole and north pole, and that the magnetic power has a tendency to proceed from pole to pole in a *spiral* path from south-east to north-west, a movement which produces an apparent change in the equinoxes, or the outer section of the plane of the ecliptic with the equator, a phenomenon known to astronomers as the precession of the equinoxes.

Such is a very brief summary of the arguments by which Mr. Evan Hopkins maintains the literal [24]
correctness of the Mosaic account of the creation, and attempts to show that all the facts discovered by geologists may have occurred in the ages included in the Mosaic chronology.

That the mysterious power of terrestrial magnetism can perform all that he claims for it, we can perhaps admit. But how does this explain the succession of Silurian, Old Red Sandstone, Carboniferous and other strata, up to the Tertiary deposits, with their fossils, each differing in character from those of the preceding series? That these were successive creations admits of no doubt, and while it is undeniable that the fiat of the Creator could readily produce all these phenomena, it may reasonably be asked if it is probable that all these myriads of organic beings, whose remains serve as records of their existence, were created only to be immediately destroyed.

Again, does not the author of the “Principles of Terrestrial Physics” prove too much? He admits that 3,000 years ago the climate of England was tropical: he does not deny that a subsequent period of intense cold intervened, 2,550 years ago. He admits historical records, and 2,350 years ago Pythagoras constructed his cosmography of the world, which has never been seriously impugned; and yet he has no suspicion that countries so near to his own had changed their climates first from tropical to glacial, and back again to a temperate zone. It is not reasonable to believe this parable.

The school of philosophy generally considered to be the most advanced in modern science has yet another view of cosmogony, of which we venture to give a brief outline. Space is infinite, says the exponent of this system,[9] for wherever in imagination we erect a boundary, we are compelled to think of space as existing beyond it. The starry heavens proclaim that it is not entirely void; but the question remains, are the vast regions which surround the stars, and across which light is propagated, absolutely empty? No. Modern science, while it rejects the notion of the luminiferous particles of the old philosophy, has cogent proofs of the existence of a luminiferous ether with definite mechanical properties. It is infinitely more attenuated, but more solid than gas. It resembles jelly rather than air, and if not co-extensive with space, it extends as far as the most distant star the telescope reveals to us; it is the vehicle of their light in fact; it takes up their molecular tremors and conveys them with inconceivable rapidity to our organs of vision. The [25]
splendour of the firmament at night is due to this vibration. If this ether has a boundary, masses of ponderable matter may exist beyond it, but they could emit no light. Dark suns may burn there, metals may be heated to fusion in invisible furnaces, planets may be molten amid intense darkness; for the loss of heat being simply the abstraction of molecular motion by the ether, where this medium is absent no cooling could take place.

This, however, does not concern us; as far as our knowledge of space extends, we are to conceive of it as the holder of this luminiferous ether, through which the fixed stars are interspersed at enormous distances apart. Associated with our planet we have a group of dark planetary masses revolving at various distances around it, each rotating on its axis; and, connected with them, their moons. Was space furnished at once, by the fiat of Omnipotence, with these burning orbs? The man of science should give no answer to this question: but he has better materials to guide him than anybody else, and can clearly show that the present state of things *may* be derivative. He can perhaps assign reasons which render it probable that it *is derivative*. The law of gravitation enunciated by Newton is, that every particle of matter in the universe attracts every other particle with a force which diminishes as the square of the distance increases. Under this law a stone falls to the ground, and heat is produced by the shock; meteors plunge into the atmosphere and become incandescent; showers of such doubtless fall incessantly upon the sun, and were it stopped in its orbit, the earth would rush towards the sun, developing heat in the collision (according to the calculations of MM. Joule, Mayer, Helmholtz, and Thomson), equal to the combustion of five thousand worlds of solid coal. In the attraction of gravity, therefore, acting upon this luminous matter, we have a source of heat more powerful than could be derived from any terrestrial combustion.

To the above conception of space we must add that of its being in a continual state of tremor. The sources of vibration are the ponderable masses of the universe. Our own planet is an aggregate of solids, liquids, and gases. On closer examination, these are found to be composed of still more elementary parts: the water of our rivers is formed by the union, in definite proportions, of two gases, oxygen and hydrogen. So, likewise, our chalk hills are formed by a combination of carbon, oxygen, and calcium; elements which in definite proportions form chalk. The flint found within that chalk is compounded of oxygen and silicon, and our ordinary clay is for the most part formed [26] by a union of silicon, oxygen, and aluminum. By far the greater part of the earthy crust is thus compounded of a few elementary substances.

Such is Professor Tyndall's view of the universe, rising incidentally out of his theory of heat, his main object being to elucidate his theory of heat and light.

Modifications of the Surface of the Globe.

As a consequence of the hypothesis of central heat, it is admitted that our planet has been agitated by a series of local disturbances; that is to say, by ruptures of its solid crust occurring at more or less distant intervals. These partial revolutions at the surface are supposed to have been produced, as we shall have occasion to explain, by upheavals or depressions of the solid crust, resulting from the fluidity of the central parts, and by the cooling down of the external crust of the globe.

Almost all bodies, in passing from a liquid to a solid state, are diminished in size in the process. In molten metals which resume the solid state by cooling, this diminution amounts to about a tenth of their volume; but the decrease in size is not equal throughout the whole mass. Hence, as a result of the solidification of the internal parts of the globe, the outer envelope would be too large; and would no longer fit the inner sphere, which had contracted in cooling. Cracks and hollows occur under such circumstances, even in small masses, and the effect of converting such a vast body as the earth from a liquid, or rather molten condition, to a solid state, may be imagined. As the interior became solid and concrete by cooling, furrows, corrugations, and depressions in the external crust of the globe would occur, causing great inequalities in its surface; producing, in short, what are now called *chains of mountains*.

At other times, in lieu of furrows and irregularities, the solid crust has become ruptured, producing fissures and fractures in the outer envelope, sometimes of immense extent. The liquid substances contained in the interior of the globe, with or without the action of the gases they enclose, escape through these openings; and, accumulating on the surface, become, on cooling and consolidating, *mountains* of various heights.

It would also happen, and always from the same cause, namely, from the internal contraction caused by the unequal cooling of the globe, that minor fissures would be formed in the earth's crust; incandescent liquid matter would be afterwards injected into these fissures, filling them [27] up, and forming in the rocky crust those long narrow lines of foreign substances which we call *dykes*.

Finally, it would occasionally happen, that in place of molten matter, such as granite or metalliferous compounds, escaping through these fractures and fissures in the globe, actual rivers of boiling water, abundantly charged with various mineral salts (that is to say, with silicates, and with calcareous and magnesian compounds), would also escape, since the elements of water would be abundant in the incandescent mass. Added to these the chemical and mechanical action of the atmosphere, of rain, rivers, and the sea, have all a tendency to destroy the hardest rocks. The mineral salts and other foreign substances, entering into combination with those already present in the waters of the sea, and separating at a subsequent period from these waters, would be thrown down, and thus constitute extensive deposits—that is to say, *sedimentary formations*. These became, on consolidation, the *sedimentary rocks*.

The furrows, corrugations, and fractures in the terrestrial crust, which so changed the aspect of the surface, and for the time displaced the sea-basins, would be followed by periods of calm. During these periods, the débris, torn by the movement of the waters from certain points of the land, would be transported to other parts of the globe by the oceanic currents. These accumulated heterogeneous materials, when deposited at a later period, would ultimately constitute formations—that is, *transported or drifted rocks*.

We have ventured to explain some of the theories by which it is sought to explain the cosmography of the world. But our readers must understand that all such speculations are, of necessity, purely hypothetical.

In conformity with the preceding considerations we shall divide the mineral substances of which the earth is composed into three general groups, under the following heads:—

1. *Eruptive Rocks.*—Crystalline, like the second, but formed at all geological periods by the irruption or intrusion of the liquid matter occupying the interior of our globe through all the pre-existing rocks.

2. *Crystalline Rocks.*—That portion of the terrestrial crust which was primarily liquid, owing to the heat of the globe, but which solidified at the period of its first cooling down; forming the masses known as Fundamental Gneiss, and Laurentian, &c.

3. *Sedimentary Rocks.*—Consisting of various mineral substances deposited by the water of the sea, such as silica, the carbonates of lime and magnesia, &c.

The mineral masses which constitute the *sedimentary rocks* form beds, or *strata*, having among [28] themselves a constant order of superposition which indicates their relative age. The mineral structure of these beds, and the remains of the organised beings they contain, impress on them characters which enable us to distinguish each bed from that which precedes and follows it.

It does not follow, however, that all these beds are met with, regularly superimposed, over the whole surface of the globe; under such circumstances geology would be a very simple science, only requiring the use of the eyes. In consequence of the frequent eruptions of granite, porphyry, serpentine, trachyte, basalt, and lava, these beds are often broken, cut off, and replaced by others.

Denudation has been another fruitful source of change. Professor Ramsay[10] shows, in the "Memoirs of the Geological Survey," that beds once existed above a great part of the Mendip Hills to the extent of at least 6,000 feet, which have been removed by the denuding agency of the sea; while in South Wales and the adjacent country, a series of Palaeozoic rocks, eleven thousand feet in thickness, has been removed by the action of water. In fact, every foot of the earth now forming the dry land is supposed to have been at one time under water—to have emerged, and to have been again submerged, and subjected to the destructive action of the ocean. At certain points a whole series of sedimentary deposits, and often several of them, have been removed by this cause, known by geologists as *Denudation*. The regular series of rock formations are, in fact, rarely found in unbroken order. It is only by combining the collected observations of the geologists of all countries, that we are enabled to arrange, according to their relative ages, the several beds composing the solid terrestrial crust as they occur in the following Table, which proceeds from the surface towards the centre, in descending order:—

ORDER OF STRATIFICATION.

Quaternary Epoch	Modern Period.
Tertiary Epoch	Pliocene Period. Miocene Period. Eocene Period.
Secondary Epoch	Cretaceous Rocks. Jurassic Rocks. Triassic Rocks.
Primary Epoch	Permian Rocks. Carboniferous Rocks. Devonian Rocks. Silurian Rocks.
Metamorphic Series	Cambrian Rocks. Fundamental Gneiss, or Laurentian.

Under these heads we propose to examine the successive transformations to which the earth has [29] been subjected in reaching its present condition; in other words, we propose, both from an historical and descriptive point of view, to take a survey of the several *epochs* which can be distinguished in the gradual formation of the earth, corresponding with the formation of the great groups of rocks enumerated in the preceding table. We shall describe the living creatures which have peopled the earth at each of these epochs, and which have disappeared, from causes which we shall also endeavour to trace. We shall describe the plants belonging to each great phase in the history of the globe. At the same time, we shall not pass over entirely in silence the rocks deposited by the waters, or thrown up by eruption during these periods; we propose, also, to give a summary of the mineralogical characters and of the fossils characteristic of, or peculiar to each formation. What we propose, in short, is to give a history of the formation of the globe, and a description of the principal rocks which actually compose it; and to take also a rapid glance at the several generations of animals and plants which have succeeded and replaced each other on the earth, from the very beginning of organic life up to the time of man's appearance.

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[1] Dei corpi marini, &c., 1721.

[2] Sui crostaccei ed altri corpi marini che sè trovano sui monti, 1740.

[3] Consult Lyell's "Principles of Geology" and the sixth edition of the "Elements," with much new matter, for further information relative to the study of fossils during the last two centuries.

[4] "Ossements Fossiles" (4to), vol. i., p. 29.

[5] "Ossements Fossiles" (4to), vol. i., pp. 1, 2.

[6] "Ossements Fossiles," vol. iv. (4to), p. 32.

[7] See *Phil. Transactions*, 1839-40-42; also, *Quarterly Journal of the Geological Society*, vol. viii., p. 56.

[8] “Fresh Springs of Truth.” R. Griffin and Co.

[9] Professor Tyndall in *Fortnightly Review*.

[10] “Memoirs of the Geological Survey of Great Britain,” vol. i., p. 297.

ERUPTIVE ROCKS. [30]

Nothing is more difficult than to write a chronological history of the revolutions and changes to which the earth has been subjected during the ages which preceded the historic times. The phenomena which have concurred to fashion its enormous mass, and to give to it its present form and structure, are so numerous, so varied, and sometimes so nearly simultaneous in their action, that the records defy the powers of observation to separate them. The deposition of the sedimentary rocks has been subject to interruption during all ages of the world. Violent igneous eruptions have penetrated the sedimentary beds, elevating them in some places, depressing them in others, and in all cases disturbing their order of superposition, and ejecting masses of crystalline rocks from the incandescent centre to the surface. Amidst these perturbations, sometimes stretching over a vast extent of country, anything like a rigorous chronological record becomes impossible, for the phenomena are so continuous and complex that it is no longer possible to distinguish the fundamental from the accidental and secondary causes.

In order to render the subject somewhat clearer, the great facts relative to the progressive formation of the terrestrial globe are divided into epochs, during which the sedimentary rocks were formed in due order in the seas of the ancient world, the mud and sand in which were deposited day by day. Again, even where the line of demarcation is clearest between one formation and another, it must not be supposed there is any sharply defined line of separation between them. On the contrary, one system gradually merges into that which succeeds it. The rocks and fossils of the one gradually disappear, to be succeeded by those of the overlying series in the regular order of succession. The newly-made strata became the cemetery of the myriads of beings which lived and died in the bosom of the ocean. The rocks thus deposited were called *Neptunian* by the older geologists.

But while the seas of each epoch were thus building up, grain by grain, and bed by bed, the new [31] formation out of the ruins of the older, other influences were at work, sometimes, to all appearance, impeding sometimes advancing, the great work. The *Plutonic rocks*—the *igneous or eruptive rocks* of modern geology, as we have seen above, were the great disturbing agents, and these disturbances occur in every age of the earth’s history. We shall have occasion to speak of these eruptive formations while describing the phenomena of the several epochs. But it is thought that the narrative will be made clearer and more instructive by grouping this class of phenomena into one chapter, which we place at the commencement, inasmuch as the constant reference to the eruptive rocks will thus be rendered more intelligible. To these are now added the section “Metamorphic Rocks,” from the fifth edition of the French work.

The rocks which issued from the centre of the earth in a state of fusion are found associated or interstratified with masses of every epoch, more especially with those of the more ancient strata. The formations which these rocks have originated possess great interest; first, because they enter into the composition of the terrestrial crust; secondly, because they have impressed on its surface, in the course of their eruption, some of the characteristics of its configuration and structure; finally, because, by their means, the metals which are the objects of human industry have been brought nearer to the surface. According to the order of their appearance, or as nearly so as can be ascertained, we shall class the eruptive rocks in two groups:—

I. The *Volcanic Rocks*, of comparatively recent origin, which have given rise to a succession of trachytes, basalts, and modern lavas. These, being of looser texture, are presumed to have cooled more rapidly than the Plutonic rocks, and at or near the surface.

II. The *Plutonic Rocks*, of older date, which are exemplified in the various kinds of granites, the syenites, the protogines, porphyries, &c. These differ from the volcanic rocks in their more compact crystalline structure, in the absence of tufa, as well as of pores and cavities; from which it is inferred that they were formed at considerable depths in the earth, and that they have cooled and crystallised slowly under great pressure.

Plutonic Eruptions.

The great eruptions of *ancient granite* are supposed to have occurred during the primary epoch, and chiefly in the carboniferous period. They present themselves sometimes in considerable masses, for the earth’s crust being still thin and permeable, it was prepared as it were for [32] absorbing the granite masses. In consequence of its weak cohesion, the primitive crust of the globe would be rent and penetrated in all directions, as represented in the following section of Cape Wrath, in Sutherlandshire, in which the veins of granite ramify in a very irregular manner across the gneiss and hornblende-schist, there associated with it. (Fig. 3.)

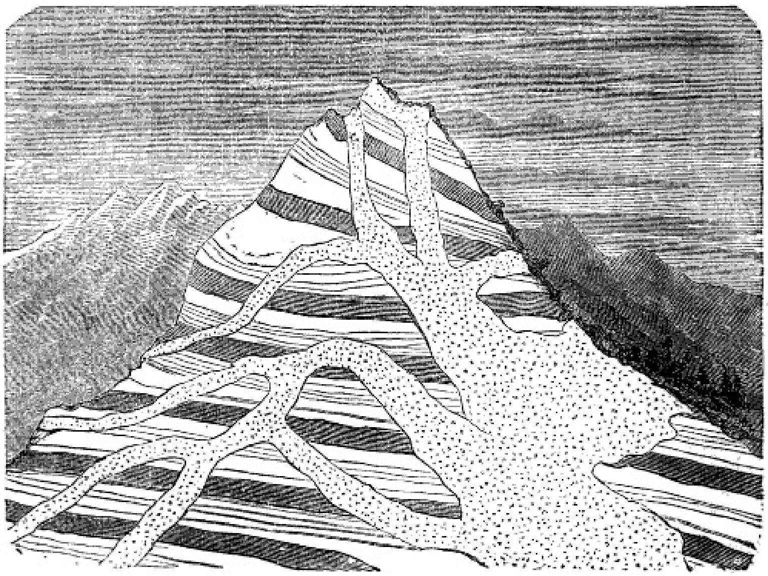


Fig. 3.—Veins of granite traversing the gneiss of Cape Wrath.

Granite, when it is sound, furnishes a fine building-stone, but we must not suppose that it deserves that character of extreme hardness with which the poets have gratuitously gifted it. Its granular texture renders it unfit for road-stone, where it gets crushed too quickly to dust. With his hammer the geologist easily shapes his specimens; and in the Russian War, at the bombardment of Bomarsund, the shot from our ships demonstrated that ramparts of granite could be as easily demolished as those constructed of limestone.

The component minerals of granite are felspar, quartz, and mica, in varying proportions; felspar being generally the predominant ingredient, and quartz more plentiful than mica—the whole being united into a confusedly granular or crystalline mass. Occasionally it passes insensibly from fine to coarse-grained granite, and the finer grained is even sometimes found embedded in the more coarsely granular variety: sometimes it assumes a porphyritic texture. Porphyritic granite is a variety of granite, the components of which—quartz, felspar, and mica—are set in a non-crystallised paste, uniting the mass in a manner which will be familiar to many of our readers who may have seen the granite of the Land's End, in Cornwall. Alongside these orthoclase crystals, quartz is implanted, usually in grains of irregular shape, more rarely crystallised, and seldom in the form of perfect crystals. To these ingredients are added thin scales or small hexagonal plates and crystals of white, brown, black, or greenish-coloured mica. Finally, the name of *quartziferous porphyry* is reserved for those varieties which present crystals of quartz; the other varieties are simply called *porphyritic granite*. *True* porphyry presents a paste essentially composed of compact felspar, in which the crystals of orthoclase—that is, felspar with a potash base—are abundantly disseminated, and sometimes with great regularity. [33]

Granite is supposed to have been "formed at considerable depths in the earth, where it has cooled and crystallised slowly under great pressure, where the contained gases could not expand."[11] "The influence," says Lyell, "of subterranean heat may extend downwards from the crater of every active volcano to a great depth below, perhaps several miles or leagues, and the effects which are produced deep in the bowels of the earth may, or rather must, be distinct; so that volcanic and plutonic rocks, each different in texture, and sometimes even in composition, may originate simultaneously, the one at the surface, the other far beneath it." Other views, however, of its origin are not unknown to science: Professor Ramsay and some other geologists consider granite to be metamorphic. "For my own part," says the Professor, "I believe that in one sense it is an igneous rock; that is to say, that it has been completely fused. But in another sense it is a metamorphic rock, partly because it is impossible in many cases to draw any definite line between gneiss and granite, for they pass into each other by insensible gradations; and granite frequently *occupies the space that ought to be filled with gneiss*, were it not that the gneiss has been entirely fused. I believe therefore that granite and its allies are simply the effect of the extreme of metamorphism, brought about by great heat with presence of water. In other words, [34] when the metamorphism has been so great that all traces of the semi-crystalline laminated structure have disappeared, a more perfect crystallisation has taken place."[12] It is obvious that the very result on which the Professor founds his theory, namely, the difficulty "in many cases," of drawing a line between the granite and the gneiss, would be produced by the sudden injection of the fluid minerals into gneiss, composed of the same materials. Moreover, it is only in some cases that the difficulty exists; in many others the line of separation is definable enough.[13]

The granitic rock called *Syenite*, in which a part of the mica is replaced by hornblende or amphibole, has to all appearance been erupted to the surface subsequently to the granite, and very often alongside of it. Thus the two extremities of the Vosges, towards Belfort and Strasburg, are eminently syenitic, while the intermediate part, towards Colmar, is as markedly granitic. In the Lyonnais, the southern region is granitic; the northern region, from Arbresle, is in great part syenitic. Syenite also makes its appearance in the Limousin.

Syenite, into which rose-coloured felspar often enters, forms a beautiful rock, because the green or nearly black hornblende heightens, by contrast, the effect of its colour. This rock is a valuable adjunct for architectural ornament; it is that out of which the ancient Egyptians shaped many of their monumental columns, sphinxes, and sarcophagi; the most perfect type of it is found in Egypt, not far from the city of Syene, from which it derives its name. The obelisk of Luxor now in Paris, several of the Egyptian obelisks in Rome, and the celebrated sphinxes, of which copies may be seen in front of the Egyptian Court at the Crystal Palace, the pedestal of the statue of Peter the Great at St. Petersburg, and the facing of the sub-basement of the column in the Place Vendôme in Paris, are of this stone, of which there are quarries in the neighbourhood of Plancher-les-Mines in the Vosges.

Syenite disintegrates more readily than granite, and it contains indurated nodular concretions, which often remain in the form of large spherical balls, in the midst of the débris resulting from disintegration of the mass. It remains to be added that syenitic masses are often very variable as [35] regards their composition; the hornblende is sometimes wanting, in which case we can only recognise an ancient granite. In other instances the hornblende predominates to such a degree, that a large or small-grained *diorite*, or greenstone, results. The geologist should be prepared to observe these transitions, which are apt to lead him into error if passed over without being noticed.

Protogine is a talcose granite, composed of felspar, quartz, and talc or *chlorite*, or decomposed mica, which take the place of the usual mica. Excessively variable in its texture, protogine passes from the most perfect granitic aspect to that of a porphyry, in such a manner as to present continual subjects of uncertainty, rendering it very difficult to determine its geological age. Nevertheless, it is supposed to have come to the surface before and during the coal-period; in short, at Creusot, protogine covers the coal-fields so completely, that it is necessary to sink the pits through the protogine, in order to penetrate to the coal, and the rock has so manifestly acted on the coal-measure strata, as to have contorted and metamorphosed them. Something analogous to this manifests itself near Mont Blanc, where the colossal mass which predominates in that chain, and the peaks which belong to it, consist of protogine. But as no such action can be perceived in the overlying rocks of the Triassic period, it may be assumed that at the time of the deposition of the New Red Sandstone the protoginous eruptions had ceased.

It is necessary to add, however, that if the protogine rises in such bold pinnacles round Mont Blanc, the circumstance only applies to the more elevated parts of the mountain, and is influenced by the excessive rigour of the seasons, which demolishes and continually wears away all the parts of the rock which have been decomposed by atmospheric agency. Where protogine occurs in milder climates—around Creusot, and at Pierre-sur-Autre, in the Forez chain, for instance—the mountains show none of the scarped and bristling peaks exhibited in the chain of Mont Blanc. Only single isolated masses occasionally form *rocking-stones*, so called because, resting with a convex base upon a pedestal also convex, but in a contrary way, it is easy to move these naturally balanced blocks, although from their vast size it would require very considerable force to displace them. This tendency to fashion themselves into rounded or ellipsoidal forms belongs, also, to other granitic rocks, and even to some of the variegated sandstones. The rocking-stones have often given rise to legends and popular myths.

The great eruptions of granite, protogine, and porphyry took place, according to M. Fournet, [36] during the carboniferous period, for porphyritic pebbles are found in the conglomerates of the Coal-measure period. “The granite of Dartmoor, in Devonshire,” says Lyell,[14] “was formerly supposed to be one of the most ancient of the plutonic rocks, but it is now ascertained to be posterior in date to the culm-measures of that county, which from their position, and as containing true coal-plants, are regarded by Professor Sedgwick and Sir R. Murchison as members of the true Carboniferous series. This granite, like the syenitic granite of Christiana, has broken through the stratified formations without much changing their strike. Hence, on the north-west side of Dartmoor, the successive members of the Culm-measures abut against the granite, and become metamorphic as they approach. The granite of Cornwall is probably of the same date, and therefore as modern as the Carboniferous strata, if not newer.”

The *ancient granites* show themselves in France in the Vosges, in Auvergne, at Espinouse in Languedoc, at Plan-de-la-Tour in Provence, in the chain of the Cévennes, at Mont Pilat near Lyons, and in the southern part of the Lyonnaise chain. They rarely impart boldness or grandeur to the landscape, as might be expected from their crystallised texture and hardness; for having been exposed to the effects of atmospheric changes from the earliest times of the earth’s consolidation, the rocks have become greatly worn away and rounded in the outlines of their masses. It is only when recent dislocations have broken them up that they assume a picturesque character.

The Christiania granite alluded to above was at one time thought to have belonged to the Silurian period. But, in 1813, Von Buch announced that the strata in question consisted of limestones containing orthoceratites and trilobites; the shales and limestone being only penetrated by granite-veins, and altered for a considerable distance from the point of contact.[15] The same granite is found to penetrate the ancient gneiss of the country on which the fossiliferous beds rest—unconformably, as the geologists say; that is, they rest on the edges of the gneiss, from which other stratified deposits had been washed away, leaving the gneiss denuded before the sedimentary beds were deposited. “Between the origin, therefore, of the gneiss and the granite,”[16] says Lyell, “there intervened, first, the period when the strata of gneiss were denuded; secondly, the period of the deposition of the Silurian deposits. Yet the granite produced [37] after this long interval is often so intimately blended with the ancient gneiss at the point of the junction, that it is impossible to draw any other than an arbitrary line of separation between them; and where this is not the case, tortuous veins of granite pass freely through gneiss, ending sometimes in threads, as if the older rock had offered no resistance to their passage." From this example Sir Charles concludes that it is impossible to conjecture whether certain granites, which send veins into gneiss and other metamorphic rocks, have been so injected while the gneiss was scarcely solidified, or at some time during the Secondary or Tertiary period. As it is, no single mass of granite can be pointed out more ancient than the oldest known fossiliferous deposits; no Lower Cambrian stratum is known to rest immediately on granite; no pebbles of granite are found in the conglomerates of the Lower Cambrian. On the contrary, granite is usually found, as in the case of Dartmoor, in immediate contact with primary formations, with every sign of elevation subsequent to their deposition. Porphyritic pebbles are found in the Coal-measures; porpyhries continue during the Triassic period; since, in some parts of Germany, veins of porphyry are found traversing the New Red Sandstone, or *grès bigarré* of French geologists. Syenites have especially reacted upon the Silurian deposits and other old sedimentary rocks, up to those of the Lower Carboniferous period.

The term porphyry is usually applied to a rock with a paste or base of compact felspar, in which felspathic crystals of various sizes assume their natural form. The variety of their mineralogical characters, the admirable polish which can be given to them, and which renders them eminently useful for ornamentation, give to the porphyries an artistic and industrial importance, which would be greatly enhanced if the difficulty of working such a hard material did not render the price so high.

The porphyries possess various degrees of hardness and compactness. When a fine dark-red colour—which contrasts well with the white of the felspar—is combined with hardness, a magnificent stone is the result, susceptible of taking a polish, and fit for any kind of ornamental work; for the decoration of buildings, for the construction of vases, columns, &c. The red Egyptian porphyry, called *Rosso antico*, was particularly sought after by the ancients, who made sepulchres, baths, and obelisks of it. The grandest known mass of this kind of porphyry is the Obelisk of Sextus V. at Rome. In the Museum of the Louvre, in Paris, some magnificent basins and statues, made of the same stone, may also be seen.

In spite of its compact texture porphyry disintegrates, like other rocks, when exposed to air and [38] water. One of the sphinxes transported from Egypt to Paris, being accidentally placed under a gutter of the Louvre, soon began to exhibit signs of exfoliation, notwithstanding it had remained sound for ages under the climate of Egypt. In this country, and even in France, where the climate is much drier, the porphyries frequently decompose so as to become scarcely recognisable. They crop out in various parts of France, but are only abundant in the north-eastern part of the central plateau, and in some parts of the south. They form mountains of a conical form, presenting, nearly always, considerable depressions on their flanks. In the Vosges they attain a height of from three to four thousand feet.

The *Serpentine* rocks are a sort of compact *talc*, which owe their soapy texture and greasy feel to silicate of magnesia. Their softness permits of their being turned in a lathe and fashioned into vessels of various forms. Even stoves are constructed of this substance, which bears heat well. The serpentine quarried on the banks of Lake Como, which bears the name of pierre ollaire, or pot-stone, is excellently adapted for this purpose. Serpentine shows itself in the Vosges, in the Limousin, in the Lyonnais, and in the Var; it occupies an immense tract in the Alps, as well as in the Apennines. Mona marble is an example of serpentine; and the Lizard Point, Cornwall, is a mass of it. A portion of the stratified rocks of Tuscany, and also those of the Island of Elba, have been upheaved and overturned by eruptions of it.

As for the British Islands, plutonic rocks are extensively developed in Scotland, where the Cambrian and Silurian rocks, often of gneissic character—associated here and there with great bosses of granite and syenite—form by far the greater part of the region known as the Highlands. In the Isle of Arran a circular mass of coarse-grained granite protrudes through the schists of the northern part of the island; while, in the southern part, a finer-grained granite and veins of porphyry and coarse-grained granite have broken through the stratified rocks.[17] In Devonshire and Cornwall there are four great bosses of granite; in the southern parts of Cornwall the mineral axis is defined by a line drawn through the centre of the several bosses from south-west to north-east; but in the north of Cornwall, and extending into Devonshire, it strikes nearly east and west. The great granite mass in Cornwall lies on the moors north of St. Austell, and indicates [39] the existence of more than one disturbing force. "There was an elevating force," says Professor Sedgwick,[18] "protruding from the St. Austell granite; and, if I interpret the phenomena correctly, there was a contemporaneous elevating force acting from the south; and between these two forces, the beds, now spread over the surface from the St. Austell granite to the Dodman and Narehead, were broken, contorted, and placed in their present disturbed position. Some great disturbing forces," he observes, "have modified the symmetry of this part of Cornwall, affecting," he believes, "the whole transverse section of the country from the headlands near Fowey to those south of Padstow." This great granite-axis was upheaved in a line commencing at the west end of Cornwall, rising through the slate-rocks of the older Devonian group, continuing in association with them as far as the boss north of St. Austell, producing much confusion in the stratified masses; the granite-mass between St. Clear and Camelford rose between the deposition of the Petherwin and that of the Plymouth group; lastly, the Dartmoor granite rose, partially moving the adjacent slates in such a manner that its north end abuts against and tilts up the base of the Culm-trough, mineralising the great Culm-limestone, while on the south it does the same to the base of the Plymouth slates. These facts prove that the granite of Dartmoor, which was formerly thought to be the most ancient of the Plutonic rocks, is of a date subsequent to the Culm-measures of Devonshire, which are now regarded as forming part of the true carboniferous series.

Volcanic Rocks.

Considered as a whole, the volcanic rocks may be grouped into three distinct formations, which we shall notice in the following order, which is that of their relative antiquity, namely:—1. *Trachytic*; 2. *Basaltic*; 3. *Volcanic or Lava formations*.

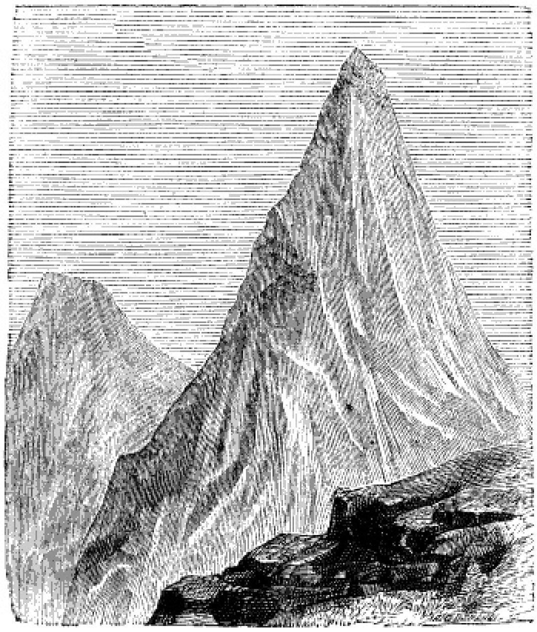
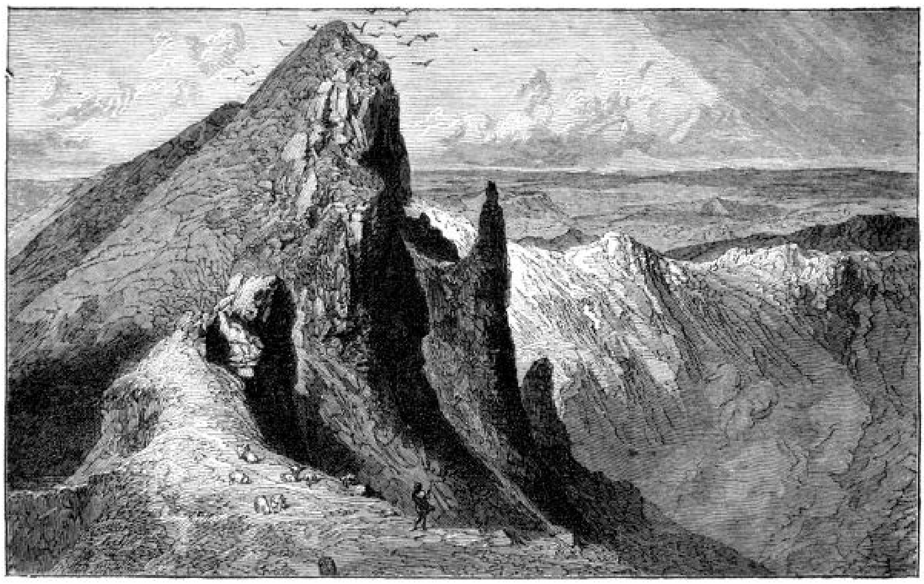


Fig. 4.—A peak of the Cantal chain.

Trachytic Formations.

Trachyte (derived from τραχυς, rough), having a coarse, cellular appearance, and a rough and gritty feel, belongs to the class of volcanic rocks. The eruptions of trachyte seem to have commenced towards the middle of the Tertiary period, and to have continued up to its close. The [40] trachytes present considerable analogy in their composition to the felspathic porphyries, but their mineralogical characters are different. Their texture is porous; they form a white, grey, black, sometimes yellowish matrix, in which, as a rule, felspar predominates, together with disseminated crystals of felspar, some hornblende or augite, and dark-coloured mica. In its external appearance trachyte is very variable. It forms the three most elevated mountain ranges of Central France; the groups of Cantal and Mont Dore, and the chain of the Velay (Puy-de-Dôme).[19]

[42]



I.—Peak of Sancy in the Mont Dore group, Auvergne.

[43] The igneous group of Cantal may be described as a series of lofty summits, ranged around a large cavity, which was at one period probably a volcanic crater, the circular base of which occupies an

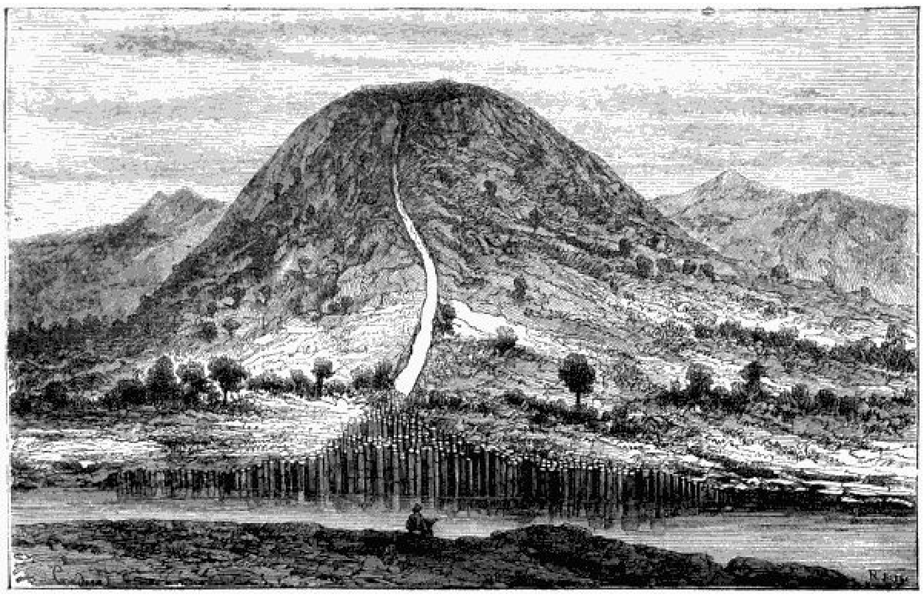
area of nearly fifteen leagues in diameter. The strictly trachytic portion of the group rises in the centre, and is composed of high mountains, throwing off spurs, which gradually decrease in height, and terminate in plateaux more or less inclined. These central mountains attain a height varying between 4,500 and 5,500 feet above the level of the sea. A scaly or schistose variety of trachyte, called *phonolite*, or clinkstone (from the ringing metallic sound it emits when struck with the hammer), with an unusual proportion of felspar, or, according to Gmelin, composed of felspar and zeolite, forms the steep trachytic escarpments at the centre, which enclose the principal valleys; their abrupt peaks giving a remarkably picturesque appearance to the landscape. In the engraving on p. 40 (Fig. 4) the slaty, laminated character of the clinkstone is well represented in one of the phonolitic peaks of the Cantal group. The group at Mont Dore consists of seven or eight rocky summits, occupying a circuit of about five leagues in diameter. The massive trachytic rock, of which this mountainous mass is chiefly formed, has an average thickness of 1,200 to 2,600 feet; comprehending over that range prodigious layers of scoriæ, pumiceous conglomerates, and detritus, interstratified with beds of trachyte and basalt, bearing the signs of an igneous origin, tufa forming the base; and between them occur layers of lignite, or imperfectly mineralised woody fibre, the whole being superimposed on a primitive plateau of about 3,250 feet in height. Scored and furrowed out by deep valleys, the viscous mass was gradually upheaved, until in the needle-like Pic de Sancy (Plate I.), a pyramidal rock of porphyritic trachyte, which is the loftiest point of Mont Dore, it attains the height of 6,258 feet. The Pic de Sancy, represented on page 40 (Fig. 4), gives an excellent idea of the general appearance of the trachytic mountains of Mont Dore.

Upon the same plateau with Mont Dore, and about seven miles north of its last slopes, the trachytic formation is repeated in four rounded domes—those of Puy-de-Dôme, Sarcouï, Clierzou, and Le Grand Suchet. The Puy-de-Dôme, one of the most remarkable volcanic domes in Auvergne, presents another fine and very striking example of an eruptive trachytic rock. The rock here assumes a peculiar mineral character, which has caused the name of *domite* to be given to it.

The chain of the Velay forms a zone, composed of independent plateaux and peaks, which forms upon the horizon a long and strangely intersected ridge. The bareness of the mountains, their [44] forms—pointed or rounded, sometimes terminating in scarped plateaux—give to the whole landscape an appearance at once picturesque and characteristic. The peak of Le Mezen, which rises 5,820 feet above the sea, forms the culminating point of the chain. The phonolites of which it consists have been erupted from fissures which present themselves at a great number of points, ranging from north-north-west to south-south-east.

On the banks of the Rhine and in Hungary the trachytic formation presents itself in features identical with those which indicate it in France. In America it is principally represented by some immense cones, superposed in the chain of the Andes; the colossal Chimborazo being one of those trachytic cones.

[46]



II.—Mountain and basaltic crater of La Coupe d'Ayzac, in the Vivarais.

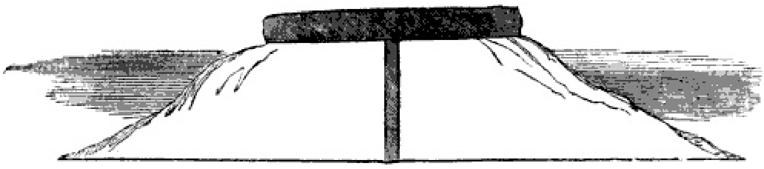


Fig. 5.—Theoretical view of a basaltic plateau.

Basaltic Formations.

Basaltic eruptions seem to have occurred during the Secondary and Tertiary periods. Basalt, according to Dr. Daubeny,[20] in its more strict sense, "is composed of an intimate mixture of augite with a zeolitic mineral, which appears to have been formed out of labradorite (felspar of Labrador), by the addition of water—the presence of water being in all *zeolites* the cause of that bubbling-up under the blow-pipe to which they owe their appellation." M. Delesse and other mineralogists are of opinion that the idea of augite being the prevailing mineral in basalt, must be abandoned; and that although its presence gives the rock its distinctive character, as compared with trachytic and most other trap rocks, still the principal element in their composition is felspar. Basalt, a lava consisting essentially of augite, labradorite (or nepheline) and magnetic iron-ore is the rock which predominates in this formation. It contains a smaller quantity of silica than the trachyte, and a larger proportion of lime and magnesia. Hence, independent of the iron in its composition, it is heavier in proportion, as it contains more or less silica. Some varieties of basalt contain very large quantities of olivine, a mineral of an olive-green colour, with a chemical composition differing but slightly from serpentine. Both basalts and trachyte contain more soda and less silica in their composition than granites; some of the basalts are highly fusible, the alkaline matter and lime in their composition acting as a flux to the silica. There are examples of basalt existing in well-defined flows, which still adhere to craters visible at [47] the present day, and with regard to the igneous origin of which there can be no doubt. One of the most striking examples of a basaltic cone is furnished by the mountain or crater of La Coupe d'Ayzac, in the Vivarais, in the south of France. Plate II., on the opposite page, gives an accurate representation of this curious basaltic flow. The remnants of the stream of liquefied basalt which once flowed down the flank of the hill may still be seen adhering in vast masses to the granite rocks on both sides of a narrow valley where the river Volant has cut across the lava and left a pavement or causeway, forming an assemblage of upright prismatic columns, fitted together with geometrical symmetry; the whole resting on a base of gneiss. Basaltic eruptions sometimes form a plateau, as represented in Fig. 5, where the process of formation is shown theoretically and in a manner which renders further explanation unnecessary. Many of these basaltic table-lands form plateaux of very considerable extent and thickness; others form fragments of the same, more or [48] less dislocated; others, again, present themselves in isolated knolls, far removed from similar formations. In short, basaltic rocks present themselves in veins or dykes, more or less, in most countries, of which Central France and the banks of the Rhine offer many striking examples. These veins present very evident proofs that the matter has been introduced from below, and in a manner which could only result from injection from the interior to the exterior of the earth. Such are the proofs presented by the basaltic veins of Villeneuve-de-Berg, which terminate in slender filaments, sometimes bifurcated, which gradually lose themselves in the rock which they traverse. In several parts of the north of Ireland, chalk-formations with flints are traversed by basaltic dykes, the chalk being converted into granular marble near the basalt, the change sometimes extending eight or ten feet from the wall of the dyke, and being greatest near the surface of contact. In the Island of Rathlin, the walls of basalt traverse the chalk in three veins or [49] dykes; the central one a foot thick, that on the right twenty feet, and on the left thirty-three feet thick, and all, according to Buckland and Conybeare, within the breadth of ninety feet.

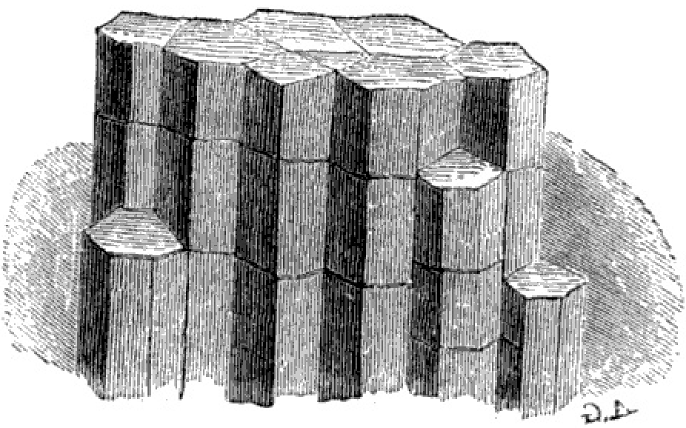


Fig. 6.—Basalt in prismatic columns.

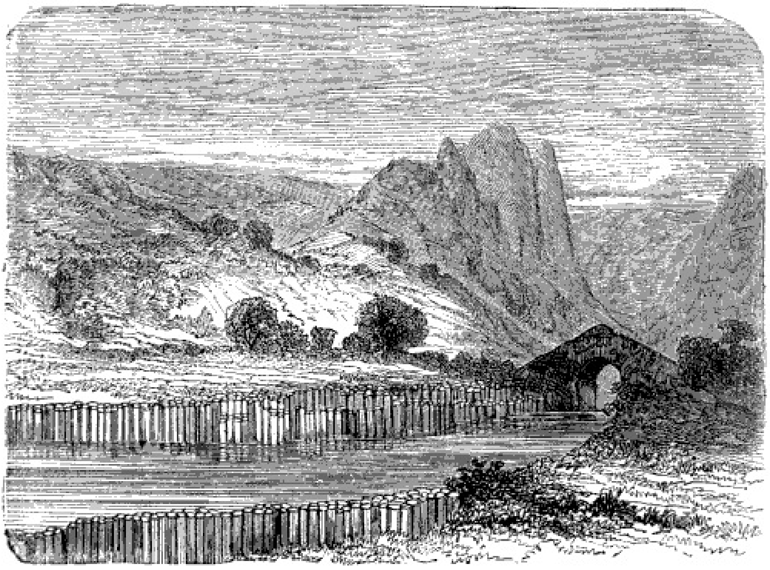


Fig. 7.—Basaltic Causeway, on the banks of the river Volant, in the Ardèche.

One of the most striking characteristics of basalt is the prismatic and columnar structure which it often assumes; the lava being homogeneous and of very fine grain, the laws which determine the direction of the fissures or divisional planes consolidated from a molten to a solid state, become here very manifest—these are always at right angles to the surfaces of the rock through which the heat of the fused mass escaped. The basaltic rocks have been at all times remarkable for this picturesque arrangement of their parts. They usually present columns of regular prisms, having generally six, often five, and sometimes four, seven, or even three sides, whose disposition is always perpendicular to the cooling surfaces. These are often divided transversely, as in Fig. 6, at nearly equal distances, like the joints of a wall, composed of regularly arranged, equal-sided pieces adhering together, and frequently extending over a more or less considerable space. The name of Giant's Causeway has been given, from time immemorial, to these curious columnar structures of basalt. In France, in the Vivarais and in the Velay, there are many such basaltic causeways. That of which Fig. 7 is a sketch lies on the banks of the river Volant, where it flows into the Ardèche. Ireland has always been celebrated for its Giant's Causeway, which extends over the whole of the northern part of Antrim, covering all the pre-existing strata of Chalk, Greensand, and Permian formations; the prismatic columns extend for miles along the cliffs, projecting into the sea at the point specially designated the Giant's Causeway.

These columnar formations vary considerably in length and diameter. McCulloch mentions some in Skye, which "are about four hundred feet high; others in Morven not exceeding an inch (vol. ii. p. 137). In diameter those of Ailsa Craig measure nine feet, and those of Morven an inch or less." Fingal's Cave, in the Isle of Staffa, is renowned among basaltic rocks, although it was scarcely known on the mainland a century ago, when Sir Joseph Banks heard of it accidentally, and was the first to visit and describe it. Fingal's Cave has been hollowed out, by the sea, through a gallery of immense prismatic columns of trap, which are continually beaten by the waves. The columns are usually upright, but sometimes they are curved and slightly inclined. Fig. 8 is a view of the basaltic grotto of Staffa.

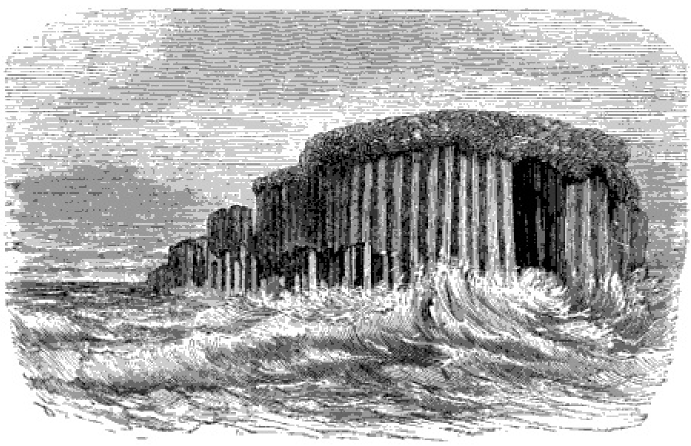
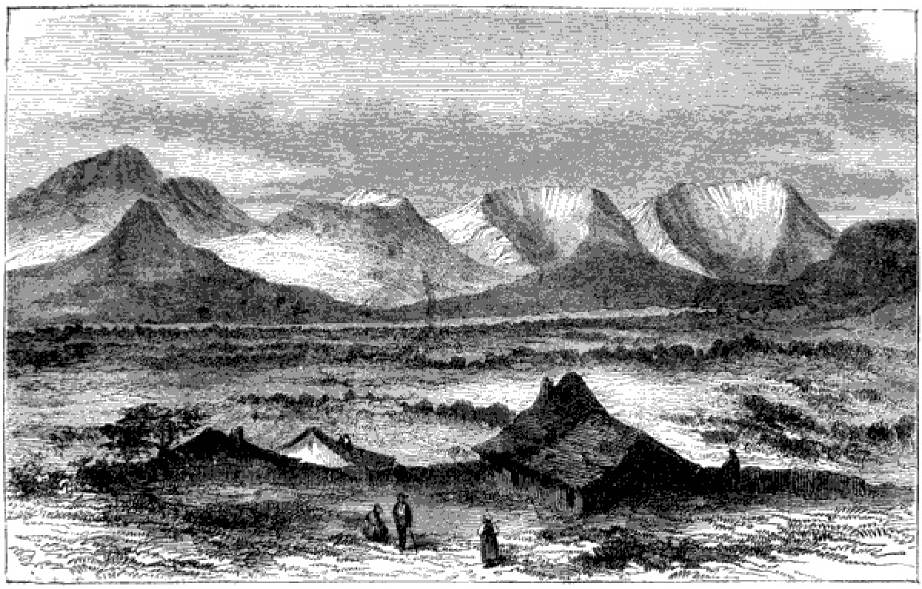


Fig. 8.—Basaltic cavern of Staffa—exterior.

Grottoes are sometimes formed by basaltic eruptions on land, followed by their separation into regular columns. The Grotto of Cheeses, at Bertrich-Baden, between Trèves and Coblentz, is a remarkable example of this kind, being so called because its columns are formed of round, and usually flattened, stones placed one above the other in such a manner as to resemble a pile of cheeses.



III.—Extinct volcanoes forming the Puy-de-Dôme Chain.

If we consider that in basalt-flows the lower part is compact, and often divided into prismatic columns, while the upper part is porous, cellular, scoriaceous, and irregularly divided—that the points of separation on which they rest are small beds presenting fragments of the porous stony concretions known under the name of *Lapilli*—that the lower portions of these masses present a multitude of points which penetrate the rocks on which they repose, thereby denoting that some fluid matter had moulded itself into its crevices—that the neighbouring rocks are often calcined to a considerable thickness, and the included vegetable remains carbonised—no doubt can exist as to the igneous origin of basaltic rocks. When it reached the surface through certain openings, the fluid basalt spread itself, flowing, as it were, over the horizontal surface of the ground; for if it had flowed upon inclined surfaces it could not have preserved the uniform surface and constant [53] thickness which it generally exhibits.

Volcanic or Lava Formations.

The *lava* formations comprehend both extinct and active volcanoes. “The term,” says Lyell, “has a somewhat vague signification, having been applied to all melted matter observed to flow in streams from volcanic vents. When this matter consolidates in the open air, the upper part is usually scoriaceous, and the mass becomes more and more stony as we descend, or in proportion as it has consolidated more slowly and under greater pressure.”[21]

The formation of extinct volcanoes is represented in France by the volcanoes situated in the ancient provinces of Auvergne, Velay, and the Vivarais, but principally by nearly seventy volcanic cones of various sizes and of the height of from 500 to 1,000 feet, composed of loose scoriæ, lava, and pozzuolana, arranged upon a granitic table-land, about twelve miles wide, which overlooks the town of Clermont-Ferrand, and which seem to have been produced along a longitudinal fracture in the earth’s crust, running in a direction from north to south. It is a range of volcanic hills, the “chain of *Puys*” nearly twenty miles in length, by two in breadth. By its cellular and porous structure, which is also granular and crystalline, the felspathic or pyroxenic lava which flowed from these volcanoes is readily distinguishable from the analogous lavas which belong to the basaltic or trachytic formations. Their surface is irregular, and bristles with asperities, formed by heaped-up angular blocks.

The volcanoes of the chain of *Puys*, represented on opposite page (Pl. III.) are so perfectly preserved, their lava is so frequently superposed on sheets of basalt, and presents a composition and texture so distinct, that there is no difficulty in establishing the fact that they are posterior to the basaltic formation, and of very recent age. Nevertheless, they do not appear to belong to the historic ages, for no tradition attests their eruption. Lyell places these eruptions in the Lower Miocene period, and their greatest activity in the Upper Miocene and Pliocene eras. “Extinct quadrupeds of those eras,” he says, “belonging to the genera mastodon, rhinoceros, and others, were buried in ashes and beds of alluvial sand and gravel, which owe their preservation to overspreading sheets of lava.”[22]

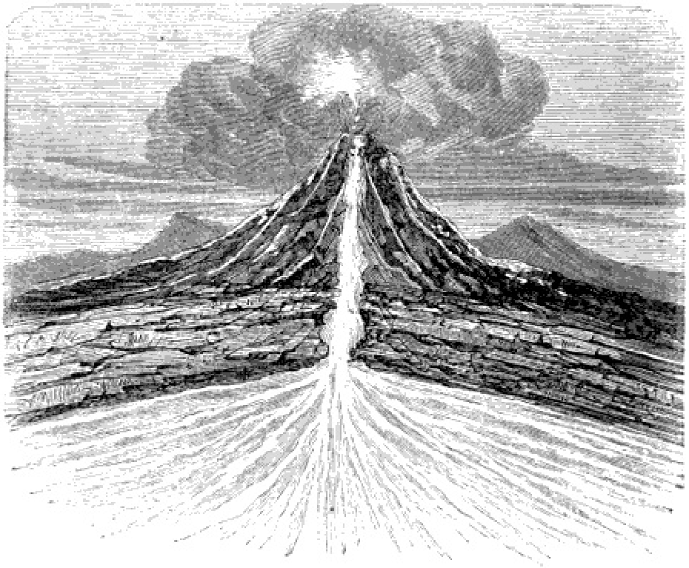


Fig. 9.—Section of a volcano in action.

All volcanic phenomena can be explained by the theory we have already indicated, of fractures in [54] the solid crust of the globe resulting from its cooling. The various phenomena which existing volcanoes present to us are, as Humboldt has said, "the result of every action exercised by the interior of a planet on its external crust."[23] We designate as volcanoes all conduits which establish a permanent communication between the interior of the earth and its surface—a conduit which gives passage at intervals to eruptions of *lava*, and in Fig. 9 we have represented, in an ideal section, the geological mode of action of volcanic eruptions. The volcanoes on the surface of the globe, known to be in an occasional state of activity, number about three hundred, [55] and these may be divided into two classes: the *isolated* or *central*, and the *linear* or those volcanoes which belong to a *series*.[24]

The first are active volcanoes, around which there may be established many secondary active mouths of eruption, always in connection with some principal crater. The second are disposed like the chimneys of furnaces, along fissures extending over considerable distances. Twenty, thirty, and even a greater number of volcanic cones may rise above one such rent in the earth's crust, the direction of which will be indicated by their linear course. The Peak of Teneriffe is an instance of a central volcano; the long rampart-like chain of the Andes, presents, from the south of Chili to the north-west coast of America, one of the grandest instances of a continental volcanic chain; the remarkable range of volcanoes in the province of Quito belong to the latter class. Darwin relates that on the 19th of March, 1835, the attention of a sentry was called to something like a large star which gradually increased in size till about three o'clock, when it presented a very magnificent spectacle. "By the aid of a glass, dark objects, in constant succession, were seen in the midst of a great glare of red light, to be thrown up and to fall down. The light was sufficient to cast on the water a long bright reflection—it was the volcano of Osorno in action." Mr. Darwin was afterwards assured that Aconcagua, in Chili, 480 miles to the north, was in action on the same night, and that the great eruption of Coseguina (2,700 miles north of Aconcagua), accompanied by an earthquake felt over 1,000 miles, also occurred within six hours of this same time; and yet Coseguina had been dormant for six-and-twenty years, and Aconcagua most rarely shows any signs of action.[25] It is also stated by Professor Dove that in the year 1835 the ashes discharged from the mountain of Coseguina were carried 700 miles, and that the roaring noise of the eruption was heard at San Salvador, a distance of 1,000 miles.

In the sea the *series* of volcanoes show themselves in groups of islands disposed in longitudinal series.

Among these may be ranged the volcanic series of Sunda, which, according to the accounts of the matter ejected and the violence of the eruptions, seem to be among the most remarkable on the globe; the series of the Moluccas and of the Philippines; those of Japan; of the Marianne Islands; of Chili; of the double series of volcanic summits near Quito, those of the Antilles, Guatemala, and Mexico.

Among the central, or isolated volcanoes, we may class those of the Lipari Islands, which have *Stromboli*, in permanent activity, for their centre; *Etna*, *Vesuvius*, the volcanoes of the *Azores*, of [56] the *Canaries*, of the *Cape de Verde*, of the *Galapagos* Islands, the *Sandwich* Islands, the *Marquesas*, the *Society* Islands, the *Friendly* Islands, *Bourbon*, and, finally, *Ararat*.

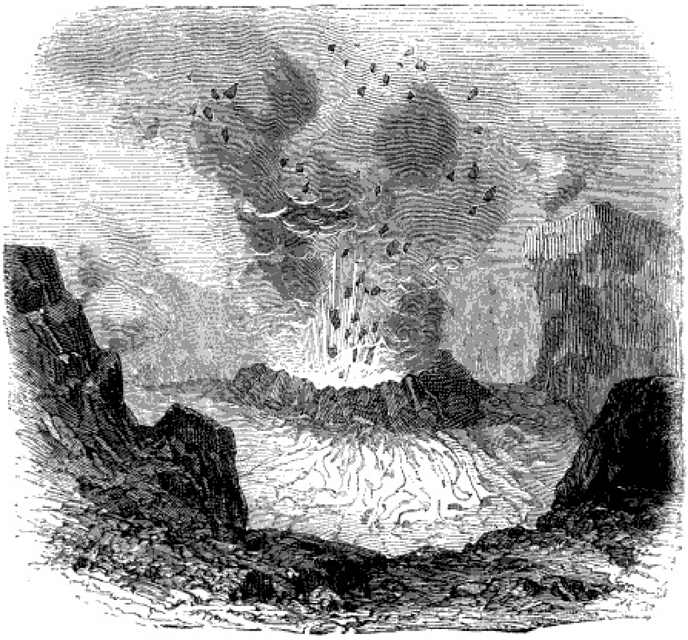


Fig. 10.—Existing crater of Vesuvius.

The mouths of volcanic chimneys are, almost always, situated near the summit of a more or less isolated conical mountain; they usually consist of an opening in the form of a funnel, which is called the *crater*, and which descends into the interior of the volcanic chimney. But in the course of ages the crater becomes extended and enlarged, until, in some of the older volcanoes, it has attained almost incredible dimensions. In 1822 the crater of Vesuvius was 2,000 feet deep, and of a very considerable circumference. The crater of Kilauea, in the Sandwich Islands group, is an immense chasm 1,000 feet deep, with an outer circle no less than from two to three miles in [57] diameter, in which lava is usually seen, Mr. Dana tells us, to boil up at the bottom of a lake, the level of which varies continually according to the active or quiescent state of the volcano. The cone which supports these craters, and which is designated the *cone of ejection*, is composed for the most part of lava or *scoriæ*, the products of eruption. Many volcanoes consist only of a *cone of scoriæ*. Such is that of Barren Isle, in the Bay of Bengal. Others, on the contrary, present a very small cone, notwithstanding the considerable height of the volcanic chain. As an example we may mention the new crater of Vesuvius, which was produced in 1829 within the former crater (Fig. 10).

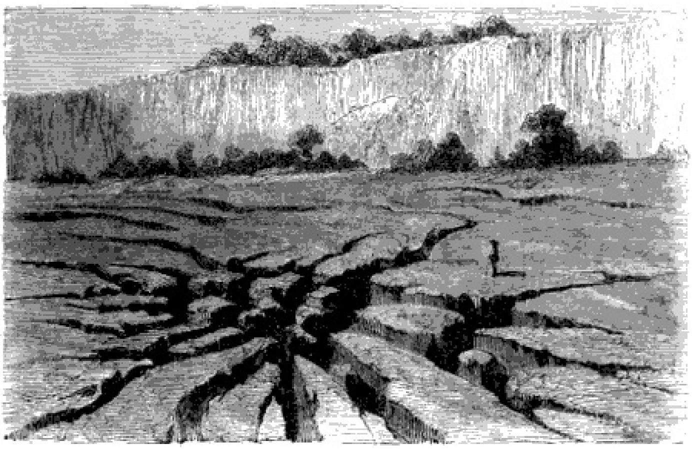


Fig. 11.—Fissures near Locarno.

The frequency and intensity of the eruptions bear no relation to the dimensions of the volcanic mountain. The eruption of a volcano is usually announced by a subterranean noise, accompanied by shocks, quivering of the ground, and sometimes by actual earthquakes. The noise, which usually proceeds from a great depth, makes itself heard, sometimes over a great extent of country, and resembles a well-sustained fire of artillery, accompanied by the rattle of musketry. [58] Sometimes it is like the heavy rolling of subterranean thunder. Fissures are frequently produced during the eruptions, extending over a considerable radius, as represented in the woodcut on page 57 of the fissures of Locarno (Fig. 11), where they present a singular appearance; the clefts radiating from a centre in all directions, not unlike the starred fracture in a cracked pane of glass. The eruption begins with a strong shock, which shakes the whole interior of the mountain; masses of heated vapour and fluids begin to ascend, revealing themselves in some cases by the melting of the snow upon the flanks of the cone of ejection; while simultaneously with the final shock, which overcomes the last resistance opposed by the solid crust of the ground, a considerable body of gas, and more especially of steam, escapes from the mouth of the crater.

The steam, it is important to remark, is essentially the cause of the terrible mechanical effects which accompany volcanic eruptions. Granitic, porphyritic, trachytic, and sometimes even basaltic matters, have reached the surface without producing any of those violent explosions or ejections of rocks and stones which accompany modern volcanic eruptions; the older granites, porphyries, trachytes, and basalts were discharged without violence, because steam did not accompany those melted rocks—a sufficient proof of the comparative calm which attended the ancient as compared with modern eruptions. Well established by scientific observations, this is a fact which enables us to explain the cause of the tremendous mechanical effects attending modern volcanic eruptions, contrasted with the more tranquil eruptions of earlier times.

During the first moments of a volcanic eruption, the accumulated masses of stones and ashes, which fill the crater, are shot up into the sky by the suddenly and powerfully developed elasticity of the steam. This steam, which has been disengaged by the heat of the fluid lava, assumes the form of great rounded bubbles, which are evolved into the air to a great height above the crater, where they expand as they rise, in clouds of dazzling whiteness, assuming that appearance which Pliny the Younger compared to a stone pine rising over Vesuvius. The masses of clouds finally condense and follow the direction of the wind.

These volcanic clouds are grey or black, according to the quantity of *ashes*, that is, of pulverulent matter or dust, mixed with watery vapour, which they convey. In some eruptions it has been observed that these clouds, on descending to the surface of the soil, spread around an odour of hydrochloric or sulphuric acid, and traces of both these acids are found in the rain which proceeds from the condensation of these clouds.

The fleecy clouds of vapour which issue from the volcanoes are streaked with lightning, followed [59]
by continuous peals of thunder; in condensing, they discharge disastrous showers, which sweep the sides of the mountain. Many eruptions, known as *mud volcanoes*, and *watery volcanoes*, are nothing more than these heavy rains, carrying down with them showers of ashes, stones, and scoriæ, more or less mixed with water.

Passing on to the phenomena of which the crater is the scene at the time of an eruption, it is stated that at first there is an incessant rise and fall of the lava which fills the interior of the crater. This double movement is often interrupted by violent explosions of gas. The crater of Kilauea, in the Island of Hawaii, contains a lake of molten matter 1,600 feet broad, which is subject to such a double movement of elevation and depression. Each of the vaporous bubbles as it issues from the crater presses the molten lava upwards, till it rises and bursts with great force at the surface. A portion of the lava, half-cooled and reduced to scoriæ, is thus projected upwards, and the several fragments are hurled violently in all directions, like those of a shell at the moment when it bursts.

The greater number of the fragments being thrown vertically into the air, fall back into the crater again. Many accumulating on the edge of the opening add more and more to the height of the cone of eruption. The lighter and smaller fragments, as well as the fine ashes, are drawn upwards by the spiral vapours, and sometimes transported by the winds over almost incredible distances.

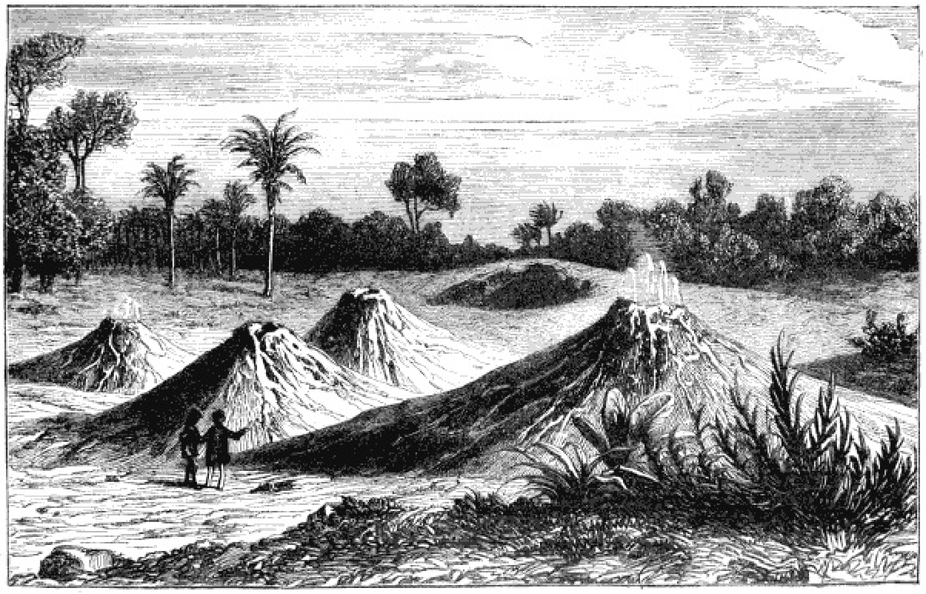
In 1794 the ashes from Vesuvius were carried as far as the extremity of Calabria. In 1812 the volcanic ashes of Saint Vincent, in the Antilles, were carried eastward as far as Barbadoes, spreading such obscurity over the island, that, in open day, passengers could not see their way. Finally, some of the masses of molten lava are shot singly into the air during an eruption with a rapid rotatory motion, which causes them to assume the rounded shape in which they are known by the name of *volcanic bombs*.

We have already remarked that the lava, which in a fluid state fills the crater and the internal vent or chimney of the volcano, is forced upwards by gaseous fluids, and by the steam which has been generated from the water, entangled with the lava. In some cases the mechanical force of this vapour is so great as to drive the lava over the edge of the crater, when it forms a fiery torrent, spreading over the sides of the mountain. This only happens in the case of volcanoes of inconsiderable height; in lofty volcanoes it is not unusual for the lava thus to force an outlet for
itself near the base of the mountain, through which the fiery stream discharges itself over the [60]
surrounding country. In such circumstances the lava cools somewhat rapidly; it becomes hard and presents a scoriaceous crust on the surface, while the vapour escapes in jets of steam through the interstices. But under this superficial crust the lava retains its fluid state, cooling slowly in the interior of the mass, while the thickening stream moves sluggishly along, impeded in its progress by the fragments of rock which this burning river drives before it.

The rate at which a current of lava moves along depends upon its mass, upon its degree of fluidity, and upon the inclination of the ground. It has been stated that certain streams of lava have traversed more than 3,000 yards in an hour; but the rate at which they travel is usually much less, a man on foot being often able to outstrip them. These streams, also, vary greatly in dimensions. The most considerable stream of lava from Etna had, in some parts, a thickness of nearly 120 feet, with a breadth of a geographical mile and a half. The largest lava-stream which has been recorded issued from the Skaptár Jokul, in Iceland, in 1783. It formed two currents, whose extremities were twenty leagues apart, and which from time to time presented a breadth of from seven to fifteen miles and a thickness of 650 feet.

A peculiar effect, and which only simulates volcanic activity, is observable in localities where *mud volcanoes* exist. Volcanoes of this class are for the most part conical hills of low elevation, with a hollow or depression at the centre, from which they discharge the mud which is forced upwards by gas and steam. The temperature of the ejected matter is only slightly elevated. The mud, generally of a greyish colour, with the odour of petroleum, is subject to the same alternating movements which have been already ascribed to the fluid lava of volcanoes, properly so called. The gases which force out this liquid mud, mixed with salts, gypsum, naphtha, sulphur, sometimes even of ammonia, are usually carburetted hydrogen and carbonic acid. Everything leads to the conclusion that these compounds proceed, at least in great part, from the reaction produced between the various elements of the subsoil under the influence of infiltrating water between bituminous marls, complex carbonates, and probably carbonic acid, derived from acidulated springs. M. Fournet saw in Languedoc, near Roujan, traces of some of these formations; and not far from that neighbourhood is the bituminous spring of Gabian.

[62]



IV.—Mud volcano at Turbaco, South America.

Mud volcanoes, or *salses*, exist in rather numerous localities. Several are found in the neighbourhood of Modena. There are some in Sicily, between Aragona and Girgenti. Pallas [63] observed them in the Crimea—in the peninsula of Kertch, and in the Isle of Tamàn. Von Humboldt has described and figured a group of them in the province of Cartagena, in South America. Finally, they have been observed in the Island of Trinidad and in Hindostan. In 1797 an eruption of mud ejected from Tunguragua, in Quito, filled a valley 1,000 feet wide to a depth of 600 feet. On the opposite page is represented the mud volcano of Turbaco, in the province of Cartagena (Plate IV.), which is described and figured by Von Humboldt in his “Voyage to the Equatorial Regions of America.”

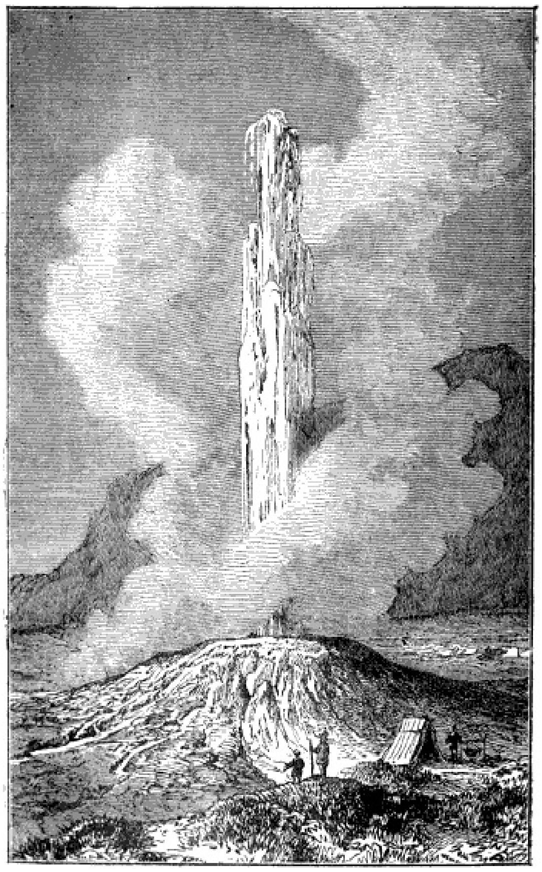
In certain countries we find small hillocks of argillaceous formation, resulting from ancient discharges of mud volcanoes, from which all disengagement of gas, water, and mud has long ceased. Sometimes, however, the phenomenon returns and resumes its interrupted course with great violence. Slight shocks of earthquakes are then felt; blocks of dried earth are projected from the ancient crater, and new waves of mud flow over its edge, and spread over the neighbouring ground.

To return to ordinary volcanoes, that is to say, those which eject lava. At the end of a lava-flow, when the violence of the volcanic action begins to subside, the discharge from the crater is confined to the disengagement of vaporous gases, mixed with steam, which make their escape in more or less abundance through a multitude of fissures in the ground.

The great number of volcanoes which have thus become extinct form what are called *solfataras*. The sulphuretted hydrogen, which is given out through the fissures in the ground, is decomposed by contact with the air, water being formed by the action of the oxygen of the atmosphere, and sulphur deposited in considerable quantities on the walls of the crater, and in the cracks of the ground. Such is the geological source of the sulphur which is collected at Pozzuoli, near Naples, and in many other similar regions—a substance which plays a most important part in the industrial occupations of the world. It is, in fact, from sulphur extracted from the ground about the mouths of extinct volcanoes, that is to say from the products of *solfataras*, that sulphuric acid is frequently made—sulphuric acid being the fundamental agent, one of the most powerful elements, of the manufacturing productions of both worlds.

The last phase of volcanic activity is the disengagement of carbonic acid gas without any increase of temperature. In places where these continued emanations of carbonic acid gas manifest themselves, the existence of ancient volcanoes may be recognised, of which these discharges are [64] the closing phenomenon. This is seen in a most remarkable manner in Auvergne, where there are a multitude of acidulated springs, that is to say, springs charged with carbonic acid. During the time when he was opening the mines of Pontgibaud, M. Fournet had to contend with emanations which sometimes exhibited themselves with explosive power. Jets of water were thrown to great heights in the galleries, roaring with the noise of steam when escaping from the boiler of a locomotive engine. The water which filled an abandoned mine-shaft was, on two separate occasions, upheaved with great violence—half emptying the pit—while vast volumes of the gas overspread the whole valley, suffocating a horse and a flock of geese. The miners were compelled to fly in all haste at the moment when the gas burst forth, holding themselves as upright as possible, to avoid plunging their heads into the carbonic acid gas, which, from its low specific gravity, was now filling the lower parts of the galleries. It represented on a small scale the effect of the *Grotto del Cane*, which excites such surprise among the ignorant near Naples; passing, also, for one of the marvels of Nature all over the world. M. Fournet states that all the minute fissures of the metalliferous gneiss near Clermont are quite saturated with free carbonic acid gas, which rises plentifully from the soil there, as well as in many parts of the surrounding country. The components of the gneiss, with the exception of the quartz, are softened by it; and fresh combinations of the acid with lime, iron, and manganese are continually taking place. In short, long after volcanoes have become extinct, hot springs, charged with mineral ingredients, continue to flow in the same area.

The same facts as those of the *Grotto del Cane* manifest themselves with even greater intensity in Java, in the so-called Valley of Poison, which is an object of terror to the natives. In this celebrated valley the ground is said to be covered with skeletons and carcases of tigers, goats, stags, birds, and even of human beings; for asphyxia or suffocation, it seems, strikes all living things which venture into this desolate place. In the same island a stream of sulphurous water, as white as milk, issues from the crater of Mount Idienne, on the east coast; and on one occasion, as cited by Nozet in the *Journal de Géologie*, a great body of hot water, charged with sulphuric acid, was discharged from the same volcano, inundating and destroying all the vegetation of a large tract of country by its noxious fumes and poisonous properties.



V.—Great Geyser of Iceland.

It is known that the alkaline waters of Plombières, in the Vosges, have a temperature of 160° Fahr. For 2,000 years, according to Daubrée, through beds of concrete, of lime, brick, and sandstone, these hot waters have percolated until they have originated calcareous spar, aragonite, and fluor spar, together with siliceous minerals, such as opal, which are found filling the interstices of the bricks and mortar. From these and other similar statements, “we are led,” says Sir Charles Lyell,[26] “to infer that when in the bowels of the earth there are large volumes of molten matter, containing heated water and various acids, under enormous pressure, these subterraneous fluid masses will gradually part with their heat by the escape of steam and various gases through fissures producing hot springs, or by the passage of the same through the pores of the overlying and injected rocks.” “Although,” he adds,[27] “we can only study the phenomena as exhibited at the surface, it is clear that the gaseous fluids must have made their way through the whole thickness of the porous or fissured rocks, which intervene between the subterraneous reservoirs of gas and the external air. The extent, therefore, of the earth’s crust which the vapours have permeated, and are now permeating, may be thousands of fathoms in thickness, and their heating and modifying influence may be spread throughout the whole of this solid mass.”

The fountains of boiling water, known under the name of *Geysers*, are another emanation connected with ancient craters. They are either continuous or intermittent. In Iceland we find great numbers of these gushing springs—in fact, the island is one entire mass of eruptive rock.

Nearly all the volcanoes are situated upon a broad band of trachyte, which traverses the island from south-west to north-east. It is traversed by immense fissures, and covered with masses of lava, such as no other country presents. The volcanic action, in short, goes on with such energy that certain paroxysms of Mount Hecla have lasted for six years without interruption. But the Great Geyser, represented on the opposite page (Plate V.), is, perhaps, even more an object of curiosity. This water-volcano projects a column of boiling water, eight yards in diameter, charged with silica, to the height, it has been said, of about 150 feet, depositing vast quantities of silica as it cools after reaching the earth.

The volcanoes in actual activity are, as we have said, very numerous, being more than 200 in number, scattered over the whole surface of the globe, but mostly occurring in tropical regions. The island of Java alone contains about fifty, which have been mapped and described by Dr. [68] Junghahn. Those best known are Vesuvius, near Naples; Etna, in Sicily; and Stromboli, in the Lipari Islands. A rapid sketch of a few of these may interest the reader.

Vesuvius is of all volcanoes that which has been most closely studied; it is, so to speak, the classical volcano. Few persons are ignorant of the fact that it opened—after a period of quiescence extending beyond the memory of living man—in the year 79 of our era. This eruption cost the elder Pliny his life, who fell a sacrifice to his desire to witness one of the most imposing of natural phenomena. After many mutations the present crater of Vesuvius consists of a cone, surrounded on the side opposite the sea by a semicircular crest, composed of pumiceous matter, foreign to Vesuvius properly speaking, for we believe that Mount Vesuvius was originally the mountain to which the name of *Somma* is now given. The cone which now bears the name of Vesuvius was probably formed during the celebrated eruption of 79, which buried under its showers of pumiceous ashes the cities of Pompeii and Herculaneum. This cone terminates in a crater, the shape of which has undergone many changes, and which has, since its origin, thrown out eruptions of a varied character, together with streams of lava. In our days the eruptions of Vesuvius have only been separated by intervals of a few years.

The Lipari Isles contain the volcano of Stromboli, which is continually in a state of ignition, and forms the natural lighthouse of the Tyrrhenian Sea; such it was when Homer mentioned it, such it was before old Homer's time, and such it still appears in our days. Its eruptions are incessant. The crater whence they issue is not situated on the summit of the cone, but upon one of its sides, at nearly two-thirds of its height. It is in part filled with fluid lava, which is continually subjected to alternate elevation and depression—a movement provoked by the ebullition and ascension of bubbles of steam which rise to the surface, projecting upwards a tall column of ashes. During the night these clouds of vapour shine with a magnificent red reflection, which lights up the whole isle and the surrounding sea with a lurid glow.

Situated on the eastern coast of Sicily, Etna appears, at the first glance, to have a much more simple structure than Vesuvius. Its slopes are less steep, more uniform on all sides; its vast base nearly represents the form of a buckler. The lower portion of Etna, or the cultivated region of the mountain, has an inclination of about three degrees. The middle, or forest region, is steeper, and has an inclination of about eight degrees. The mountain terminates in a cone of an elliptical form [69] of thirty-two degrees of inclination, which bears in the middle, above a nearly horizontal terrace, the cone of eruption with its circular crater. The crater is 10,874 feet high. It gives out no lava, but only vomits forth gas and vapour, the streams of lava issuing from sixteen smaller cones which have been formed on the slopes of the mountain. The observer may, by looking at the summit, convince himself that these cones are disposed in rays, and are based upon clefts or fissures which converge towards the crater as towards a centre.

But the most extraordinary display of volcanic phenomena occurs in the Pacific Ocean, in the Sandwich Islands, and in Java. Mauna Loa and Mauna Kea, in Hawaii, are huge flattened cones, 14,000 feet high. According to Mr. Dana, these lofty, featureless hills sometimes throw out successive streams of lava, not very far below their summits, often two miles in breadth and six-and-twenty in length; and that not from one vent, but in every direction, from the apex of the cone down slopes varying from four to eight degrees of inclination. The lateral crater of Kilauea, on the flank of Mauna Loa, is from 3,000 to 4,000 feet above the level of the sea—an immense chasm 1,000 feet deep, with an outer circuit two to three miles in diameter. At the bottom lava is seen to boil up in a molten lake, the level of which rises or falls according to the active or quiescent state of the volcano; but in place of overflowing, the column of melted rock, when the pressure becomes excessive, forces a passage through subterranean communications leading to the sea. One of these outbursts, which took place at an ancient wooded crater six miles east of Kilauea, was observed by Mr. Coan, a missionary, in June, 1840. Another indication of the subterranean progress of the lava took place a mile or two beyond this, in which the fiery flood spread itself over fifty acres of land, and then found its way underground for several miles further, to reappear at the bottom of a second ancient wooded crater which it partly filled up.[28]

The volcanic mountains of Java constitute the highest peaks of a mountain-range running through the island from east to west, on which Dr. Junghahn described and mapped forty-six conical eminences, ranging from 4,000 to 11,000 feet high. At the top of many of the loftiest of these Dr. Junghahn found the active cones and craters of small size, and surrounded by a plain of ashes and sand, which he calls the "old crater wall," sometimes exceeding 1,000 feet in vertical height, [70] and many of the semicircular walls enclosing large cavities or *calderas*, four geographical miles in diameter. From the highest parts of many of these hollows rivers flow, which, in the course of ages, have cut out deep valleys in the mountain's side.[29]

To this rapid sketch of actually existing volcanic phenomena we may add a brief notice of submarine volcanoes. If these are known to us only in small numbers, the circumstance is explained by the fact that their appearance above the bosom of the sea is almost invariably followed by a more or less complete disappearance; at the same time such very striking and visible phenomena afford a sufficient proof of the continued persistence of volcanic action beneath the bed of the sea-basin. At various times islands have suddenly appeared, amid the ocean, at points where the navigator had not before noticed them. In this manner we have witnessed the island called Graham's, Ferdinanda, or Julia, which suddenly appeared off the south-west coast Sicily in 1831, and was swept away by the waves two months afterwards.[30] At several periods also, and notably in 1811, new islands were formed in the Azores, which raised themselves above the waves by repeated efforts all round the islands, and at many other points.

The island which appeared in 1796 ten leagues from the northern point of Unalaska, one of the Aleutian group of islands, is specially remarkable. We first see a column of smoke issuing from the bosom of the ocean, afterwards a black point appears, from which bundles of fiery sparks seem to rise over the surface of the sea. During the many months that these phenomena continue, the island increases in breadth and in height. Finally smoke only is seen; at the end of four years, even this last trace of volcanic convulsion altogether ceases. The island continued, nevertheless, to enlarge and to increase in height, and in 1806 it formed a cone, surmounted by four other smaller ones.

In the space comprised between the isles of Santorin, Tharasia, and Aspronisi, in the Mediterranean, there arose, 160 years before our era, the island of *Hyera*, which was enlarged by the upheaval of islets on its margin during the years 19, 726, and 1427. Again, in 1773, Micra-Kameni, and in 1707, Nea-Kameni, made their appearance. These islands increased in size successively in 1709, in 1711, in 1712. According to ancient writers, Santorin, Tharasia, and Aspronisi, made their appearance many ages before the Christian era, at the termination of earthquakes of great violence.

Metamorphic Rocks. [71]

The rocks composing the terrestrial crust have not always remained in their original state. They have frequently undergone changes which have altogether modified their properties, physical and chemical.

When they present these characteristics, we term them *Metamorphic Rocks*. The phenomena which belong to this subject are at once important and new, and have lately much attracted the attention of geologists. We shall best enlighten our readers on the metamorphism of rocks, if we treat of it under the heads of *special* and *general* metamorphism.

When a mass of eruptive rock penetrates the terrestrial crust it subjects the rocks through which it passes to a special metamorphism—to the effects of *heat* produced by *contact*. Such effects may almost always be observed near the margin of masses of eruptive rock, and they are attributable either to the communicated heat of the eruptive rock itself, or to the disengagement of gases, of steam, or of mineral and thermal waters, which have accompanied its eruption. The effects vary not only with the rock ejected, but even with the nature of the rock surrounding it.

In the case of volcanic lava ejected in a molten state, for instance, the modifications it effects on the surrounding rock are very characteristic. Its structure becomes prismatic, full of cracks, often cellular and scoriaceous. Wood and other combustibles touched by the lava are consumed or partially carbonised. Limestone assumes a granular and crystalline texture. Siliceous rocks are transformed, not only into quartz like glass, but they also combine with various bases, and yield vitreous and cellular silicates. It is nearly the same with argillaceous rocks, which adhere together, and frequently take the colour of red bricks.

The surrounding rock is frequently impregnated with specular iron-ore, and penetrated with hydrochloric or sulphuric acid, and by divers salts formed from these acids.

At a certain distance from the place of contact with the lava, the action of water aided by heat produces silica, carbonate of lime, aragonite, zeolite, and various other minerals.

From immediate contact with the lava, then, the metamorphic rocks denote the action of a very strong heat. They bear evident traces of calcination, of softening, and even of fusion. When they
present themselves as hydrosilicates and carbonates, the silica and associated minerals are most [72]
frequently at some distance from the points of contact; and the formation of these minerals is probably due to the combination of water and heat, although this last ceases to be the principal agent.

The hydrated volcanic rocks, such as the basalts and trappean rocks in general, continue to produce effects of metamorphism, in which heat operates, although its influence is inconsiderable, water being much the more powerful agent. The metamorphosis which is observable in the structure and mineralogical composition of neighbouring rocks is as follows:—The structure of separation becomes fragmentary, columnar, or many-sided, and even prismatic. It becomes especially prismatic in combustibles, in sandstones, in argillaceous formations, in felspathic rocks, and even in limestones. Prisms are formed perpendicular to the surface of contact, their length sometimes exceeding six feet. Most commonly they still contain water or volatile matter. These characters may be observed at the junction of the basalts which has been ejected upon the argillaceous strata near Clermont in Auvergne, at Polignac, and in the neighbourhood of Le Puy-en-Velay.

If the vein of Basalt or Trap has traversed a bed of coal or of lignite, we find the combustible strongly *metamorphosed* at the point of contact. Sometimes it becomes cellular and is changed into *coke*. This is especially the case in the coal-basin of Brassac. But more frequently the coal has lost all, or part of, its bituminous and volatile matter—it has been metamorphosed into anthracite—as an example we may quote the lignite of Mont Meisner.

Again, in some exceptional cases, the combustible may even be changed into graphite near to its junction with Trap. This is observed at the coal-mine of New Cumnock in Ayrshire.

When near its junction with a *trappean* rock, a combustible has been metamorphosed into *coke* or anthracite, it is also frequently impregnated by hydrated oxide of iron, by clay, foliated carbonate of lime, iron pyrites, and by various mineral veins. It may happen that the combustible has been reduced to a pulverulent state, in which case it is unfit for use. Such is the case in a coal-mine at Newcastle, where the coal lies within thirty yards of a dyke of Trap.

When Basalt and Trap have been ejected through limestone rock, the latter becomes more or less altered. Near the points of contact, the metamorphism which they have undergone is revealed by the change of colour and aspect, which is exhibited all around the vein, often also by the development of a crystalline structure. Limestone becomes granular and saccharoid—it is changed into marble. The most remarkable instance of this metamorphism is the Carrara marble, [73] a non-fossiliferous limestone of the Oolite series, which has been altered and the fossils destroyed; so that the marble of these celebrated quarries, once supposed to have been formed before the creation of organic beings, is now shown to be an altered limestone of the Oolitic period, and the underlying crystalline schists are sandstones and shales of secondary age modified by plutonic action.

The action of basalt upon limestone is observable at Villeneuve de Berg, in Auvergne; but still more in the neighbourhood of Belfast, where we may see the Chalk changed into saccharoid limestone near to its contact with the Trap. Sometimes the metamorphism extends many feet from the point of contact; nay, more than that, some zeolites and other minerals seem to be developed in the crystallised limestone.

When sandstone is found in contact with trappean rock, it presents unequivocal traces of metamorphism; it loses its reddish colour and becomes white, grey, green, or black; parallel veins may be detected which give it a jaspideous structure; it separates into prisms perpendicular to the walls of the injected veins, when it assumes a brilliant and vitreous lustre. Sometimes it is even also found penetrated by zeolites, a family of minerals which melt before the blowpipe with considerable ebullition. The mottled sandstones of Germany, which are traversed by veins of basalt, often exhibit metamorphism, particularly at Wildenstern, in Würtemberg.

Argillaceous rocks, like all others, are subject to metamorphism when they come in contact with eruptive trappean rocks. In these circumstances they change colour and assume a varied or prismatic structure; at the same time their hardness increases, and they become lithoidal or stony in structure. They may also become cellular—form zeolites in their cavities with foliated carbonate of lime, as well as minerals which commonly occur in amygdaloid. Sometimes even the fissures are coated by the metallic minerals, and the other minerals which accompany them in their metalliferous beds. Generally they lose a part of their water and of their carbonic acid. In other circumstances they combine with oxide of iron and the alkalies. This has been asserted, for example, at Essey, in the department of the Meurthe, where a very argillaceous sandstone is found, charged with jasper porcellanite, near to the junction of the rock with a vein of basalt.

Hitherto we have spoken only of the metamorphosis the result of volcanic action. A few words will suffice to acquaint the reader with the metamorphism exercised by the porphyries and granites. By contact with granite, we find coal changed into anthracite or graphite. It is [74] important to note, however, that coal has seldom been metamorphosed into coke. As to the limestone, it is sometimes, as we have seen, transformed into marble; we even find in its interior divers minerals, notably silicates with a calcareous base, such as garnets, pyroxene, hornblende, &c. The sandstones and clay-slates have alike been altered.

The surrounding deposit and the eruptive rock are both frequently impregnated with quartz, carbonate of lime, sulphate of baryta, fluorides, and, in a word, with the whole tribe of metalliferous minerals, which present themselves, besides, with the characteristics which are common to them in the veins.

General Metamorphism.

Sedimentary rocks sometimes exhibit all the symptoms of metamorphism where there is no evidence of direct eruptive action, and that upon a scale much grander than in the case of special metamorphism. It is observable over whole regions, in which it has modified and altered simultaneously all the surrounding rocks. This state of things is called general, or normal, metamorphism. The fundamental gneiss, which covers such a vast extent of country, is the most striking instance known of general metamorphism. It was first described by Sir W. E. Logan, Director of the Canadian Geological Survey, who estimates its thickness at 30,000 feet. The Laurentian Gneiss is a term which is used by geologists to designate those metamorphic rocks which are known to be older than the Cambrian system. They are parts of the old pre-Cambrian continents which lie at the base of the great American continent, Scandinavia, the Hebrides, &c.; and which are largely developed on the west coast of Scotland. In order to give the reader some idea of this metamorphism, we shall endeavour to trace its effects in rocks of the same nature, indicating the characters successively presented by the rocks according to the intensity of the metamorphism to which they have been subjected.

Combustibles, which have a special composition, totally different from all other rocks, are obviously the first objects of examination. When we descend in the series of sedimentary deposits, the combustibles are observed completely to change their characters. From the *peat* which is the product of our own epoch, we pass to *lignite*, to *coal*, to *anthracite*, and even to *graphite*; and find that their density increases, varying up to at least double. Hydrogen, nitrogen, and, above all, oxygen, diminish rapidly. Volatile and bituminous matters decrease, while carbon [75] undergoes a proportionate increase.

This metamorphism of the combustible minerals, which takes place in deposits of different ages, may also be observed even in the same bed. For instance, in the coal formations of America, which extend to the west of the Alleghany mountains, the Coal-measures contain a certain proportion of volatile matter, which goes on diminishing in proportion as we approach the granite rocks; this proportion rises to fifty per cent. upon the Ohio, but it falls to forty upon the Manon-Gahela, and even to sixteen in the Alleghanies. Finally, in the regions where the strata have been most disturbed, in Pennsylvania and Massachusetts, the coal has been metamorphosed into anthracite and even into graphite or plumbago.

Limestone is one of the rocks upon which we can most easily follow the effects of general metamorphism. When it has not been modified, it is usually found in sedimentary rocks in the state of compact limestone, of coarse limestone, or of earthy limestone such as chalk. But let us consider it in the mountains, especially in mountains which are at the same time granitic, such as the Pyrenees, the Vosges, and the Alps. We shall then see its characters completely modified. In the long and deep valleys of the Alps, for example, we can follow the alterations of the limestone for many leagues, the beds losing more and more their regularity in proportion as we approach the central chain, until they lose themselves in solitary pinnacles and projections enclosed in crystalline schists or granitic rocks. Towards the upper regions of the Alps the limestone divides itself into pseudo-regular fragments, it is more strongly cemented, more compact, more sonorous; its colour becomes paler, and it passes from black to grey by the gradual disappearance of organic and bituminous matter with which it has been impregnated, at the same time its crystalline structure increases in a manner scarcely perceptible. It may even be observed to be metamorphosed into an aggregate of microscopic crystals, and finally to pass into a white saccharoid limestone.

This metamorphism is produced without any decomposition of the limestone; it has rather been softened and half melted by the heat, that is, rendered plastic, so to speak, for we find in it fossils still recognisable, and among these, notably, some Ammonites and Belemnites, the presence of which enables us to state that it is the greyish-black Jurassic limestone, which has been transformed into white saccharoid or granular limestone. If the limestone subjected to this transformation were perfectly pure, it would simply take a crystalline structure; but it is [76] generally mixed with sand and various argillaceous matters, which have been deposited along with it, matters which go to form new minerals. These new minerals, however, are not disseminated by chance; they develop themselves in the direction of the lamination, so to speak, of the limestone, and in its fissures, in such a manner that they present themselves in nodules, seams, and sometimes in veins.

Among the principal minerals of the saccharoid limestone we may mention graphite, quartz, some very varied silicates, such as andalusite, disthene, serpentine, talc, garnet, augite, hornblende, epidote, chlorite, the micas, the felspars; finally, spinel, corundum, phosphate of lime, oxide of iron and oligiste, iron pyrites, &c. Besides these, various minerals in veins figure among those which exist more commonly in the saccharoid limestone.

When metamorphic limestone is sufficiently pure, it is employed as statuary marble. Such is the geological origin of Carrara marble, which is quarried in the Apuan Alps on a great scale; such, also, was the marble of Paros and Antiparos, still so celebrated for its purity. On examination, however, with the lens the Carrara marble exhibits blackish veins and spangles of graphite; the finest blocks, also, frequently contain nodules of ironstone, which are lined with perfectly limpid crystals of quartz. These accidental defects are very annoying to the sculptor, for they are very minute, and nothing on the exterior of the block betrays their existence. In the marble of Paros, even when it is strongly translucent, specks of mica are often found. In the ancient quarries the nodules are so numerous as to have hindered their being worked, up even to the present time.

When the mica which occurs in granular limestone takes a green colour and forms veins, it constitutes the Cipoline marble, which is found in Corsica, and in the Val Godemar in the Alps. Some white marbles are quarried in France, chiefly at Loubie, at Sost, at Saint-Béat in the Pyrenees, and at Chippal in the Vosges. In our country, and especially in Ireland, there are numerous quarries of marble, veined and coloured of every hue, but none of a purity suitable for the finest statuary purposes. All these marbles are only metamorphosed limestones.

The white marbles employed almost all over the world are those of Carrara. They result from the metamorphism of limestone of the Lias. They have not been penetrated by the eruptive rocks, but they have been subjected upon a great scale to a general metamorphism, to which their crystalline structure may be attributed.

It is easily understood that the calcareous strata have not undergone such an energetic [77] metamorphism without the beds of sandstone and clay, associated with them, having also undergone some modification of the same kind. The siliceous beds accompanying the saccharoid limestone have, in short, a character of their own. They are formed of small grains of transparent quartz more or less cemented one to the other in a manner strongly resembling those of the saccharoid limestone. Between these grains are usually developed some lamellæ of mica of brilliant and silky lustre, of which the colour is white, red, or green; in a word, it has produced a *quartzite*. Some veins of quartz frequently traverse this quartzite in all directions. Independent of the mica, it may contain, besides, the different minerals already mentioned as occurring in the limestone, and particularly silicates—such as disthene, andalusite, staurotide, garnet, and hornblende.

The argillaceous beds present a series of metamorphisms analogous to the preceding. We can follow them readily through all their gradations when we direct our attention towards such granitic masses as those which constitute the Alps, Pyrenees, the Bretagne Mountains, or our own Grampians. The schists may perhaps be considered the first step towards the metamorphism of certain argillaceous rocks; in fact, the schists are not susceptible of mixing with water like clay; they become stony, and acquire a much greater density, but their chief characteristic is a foliated structure.

Experiment proves that when we subject a substance to a great pressure a foliated structure is produced in a direction perpendicular to that in which the pressure is exercised. Everything leads us, therefore, to believe that pressure is the principal cause of the schistous texture, and of the foliation of clay-slates, the most characteristic variety of which is the roofing-slate which is quarried so extensively in North Wales, in Cumberland, and various parts of Scotland in the British Islands; in the Ardennes; and in the neighbourhood of Angers, in France.

In some localities the slate becomes siliceous and is charged with crystals of felspar. Nevertheless, it still presents itself in parallel beds, and contains the same fossil remains still in a recognisable state. For example, in the neighbourhood of Thann, in the Vosges, certain vegetable imprints are perfectly preserved in the metamorphic schist, and in their midst are developed some crystals of felspar.

Mica-schist, which is formed of layers of quartz and mica, is found habitually associated with rocks which have taken a crystalline structure, proceeding evidently from an energetic metamorphism of beds originally argillaceous. Chiastolite, disthene, staurotide, hornblende, and [78] other minerals are found in it. Mica-schists occur extensively in Brittany, in the Vosges, in the Pyrenees. In all cases, as we approach the masses of granite, in these regions, the crystalline structure becomes more and more marked.

In describing the various facts relating to the metamorphism of rocks, we have said little of the causes which have produced it. The causes are, indeed, in the region of hypothesis, and somewhat mysterious.

In what concerns special metamorphism, the cause is supposed to admit of easy explanation—it is heat. When a rock is ejected from the interior of the earth in a state of igneous fusion, we comprehend readily enough that the strata, which it traverses, should sustain alterations due to the influence of heat, and varying with its intensity. This is clear enough in the case of *lava*. On the other hand, as water always exists in the interior of the earth’s crust, and as this water must be at a very high temperature in the neighbourhood of volcanic fires, it contributes, no doubt, largely to the metamorphism. If the rocks have not been ejected in a state of fusion, it is evidently water, with the different mineral substances it holds in solution, which is the chief actor in the special metamorphism which is produced.

In general metamorphism, water appears still to be the principal agent. As it is infiltered through the various beds it will modify their composition, either by dissolving certain substances, or by introducing into the metalliferous deposits certain new substances, such as may be seen forming, even under our eyes, in mineral springs. This has tended to render the sedimentary deposits plastic, and has permitted the development of that crystalline structure, which is one of the principal characteristics of metamorphic rocks. This action has been seconded by other causes, notably by heat and pressure, which would have an immense increase of power and energy when metamorphism takes place at a great depth beneath the surface. Dr. Holl, in an able paper descriptive of the geology of the Malvern Hills, read before the Geological Society in February, 1865, adopts this hypothesis as explanatory of the vast phenomena which are there displayed. After describing the position of this interesting and strangely-mingled range of rocks, he adds: “These metamorphic rocks are for the most part highly inclined, and often in a position nearly vertical. Their disturbance and metamorphism, their being traversed by granitic veins, and still later their invasion by trap-dykes and their subsequent elevation above the sea-level, were all events which must have occupied no inconsiderable period, even of geological time. I presume,” he adds, “that it will not be maintained in the present day that the metamorphism of rocks over [79] areas of any but very moderate extent is due to the intrusion of veins and erupted masses. The insufficiency of such agency becomes the more obvious when we consider the slight effects produced by even tolerably extensive outbursts, such as the Dartmoor granite; while in the case of the Malverns there is an absence of any local cause whatever. The more probable explanation in the case of these larger areas is, that they were faulted down, or otherwise depressed, so as to be brought within the influence of the earth's internal heat, and this is the more likely as they belong to an epoch when the crust is believed to have been thinner." When it is considered that, according to the doctrine of modern geology, the Laurentian rocks, or their equivalents, lie at the base of all the sedimentary deposits; that this, like other systems of stratified rocks, was deposited in the form of sand, mud, and clay, to the thickness of 30,000 feet; and that over an area embracing Scandinavia, the Hebrides, great part of Scotland, and England as far south as the Malverns, besides a large proportion of the American continent, with certain forms of animal life, as recent investigations demonstrate—can the mind of man realise any other cause by which this vast extent of metamorphism could have been produced?

Electric and galvanic currents, circulating in the stratified crust, are not to be overlooked. The experiments of Mr. R. W. Fox and Mr. Robert Hunt suggest that, in passing long-continued galvanic currents through masses of moistened clay, there is a tendency to produce cleavage and a semi-crystalline arrangement of the particles of matter.[31]

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[11] Lyell's "Elements of Geology," p. 694.

[12] "Physical Geology and Geography of Great Britain," by A. C. Ramsay, p. 38, 2nd ed.

[13] At the same time it may be safely assumed (as Professor Ramsay believes to be the case) that granite in most cases is a metamorphic rock; yet are there many instances in which it may with greater truth be considered as a true plutonic rock.

[14] "Elements of Geology," p. 716, 6th edition.

[15] "Elements of Geology," p. 717.

[16] Ibid, p. 718.

[17] "Geology of the Island of Arran," by Andrew C. Ramsay. "Geology of Arran and Clydesdale," by James Bryce.

[18] See *Quarterly Journal of Geological Society*, vol. viii., pp. 9 and 10.

[19] For full information in reference to the rocks and geology of this part of France, the reader is referred to the masterly work on "The Geology and Extinct Volcanoes of Central France," by G. Poulett Scrope, 2nd edition, 1858.

[20] "Volcanoes," 2nd ed.

[21] "Elements of Geology," p. 596.

[22] Ibid, p. 677.

[23] "Cosmos," vol. i., p. 25. Bohn.

[24] "Cosmos," vol. i., p. 237.

[25] Darwin's "Journal," p. 291, 2nd edition.

[26] "Elements of Geology," p. 732.

[27] Ibid, p. 733.

[28] Lyell's "Elements of Geology," p. 617.

[29] Lyell's "Elements of Geology," p. 620.

[30] Ibid, p. 620.

[31] Report of the Royal Cornwall Polytechnic Society for 1837. Robert Hunt, in "Memoirs of the Geological Survey of Great Britain," vol. i., p. 433.

THE BEGINNING. [80]

The theory which has been developed, and which considers the earth as an extinct sun, as a star cooled down from its original heated condition, as a nebula, or luminous cloud, which has passed from the gaseous to the solid state—this fine conception, which unites so brilliantly the kindred sciences of astronomy and geology, belongs to the French mathematician, Laplace, the immortal author of the "Mécanique Céleste."

The hypothesis of Laplace assigns to the sun, and to all bodies which gravitate in what Descartes calls his *tourbillon*, a common origin. "In the primitive state in which we must suppose the sun to be," he says, "it resembles one of those nebulæ which the telescope reveals to us, consisting of a more or less brilliant central *nucleus*, surrounded by luminous clouds, which clouds, condensing at the surface, become transformed into a star."

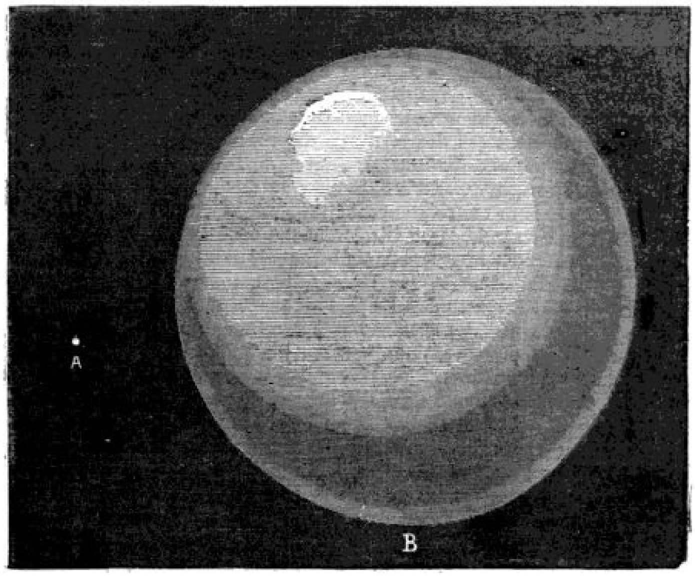


Fig. 12.—Comparative volume of the earth in the gaseous and solid state.

It has been calculated that the centre of the earth has a temperature of about 195,000° Cent., a degree of heat which surpasses all that the imagination can conceive. We can have no difficulty in admitting that, at a heat so excessive, all the substances which now enter into the composition of the globe would be reduced to the state of gas or vapour. Our planet, then, must have been originally an aggregation of aëriform fluids—a mass of matter entirely gaseous; and if we reflect that substances in their gaseous state occupy a volume eighteen hundred times larger than when solid, we shall have some conception of the enormous volume of this gaseous mass. It would be as large as the sun, which is fourteen hundred thousand times larger than the terrestrial sphere. In Fig. 12 we have attempted to give an idea of the vast difference of volume between the earth in its present solid state and in its primitive gaseous condition. One of the globes, A, represents the former, B the latter. It is simply a comparison of size, which is made the more strikingly apparent by means of these geometrical figures—one the twentieth part of an inch in diameter, [83] the other two inches and three quarters.

VI.—The Earth circulating in space in the state of a gaseous star.

At this excessive temperature the gaseous mass, which we have described, would shine in space as the sun does at the present day; and with the same brilliancy as that with which, to our eyes, the fixed stars and planets shine in the serenity of night, as represented on the opposite page (Plate VI.). Circulating round the sun in obedience to the laws of universal gravitation, this incandescent gaseous mass was necessarily regulated by the laws which govern other material substances. As it got cooler it gradually transferred part of its warmth to the glacial regions of the inter-planetary spaces, in the midst of which it traced the line of its flaming orbit. Consequent on its continual cooling (but at the end of a period of time of which it would be impossible, even [84] approximately, to fix the duration), the star, originally gaseous, would attain a liquid state. It would then be considerably diminished in volume.

The laws of mechanics teach us that liquid bodies, when in a state of rotation, assume a spherical form; it is one of the laws of their being, emanating from the Creator, and is due to the force of attraction. Thus the Earth takes the spheroidal form, belonging to it, in common with the greater number of the celestial bodies.

The Earth is subject to two distinct movements; namely, a movement of translation round the sun, and a movement of rotation on its own axis—the latter a uniform movement, which produces the regular alternations of days and nights. Mechanics have also established the fact, which is confirmed by experiment, that a fluid mass in motion produces (as the result of the variation of the centrifugal force on its different diameters), a swelling towards the equatorial diameter of the sphere, and a flattening at the poles or extremities of its axis. It is in consequence of this law, that the Earth, when it was in a liquid state, became swollen at the equator, and depressed at its two poles; and that it has passed from its primitive spherical form to the spheroidal—that is, has become flattened at each of its polar extremities, and has assumed its present shape of an oblate spheroid.

This bulging at the equator and flattening towards the poles afford the most direct proofs, that can be adduced, of the original liquid state of our planet. A solid and non-elastic sphere—a stone ball, for example—might turn for ages upon its axis, and its form would sustain no change; but a fluid ball, or one of a pasty consistence, would swell out towards the middle, and, in the same proportion, become flattened at the extremities of its axis. It was upon this principle, namely, by admitting the primitive fluidity of the globe, that Newton announced *à priori* the bulging of the globe at the equator and its flattening at the poles; and he even calculated the amount of this depression. The actual measurement, both of this expansion and flattening, by Maupertuis, Clairaut, Camus, and Lemonnier, in 1736, proved how exact the calculations of the great geometrican were. Those gentlemen, together with the Abbé Outhier, were sent into Lapland by the Academy of Sciences; the Swedish astronomer, Celsius, accompanied them, and furnished them with the best instruments for measuring and surveying. At the same time the Academy sent Bouguer and Condamine to the equatorial regions of South America. The measurements taken in both these regions established the existence of the equatorial expansion and the polar depression, as Newton had estimated it to be in his calculations.

It does not follow, as a consequence of the partial cooling down of the terrestrial mass, that all [85] the gaseous substances composing it should pass into a liquid state; some of these might remain in the state of gas or vapour, and form round the terrestrial spheroid an outer envelope or *atmosphere* (from the Greek words ατμος, *vapour*, and σφαιρα, *sphere*). But we should form a very inexact idea of the atmosphere which surrounded the globe, at this remote period, if we compared it with that which surrounds it now. The extent of the gaseous matter which enveloped the primitive earth must have been immense; it doubtless extended to the moon. It included, in short, in the state of vapour, the enormous body of water which, as such, now constitutes our existing seas, added to all the other substances which preserve their gaseous state at the temperature then exhibited by the incandescent earth; and it is certainly no exaggeration to place this temperature at 2,000° Centigrade. The atmosphere would participate in this temperature; and acted on by such excessive heat, the pressure that it would exert on the Earth would be infinitely greater than that which it exercises at the present time. To the gases which form the component parts of the present atmospheric air—namely, nitrogen, oxygen, and carbonic acid—to enormous masses of watery vapour, must be added vast quantities of mineral substances, metallic or earthy, reduced to a gaseous state, and maintained in that state by the temperature of this gigantic furnace. The metals, the chlorides—metallic, alkaline, and earthy—sulphur, the sulphides, and even the silicates of alumina and lime; all, at this temperature, would exist in a vaporous form in the atmosphere surrounding the primitive globe.

It is to be inferred that, under these circumstances, the different substances composing this atmosphere would be ranged round the globe in the order of their respective densities; the first layer—that nearest to the surface of the globe—being formed of the heavier vapours, such as those of the metals, of iron, platinum, and copper, mixed doubtless with clouds of fine metallic dust produced by the partial condensation of their vapours. This first and heaviest zone, and the thickest also, would be quite opaque, although the surface of the earth was still at a red heat. Above it would come the more vaporisable substances, such as the metallic and alkaline chlorides, particularly the chloride of sodium or common salt, sulphur and phosphorus, with all the volatile combinations of these substances. The upper zone would contain matter still more easily converted into vapour, such as water (steam), together with others naturally gaseous, as oxygen, nitrogen, and carbonic acid. This order of superposition, however, would not always be [86] preserved. In spite of their differences of density, these three atmospheric layers would often become mixed, producing formidable storms and violent ebullitions; frequently throwing down, rending, upheaving, and confounding these incandescent zones.

As to the globe itself, without being so much agitated as its hot and shifting atmosphere, it would be no less subject to perpetual tempests, occasioned by the thousand chemical actions which took place in its molten mass. On the other hand, the electricity resulting from these powerful chemical actions, operating on such a vast scale, would induce frightful electric detonations, thunder adding to the horror of this primitive scene, which no imagination, no human pencil could trace, and which constitutes that gloomy and disastrous chaos of which the legendary history of every ancient race has transmitted the tradition. In this manner would our globe circulate in space, carrying in its train the flaming streaks of its multiple atmosphere, unfitted, as yet, for living beings, and impenetrable to the rays of the sun, around which it described its vast orbit.

The temperature of the planetary regions is infinitely low; according to Laplace it cannot be estimated at less than 100° below zero. The glacial regions traversed in its course by the incandescent globe would necessarily cool it, at first superficially, when it would assume a pasty consistence. It must not be forgotten that the earth, on account of its liquid state, would be obedient in all its mass to the action of flux and reflux, which proceeds from the attraction of the sun and moon, but to which the sea alone is now subject. This action, to which all its liquid and movable particles were subject, would singularly accelerate the commencement of the solidification of the terrestrial mass. It would thus gradually assume that sort of consistence which iron attains, when it is first withdrawn from the furnace, in the process of puddling.

As the earth cooled, beds of concrete substances would necessarily be formed, which, floating at first in isolated masses on the surface of the semi-fluid matter, would in course of time come together, consolidate, and form continuous banks; just as we see with the ice of the present Polar Seas, which, when brought in contact by the agitation of the waves, coalesces and forms icebergs, more or less movable. By extending this phenomenon to the whole surface of the globe, the solidification of its entire surface would be produced. A solid, but still thin and fragile crust, would thus envelop the whole earth, enclosing entirely its still fluid interior. The entire [87]
consolidation would necessarily be a much slower process—one which, according to the received hypothesis, is very far from being completed at the present time; for it is estimated that the actual thickness of the earth's crust does not exceed thirty miles, while the mean radius or distance from the centre of the terrestrial sphere, approaches 4,000 miles, the mean diameter being 7,912·409 miles; so that the portion of our planet, supposed to be solidified, represents only a very small fraction of its total mass.

We say thirty miles, for such is the ordinary estimated thickness of the earth's crust, usually admitted by savants; and the following is the process by which this result has been obtained.

We know that the temperature of the earth increases one degree Centigrade for every hundred feet of descent. This result has been borne out by a great number of measurements, made in [88]
many of the mines of France, in the tin mines of Cornwall, in the mines of the Erzgeberge, of the Ural, of Scotland, and, above all, in the soundings effected in the Artesian wells of Grenelle and Passy, near Paris, of St. André de Iregny, and at a great number of other points.

The greatest depth to which miners have hitherto penetrated is about 973 yards, which has been reached in a boring executed in Monderf, in the Grand Duchy of Luxembourg. At Neusalzwerk, near Minden, in Prussia, another boring has been carried to the depth of 760 yards. In the coal-mines of Monkwearmouth the pits have been sunk 525 yards, and at Dukinfield 717 yards. The mean of the thermometic observations made, at all these points, leads to the conclusion that the temperature increases about one degree Fahrenheit for every sixty feet (English) of descent after the first hundred.

In admitting that this law of temperature exists for all depths of the earth's crust, we arrive at the conclusion that, at a depth of from twenty-five to thirty-five miles—which is only about five times the height of the highest mountains—the most refractory matter would be in a state of fusion. According to M. Mitscherlich, the flame of hydrogen, burning in free air, acquires a temperature of 1,560° Centigrade. In this flame platinum would be in a state of fusion. Granite melts at a lower temperature than soft iron, that is at about 1,300°; while silver melts at 1,023°. In imagining an increase of temperature equal to one degree for every hundred feet of descent, the temperature at twenty-five miles will be 1,420° C. or 2,925° F.; thirty miles below the surface there will be a probable temperature of 1,584° C. or 3,630° F.; it follows, if these arguments be admitted, and the calculation correct, that the thickness of the solid crust of the globe does not much exceed thirty miles.

This result, which gives to the terrestrial crust a thickness equal to $1/190$ of the earth's diameter, has nothing, it is true, of absolute certainty.

Prof. W. Hopkins, F.R.S., an eminent mathematician, has much insisted upon the fact, that the conductibility of granite rocks, for heat, is much greater than that of sedimentary rocks; and he argues that in the lower stratum of the earth the temperature increases much more slowly than it does nearer the surface. This consideration has led Mr. Hopkins to estimate the probable thickness of the earth's solid crust at a minimum of 200 miles.

In support of this estimate Mr. Hopkins puts forward another argument, based upon the precession of the equinoxes. We know that the terrestrial axis, instead of always preserving the same direction in space, revolves in a cone round the pole of the ecliptic. Our globe, it is [89]
calculated, will accomplish its revolution in about 25,000 years. In about this period it will return to its original position. This balancing, which has been compared to that of a top when about to cease spinning, produces the movement known as the *precession of the equinoxes*. It is due to the attraction which the sun and moon exercise upon the swelling equatorial of the globe. This attraction would act very differently upon a globe entirely solid, and upon one with a liquid interior, covered by a comparatively thin crust. Mr. Hopkins subjected this curious problem to mathematical analysis, and he calculated that the precession of the equinoxes, observed by astronomers, could only be explained by admitting that the solid shell of the earth could not be less than from about 800 to 1,000 miles in thickness.

In his researches on the *rigidity of the earth*, Sir William Thomson finds that the phenomena of precession and nutation require that the earth, if not solid to the core, must be nearly so; and that no continuous liquid vesicle at all approaching 6,000 miles in diameter can possibly exist in the earth's interior, without rendering the phenomena in question very sensibly different from what they are.

The calculations of Mr. Hennessey are in direct opposition to those of Sir William Thomson, and show that the earth’s crust cannot be less than eighteen miles, or more than 600 miles in thickness.

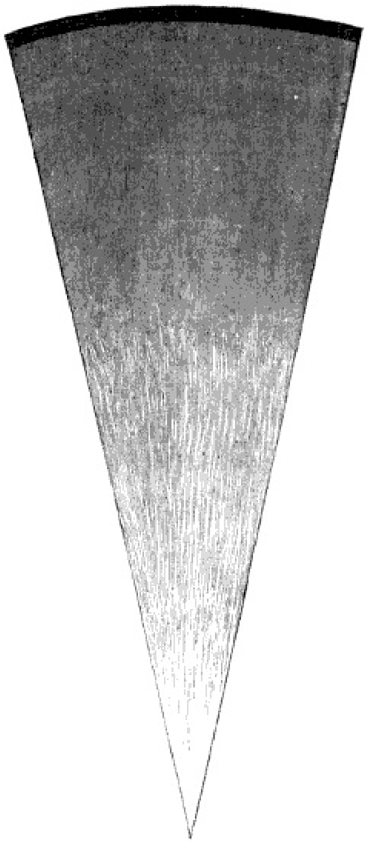


Fig. 13.—Relative volumes of the solid crust and liquid mass of the globe.

Admitting, for the present, that the terrestrial crust is only thirty miles in thickness, we can express in a familiar, but very intelligible fashion, the actual relation between the dimensions of the liquid nucleus and the solid crust of the earth. If we imagine the earth to be an orange, a tolerably thick sheet of paper applied to its surface will then represent, approximately, the thickness of the solid crust which now envelopes the globe. Fig. 13 will enable us to appreciate this fact still more correctly. The terrestrial sphere having a mean diameter of 7,912 miles, or a mean radius of 3,956 miles, and a solid crust about thirty miles thick, which is $\frac{1}{260}$ of the diameter, or $\frac{1}{130}$ of the radius, the engraving may be presumed to represent these proportions with sufficient accuracy.

To determine, even approximately, the time such a vast body would take in cooling, so as to permit of the formation of a solid crust, or to fix the duration of the transformations which we are describing, would be an impossible task.

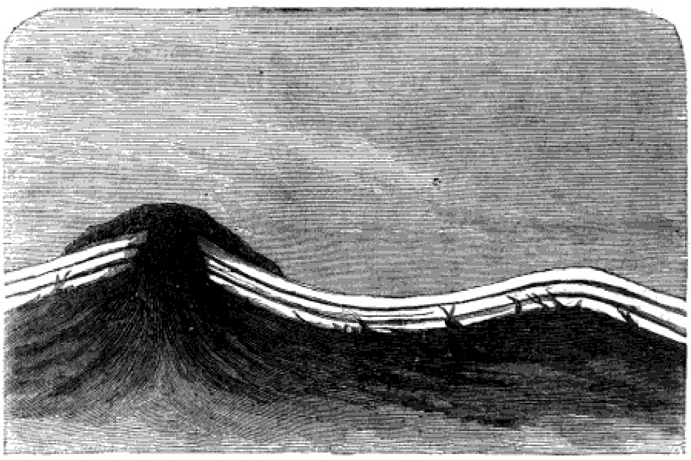


Fig. 14.—Formation of primitive granitic mountains.

The first terrestrial crust formed, as indicated, would be incapable of resisting the waves of the ocean of internal fire, which would be depressed and raised up at its daily flux and reflux in obedience to the attraction of the sun and moon. Who can trace, even in imagination, the fearful rendings, the gigantic inundations, which would result from these movements! Who would dare

to paint the sublime horrors of these first mysterious convulsions of the globe! Amid torrents of molten matter, mixed with gases, upheaving and piercing the scarcely consolidated crust, large crevices would be opened, and through these gaping cracks waves of liquid granite would be ejected, and then left to cool and consolidate on the surface. Fig. 14 represents the formation of a primitive granitic mountain, by the eruption of the internal granitic matter which forces its way to the surface through a fracture in the crust. In some of these mountains, Ben Nevis for example, three different stages of the eruption can be traced. “Ben Nevis, now the undoubted monarch of the Scottish mountains,” says Nicol, “shows well the diverse age and relations of igneous rocks. The Great Moor from Inverlochy and Fort William to the foot of the hill is gneiss. Breaking through, and partly resting on the gneiss is granite, forming the lower two-thirds of the mountain up to the small tarn on the shoulder of the hill. Higher still is the huge prism of [91]
porphyry, rising steep and rugged all around.” In this manner would the first mountains be formed. In this way, also, might some metallic veins be ejected through the smaller openings, true injections of eruptive matter produced from the interior of the globe, traversing the primitive rocks and constituting the precious depository of metals, such as copper, zinc, antimony, and lead. Fig. 15 represents the internal structure of some of these metallic veins. In this case the fracture is only a fissure in the rock, which soon became filled with injected matter, often of different kinds, which in crystallising would completely fill the hollow of this cleft, or crack; but sometimes forming cavities or geodes as a result of the contraction of the mass.

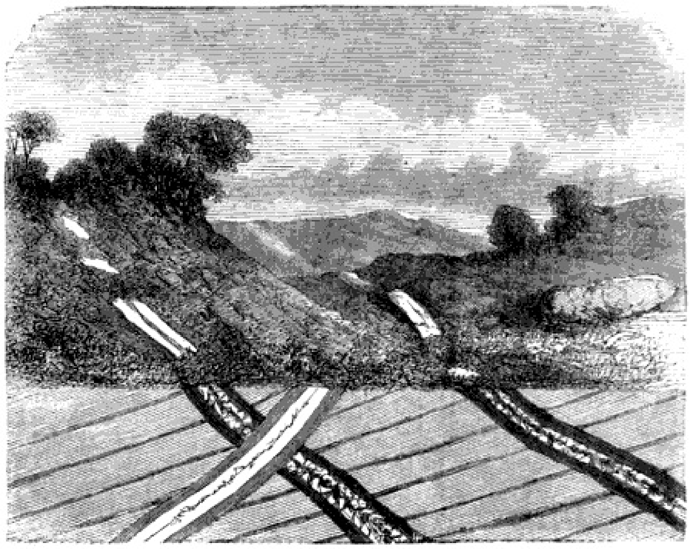


Fig. 15.—Metallic veins.

But some eruptions of granitic and other substances, ejected from the interior, never reach the [92]
surface at all. In such cases the clefts and crevices—longitudinal or oblique—are filled, but the fissures in the crust do not themselves extend to the surface. Fig. 16 represents an eruption of granite through a mass of sedimentary rock—the granite ejected from the centre fills all the clefts and fractures, but it has not been sufficiently powerful to force its way to the surface.

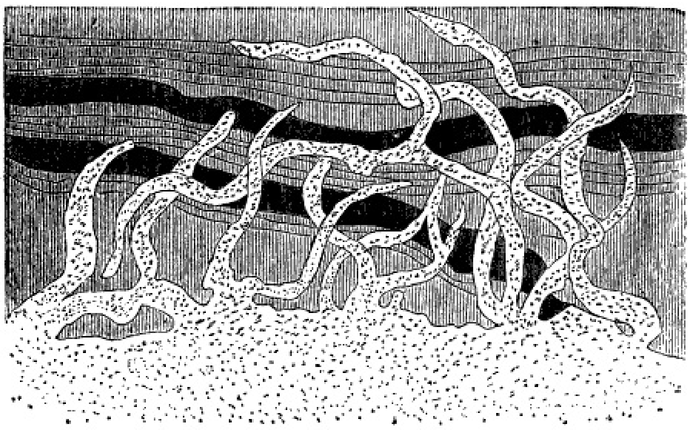
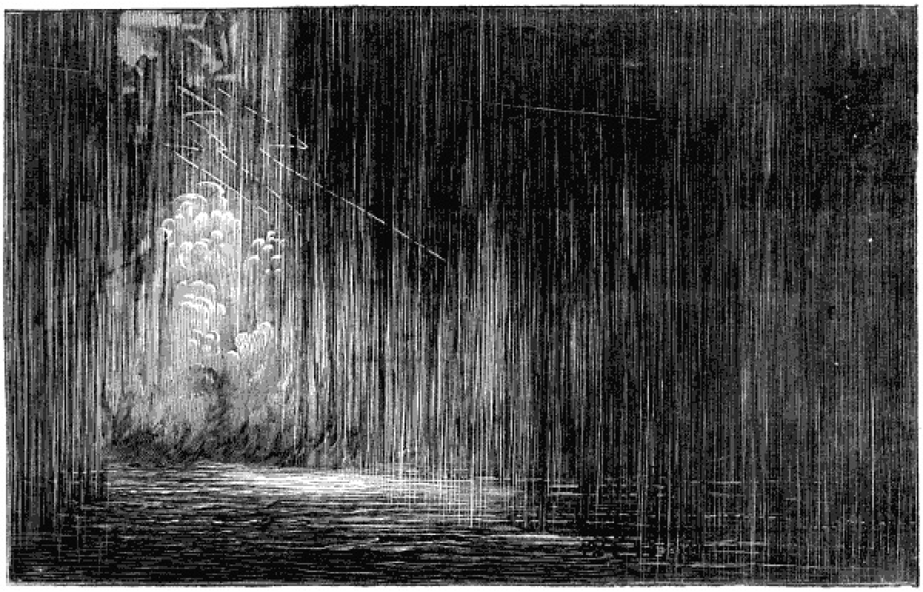


Fig. 16.—Eruption of granite.

On the surface of the earth, then, which would be at first smooth and unbroken, there were formed, from the very beginning, swelling eminences, hollows, foldings, corrugations, and crevices, which would materially alter its original aspect; its arid and burning surface bristled with rugged protuberances, or was traversed by enormous fissures and cracks. Nevertheless, as the globe continued to cool, a time arrived when its temperature became insufficient to maintain, in a state of vapour, the vast masses of water which floated in the atmosphere. These vapours would pass into the liquid state, and then the first rain fell upon the earth. Let us here remark that these were veritable rains of boiling water; for in consequence of the very considerable pressure of the atmosphere, water would be condensed and become liquid at a temperature much above 100° Centigrade (212° Fahr.)

[94]



VII.—Condensation and rainfall on the primitive globe.

The first drop of water, which fell upon the still heated terrestrial sphere, marked a new period in its evolution—a period the mechanical and chemical effects of which it is important to analyse. The contact of the condensed water with the consolidated surface of the globe opens up a series of modifications of which science may undertake the examination with a degree of confidence, or at least with more positive elements of appreciation than any we possess for the period of chaos; some of the features of which we have attempted to represent, leaving of necessity much to the imagination, and for the reader to interpret after his own fashion. [95]

The first water which fell, in the liquid state, upon the slightly cooled surface of the earth would be rapidly converted into steam by the elevation of its temperature. Thus, rendered much lighter than the surrounding atmosphere, these vapours would rise to the utmost limits of the atmosphere, where they would become condensed afresh, in consequence of their radiation towards the glacial regions of space; condensing again, they would re-descend to the earth in a liquid state, to re-ascend as vapour and fall in a state of condensation. But all these changes, in the physical condition of the water, could only be maintained by withdrawing a very considerable amount of heat from the surface of the globe, whose cooling would be greatly hastened by these continual alternations of heat and cold; its heat would thus become gradually dissipated and lost in the regions of celestial space.

This phenomenon extending itself by degrees to the whole mass of watery vapour existing in the atmosphere, the waters covered the earth in increasing quantities; and as the conversion of all liquids into vapour is provocative of a notable disengagement of electricity, a vast quantity of electric fluid necessarily resulted from the conversion of such large masses of water into vapour. Bursts of thunder, and bright flashes of lightning were the necessary accompaniments of this extraordinary struggle of the elements—a state of things which M. Maurando has attempted to represent on the opposite page (Plate VII.).

How long did this struggle for supremacy between fire and water, with the incessant noise of thunder, continue? All that can be said in reply is, that a time came when water was triumphant. After having covered vast areas on the surface of the earth, it finally occupied and entirely covered the whole surface; for there is good reason to believe that at a certain epoch, at the commencement, so to speak, of its evolution; the earth was covered by water over its whole extent. The ocean was universal. From this moment our globe entered on a regular series of [96] revolutions, interrupted only by the outbreaks of the internal fires which were concealed beneath its still imperfectly consolidated crust.

“At the early periods in which the materials of the ancient crystalline schists were accumulated, it cannot be doubted that the chemical processes which generated silicates were much more active than in more recent times. The heat of the earth’s crust was probably then far greater than at present, while a high temperature prevailed at comparatively small depths, and thermal waters abounded. A denser atmosphere, charged with carbonic acid gas, must also have contributed to maintain, at the earth’s surface, a greater degree of heat, though one not incompatible with the existence of organic life.

“These conditions must have favoured many chemical processes, which in later times have nearly ceased to operate. Hence we find that subsequently to the eozoic times, silicated rocks of clearly marked chemical origin are comparatively rare.”[32]

In order to comprehend the complex action, now mechanical, now chemical, which the waters, still in a heated state, exercised on the solid crust, let us consider what were the components of this crust. The rocks which formed its first *stratum*—the framework of the earth, the foundation upon which all others repose—may be presumed to have been a compound which, in varying proportions, forms granite and gneiss, and has latterly been designated by geologists Laurentian.

What is this gneiss, this granite, speaking of it with reference to its mineralogical character? It is a combination of silicates, with a base of alumina, potash, soda, and sometimes lime—*quartz*, *felspar*, and *mica* form, by their simple aggregation, *granite*—it is thus a ternary combination, or composed of three minerals.

Quartz, the most abundant of all minerals, is silica more or less pure and often crystallised. *Felspar* is a crystalline or crystallised mineral, composed of *silicate* of alumina, potash, soda, or lime; potash-felspar is called *orthoclase*, soda-felspar *albite*, lime-felspar *anorthite*. *Mica* is a silicate of alumina and potash, containing magnesia and oxide of iron; it takes its name from the Latin *micare*, to shine or glitter.

Granite (from the Italian *grano*, being granular in its structure) is, then, a compound rock, formed of felspar, quartz, and mica, and the three constituent minerals are more or less crystalline. *Gneiss* is a schistose variety of granite, and composed of the same minerals; the only [97] difference between the two rocks (whatever may be their difference of origin) being that the constituent minerals, instead of being confusedly aggregated, as in granite, assume a foliated texture in gneiss. This foliated structure leads sometimes to gneiss being called *stratified granite*. "The term gneiss originated with the Freiberg miners, who from ancient times have used it to designate the rock in which their veins of silver-ore were found."[33]

The felspar, which enters into the composition of granite, is a mineral that is easily decomposed by water, either cold or boiling, or by the water of springs rich in carbonic acid. The chemical action of carbonic acid and water, and the action (at once chemical and mechanical) of the hot water in the primitive seas, powerfully modified the granitic rocks which lay beneath them. The warm rains which fell upon the mountain-peaks and granitic pinnacles, the torrents of rain which fell upon the slopes or in the valleys, dissolved the several alkaline silicates which constitute felspar and mica, and swept them away to form elsewhere strata of clay and sand; thus were the first modifications in the primitive rocks produced by the united action of air and water, and thus were the first sedimentary rocks deposited from the oceanic waters.

The argillaceous deposits produced by this decomposition of the felspathic and micaceous rocks would participate in the still heated temperature of the globe—would be again subjected to long continued heat; and when they became cool again, they would assume, by a kind of semi-crystallisation, that parallel structure which is called foliation. All foliated rocks, then, are metamorphic, and the result of a metamorphic action to which sedimentary strata (and even some eruptive rocks) have been subjected subsequently to their deposition and consolidation, and which has produced a re-arrangement of their component mineral particles, and frequently, if not always, of their chemical elements also.

In this manner would the first beds of crystalline *schist*, such as mica-schist, be formed, probably out of sandy and clayey muds, or arenaceous and argillaceous shales.

At the end of this first phase of its existence, the terrestrial globe was, then, covered, over nearly its whole surface, with hot and muddy water, forming extensive but shallow seas. A few islands, raising their granitic peaks here and there, would form a sort of archipelago, surrounded by seas filled with earthy matter in suspension. During a long series of ages the solid crust of the globe went on increasing in thickness, as the process of solidification of the underlying liquid matter [98] nearest to the surface proceeded. This state of tranquillity could not last long. The solid portion of the globe had not yet attained sufficient consistency to resist the pressure of the gases and boiling liquids which it covered and compressed with its elastic crust. The waves of this internal sea triumphed, more than once, over the feeble resistances which were opposed to it, making enormous dislocations and breaches in the ground—immense upheavals of the solid crust raising the beds of the seas far above their previous levels—and thus mountains arose out of the ocean, not now exclusively granitic, but composed, besides, of those schistose rocks which have been deposited under water, after long suspension in the muddy seas.

On the other hand the Earth, as it continued to cool, would also contract; and this process of contraction, as we have already explained, was another cause of dislocation at the surface, producing either considerable ruptures or simple fissures in the continuity of the crust. These fissures would be filled, at a subsequent period, by jets of the molten matter occupying the interior of the globe—by *eruptive granite*, that is to say—or by various mineral compounds; they also opened a passage to those torrents of heated water charged with mineral salts, with silica, the bicarbonates of lime and magnesia, which, mingling with the waters of the vast primitive ocean, were deposited at the bottom of the seas, thus helping to increase the mass of the mineral substances composing the solid portion of the globe.

These eruptions of granitic or metallic matter—these vast discharges of mineral waters through the fractured surface—would be of frequent occurrence during the primitive epoch we are contemplating. It should not, therefore, be a matter for surprise to find the more ancient rocks almost always fractured, reduced in dimensions by faults and contortions, and often traversed by veins containing metals or their oxides, such as the oxides of copper and tin; or their sulphides, such as those of lead, of antimony, or of iron—which are now the object of the miner's art.

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[32] "Address to the American Association for the Advancement of Science," by Thomas Sterry Hunt, LL.D., p. 56. 1871.

[33] Cotta's "Rocks Classified and Described," by P. H. Lawrence, p. 232.

PRIMARY EPOCH. [99]

After the terrible tempests of the primitive period—after these great disturbances of the mineral kingdom—Nature would seem to have gathered herself together, in sublime silence, in order to proceed to the grand mystery of the creation of living beings.

During the primitive epoch the temperature of the earth was too high to admit the appearance of life on its surface. The darkness of thickest night shrouded this cradle of the world; the atmosphere probably was so charged with vapours of various kinds, that the sun's rays were powerless to pierce its opacity. Upon this heated surface, and in this perpetual night, organic life could not manifest itself. No plant, no animal, then, could exist upon the silent earth. In the seas of this epoch, therefore, only unfossiliferous strata were deposited.

Nevertheless, our planet continued to be subjected to a gradual refrigeration on the one hand, and, on the other, continuous rains were purifying its atmosphere. From this time, then, the sun's rays, being less obscured, could reach its surface, and, under their beneficent influence, life was not slow in disclosing itself. "Without light," said the illustrious Lavoisier, "Nature was without life; it was dead and inanimate. A benevolent God, in bestowing light, has spread on the surface of the earth organisation, sentiment, and thought." We begin, accordingly, to see upon the earth—the temperature of which was nearly that of our equatorial zone—a few plants and a few animals make their appearance. These first generations of life will be replaced by others of a higher organisation, until at the last stage of the creation, man, endowed with the supreme attribute which we call intelligence, will appear upon the earth. "The word *progress*, which we think peculiar to humanity, and even to modern times," said Albert Gaudry, in a lecture on the animals of the ancient world, delivered in 1863, "was pronounced by the Deity on the day when he created the first living organism."

Did plants precede animals? We know not; but such would appear to have been the order of creation. It is certain that in the sediment of the oldest seas, and in the vestiges which remain to [100] us of the earliest ages of organic life on the globe, that is to say, in the argillaceous schists, we find both plants and animals of advanced organisation. But, on the other hand, during the greater part of the primary epoch—especially during the Carboniferous age—the plants are particularly numerous, and terrestrial animals scarcely show themselves; this would lead us to the conclusion that plants preceded animals. It may be remarked, besides, that from their cellular nature, and their looser tissues composed of elements readily affected by the air, the first plants could be easily destroyed without leaving any material vestiges; from which it may be concluded, that, in those primitive times, an immense number of plants existed, no traces of which now remain to us.

We have stated that, during the earlier ages of our globe, the waters covered a great part of its surface; and it is in them that we find the first appearance of life. When the waters had become sufficiently cool to allow of the existence of organised beings, creation was developed, and advanced with great energy; for it manifested itself by the appearance of numerous and very different species of animals and plants.

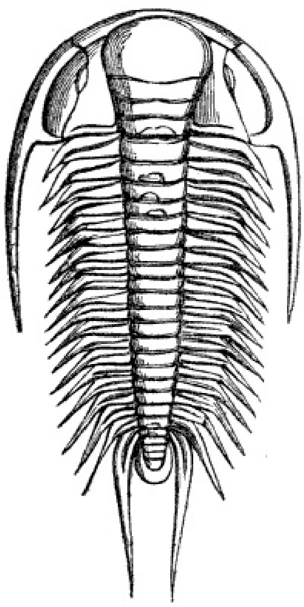


Fig. 17.—Paradoxides Bohemicus—Bohemia.

One of the most ancient groups of organic remains are the Brachiopoda, a group of Mollusca, particularly typified by the genus Lingula, a species of which still exist in the present seas; the Trilobites (Fig. 17), a family of Crustaceans, especially characteristic of this period; then come Productas, Terebratulæ, and Orthoceratites—other genera of Mollusca. The Corals, which appeared at an early period, seem to have lived in all ages, and survive to the present day.

Contemporaneously with these animals, plants of inferior organisation have left their impressions upon the schists; these are Algæ (aquatic plants, Fig. 28). As the continents enlarged, plants of a higher type made their appearance—the Equisetaceæ, herbaceous Ferns, and other plants. These we shall have occasion to specify when noticing the periods which constitute the Primary Epoch, and which consists of the following periods: the Carboniferous, the Old Red Sandstone, and Devonian, the Silurian, and the Cambrian.

Cambrian Period.

The researches of geologists have discovered but scanty traces of organic remains in the rocks which form the base of this system in England. *Arenicolites*, or worm-tracks and burrows, have been found in Shropshire, by Mr. Salter, to occur in countless numbers through a mile of thickness in the Longmynd rocks; and others were discovered by the late Dr. Kinahan in Wicklow. In Ireland, in the picturesque tract of Bray Head, on the south and east coasts of Dublin, we find, in slaty beds of the same age as the Longmynd rocks, a peculiar zoophyte, which has been named by Edward Forbes *Oldhamia*, after its discoverer, Dr. Oldham, Superintendent of the Geological Survey of India. This fossil represents one of the earliest inhabitants of the ocean, which then covered the greater part of the British Isles. “In the hard, purplish, and schistose rocks of Bray Head,” says Dr. Kinahan,[34] “as well as other parts of Ireland which are recognised as Cambrian rocks, markings of a very peculiar character are found. They occur in masses, and are recognised as hydrozoic animal assemblages. They have regularity of form, abundant, but not universal, occurrence in beds, and permanence of character even when the beds are at a distance from each other, and dissimilar in chemical and physical character.” In the course of his investigations, Dr. Kinahan discovered at least four species of Oldhamia, which he has described and figured.

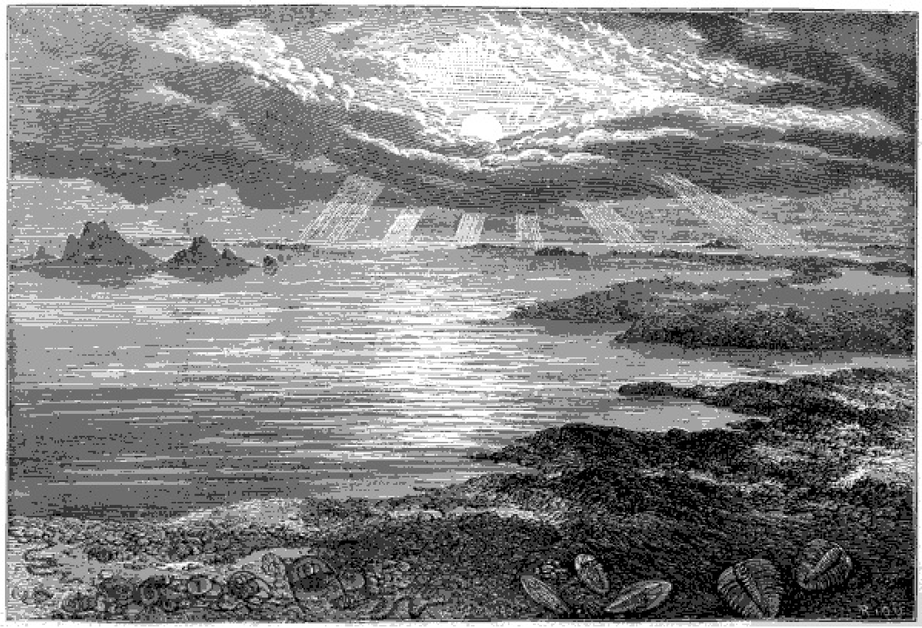
The Cambrian rocks consist of the Llanberis slates of Llanberis and Penrhyn in North Wales, which, with their associated sandy strata, attain a thickness of about 3,000 feet, and the Barmouth and Harlech Sandstones. In the Longmynd hills of Shropshire these last beds attain a thickness of 6,000 feet; and in some parts of Merionethshire they are of still greater thickness.

Neither in North Wales, nor in the Longmynd, do the Cambrian rocks afford any indications of life, except annelide-tracks and burrows. From this circumstance, together with general absence of Mollusca in these strata, and the sudden appearance of numerous shells and trilobites in the succeeding Lingula Flags, a change of conditions seems to have ensued at the close of the Cambrian period.

Believing that the red colour of rocks is frequently connected with their deposition in inland waters, Professor Ramsay conceives it to be possible, that the absence of marine mollusca in the Cambrian rocks may be due to the same cause that produced their absence in the Old Red Sandstone, and that the presence of sun-cracks and rain-pittings in the Longmynd beds is a corroboration of this suggestion.[35]

The Silurian Period.

The next period of the Primary Epoch is the *Silurian*, a system of rocks universal in extent, overspreading the whole earth more or less completely, and covering up the rocks of older age. The term “Silurian” was given by the illustrious Murchison to the epoch which now occupies our attention, because the system of rocks formed by the marine sediments, during the period in question, form large tracts of country in Shropshire and Wales, a region formerly peopled by the *Silures*, a Celtic race who fought gloriously against the Romans, under Caractacus or Caradoc, the British king of those tracts. The reader may find the nomenclature strange, as applied to the vast range of rocks which it represents in all parts of the Old and New World, but it indicates, with sufficient exactness, the particular region in our own country in which the system typically prevails—reasons which led to the term being adopted, even at a time when its vast geographical extent was not suspected.



VIII.—Ideal Landscape of the Silurian Period.

On this subject, and on the principles which have guided geologists in their classification of rocks, Professor Sedgwick remarks in one of his papers in the *Quarterly Journal of the Geological Society*: "In every country," he says,[36] "which is not made out by reference to a pre-existing type, our first labour is that of determining the physical groups, and establishing their relations by natural sections. The labour next in order is the determination of the fossils found in the successive physical groups; and, as a matter of fact, the natural groups of fossils are generally found to be nearly co-ordinate with the physical groups—each successive group resulting from certain conditions which have modified the distribution of organic types. In the third place comes the collective arrangement of the groups into systems, or groups of a higher order. The establishment of the Silurian system is an admirable example of this whole process. The groups called Caradoc, Wenlock, Ludlow, &c., were physical groups determined by good natural sections. The successive groups of fossils were determined by the sections; and the sections, as the representatives of physical groups, were hardly at all modified by any consideration of the fossils, for these two distinct views of the natural history of such groups led to co-ordinate results. Then followed the collective view of the whole series, and the establishment of a nomenclature. Not only the whole series (considered as a distinct system), but every subordinate group was defined by a geographical name, referring us to a local type within the limits of Siluria; in this respect adopting the principle of grouping and nomenclature applied by W. Smith to our secondary rocks. At the same time, the older slate rocks of Wales (inferior to the system of Siluria), were called *Cambrian*, and soon afterwards the next great collective group of rocks (superior to the system of Siluria) was called *Devonian*. In this way was established a perfect congruity of language. It was geographical in principle, and it represented the actual development of all our older rocks, which gave to it its true value and meaning." The period, then, for the purposes of scientific description, may be divided into three sub-periods—the Upper and Lower Silurian, and the Cambrian.

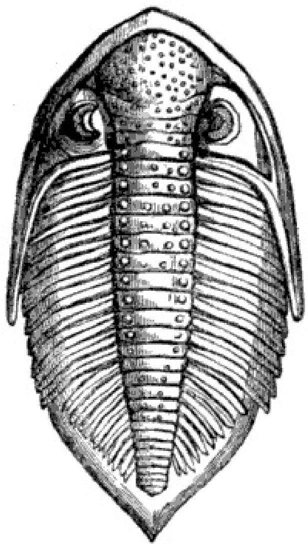


Fig. 18.—Back of Asaphus caudatus (Dudley, Mus. Stokes), with the eyes well preserved. (Buckland.)

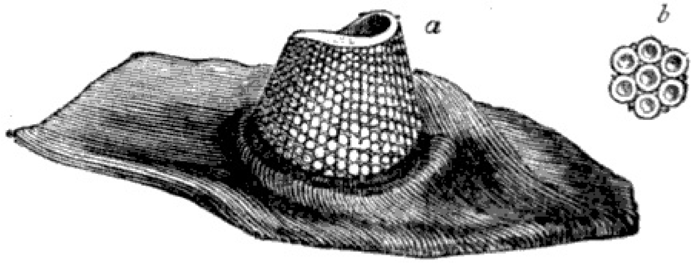


Fig. 19.—*a*, Side view of the left eye of the above, magnified, (Buckland.) *b*, Magnified view of a portion of the eye of Calymene macrophthalmus. (Hœninghaus.)

The characteristics of the Silurian period, of which we give an ideal view opposite (Plate VIII.), are supposed to have been shallow seas of great extent, with barren submarine reefs and isolated rocks rising here and there out of the water, covered with Algæ, and frequented by various Mollusca and articulated animals. The earliest traces of vegetation belong to the *Thallogens*, flowerless plants of the class Algæ (Fig. 28), without leaves or stems, which are found among the Lower Silurian rocks. To these succeed other plants, according to Dr. Hooker, belonging to the Lycopodiaceæ (Fig. 28), the seeds of which are found sparingly in the Upper Ludlow beds. Among animals, the *Orthoceratites* led a predacious life in the Silurian seas. Their organisation [106]
indicates that they preyed upon other animals, pursuing them into the deepest abysses, and strangling them in the embrace of their long arms. The *Trilobites*, a remarkable group of Crustacea, possessing simple and reticulated compound eyes, also highly characterise this period (Figs. 17 to 20); presenting at one period or other of their existence 1,677 species, 224 of which are met with in Great Britain and Ireland, as we are taught by the "Thesaurus Siluricus."[37] Add to this a sun, struggling to penetrate the dense atmosphere of the primitive world, and yielding a dim and imperfect light to the first created beings as they left the hand of the Creator, organisms often rudimentary, but at other times sufficiently advanced to indicate a progress towards more perfect creations. Such is the picture which the artist has attempted to portray.

The elaborate and highly valuable "Thesaurus Siluricus" contains the names of 8,997 species of fossil remains, but it probably does not tell us of one-tenth part of the Silurian life still lying buried in rocks of that age in various parts of the world. A rich field is here offered to the geological explorer.[38]

Lower Silurian.

The Silurian rocks have been estimated by Sir Roderick Murchison to occupy, altogether, an area of about 7,600 square miles in England and Wales, 18,420 square miles in Scotland, and nearly 7,000 square miles in Ireland. Thus, as regards the British Isles, the Silurian rocks rise to the surface over nearly 33,000 square miles.

The Silurian rocks have been traced from Cumberland to the Land's End, at the southern extremity of England. They lie at the base of the southern Highlands of Scotland, from the North Channel to the North Sea, and they range along the entire western coast of that country. In a westerly direction they extended to the sea, where the mountains of Wales—the Alps of the great chain—would stand out in bold relief, some of them facing the sea, others in detached groups; some clothed with a stunted vegetation, others naked and desolate; all of them wild and picturesque. But an interest surpassing all others belongs to these mountains. They are amongst the most ancient sedimentary rocks which exist on our globe, a page of the book in which is [107]
written the history of the antiquities of Great Britain—in fine, of the world.

In Shropshire and Wales three zones of Silurian life have been established. In rocks of three different ages *Graptolites* have left the trace of their existence. Another fossil characteristic of these ancient rocks is the *Lingula*. This shell is horny or slightly calcareous, which has probably been one cause of its preservation. The family to which the Lingula belongs is so abundant in the rocks of the Welsh mountains, that Sir R. Murchison has used it to designate a geological era. These Lingula-flags mark the beginning of the first Silurian strata.

In the Lower Llandovery beds, which mark the close of the period, other fossils present themselves, thus greatly augmenting the forms of life in the Lower Silurian rocks. These are cœlenterata, articulata, and mollusca. They mark, however, only a very ephemeral passage over the globe, and soon disappear altogether.

The vertebrated animals are only represented by rare Fishes, and it is only on reaching the Upper Ludlow rocks, and specially in those beds which pass upward into the Old Red Sandstone, that the remains have been found of fishes—the most ancient beings of their class.

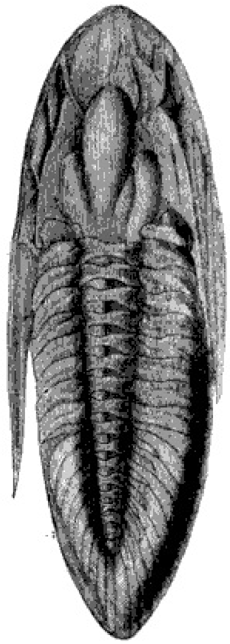


Fig. 20.—Ogygia Guettardi. Natural size.

The class of Crustaceans, of which the lobster, shrimp, and the crab of our days are the representatives, was that which predominated in this epoch of animal life. Their forms were most singular, and different from those of all existing Crustaceans. They consisted mainly of the *Trilobites*, a family which became entirely extinct at the close of the Carboniferous epoch, but in whose nicely-jointed shell the armourer of the middle ages might have found all his contrivances anticipated, with not a few besides which he has failed to discover. The head presents, in general, the form of an oval buckler; the body is composed of a series of articulations, or rings, as [108] represented in Fig. 20; the anterior portion carrying the eyes, which in some are reticulated, like those of many insects (Figs. 18 and 19); the mouth was placed forward and beneath the head. Many of these Crustaceans could roll themselves into balls, like the wood-louse (Figs. 23 and 25). They swam on their backs.

Fig. 21.—Lituites cornu-arietis. One-third natural size.

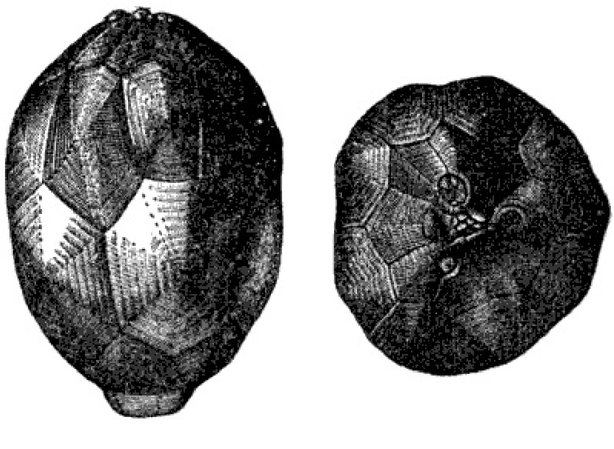


Fig. 22.—Hemicosmites pyriformis. One-third natural size.

During the middle and later Silurian ages, whole rocks were formed almost exclusively of their remains; during the Devonian period they seem to have gradually died out, almost disappearing in the Carboniferous age, and being only represented by one doubtful species in the Permian rocks of North America. The Trilobites are unique as a family, marking with certainty the rocks in which they occur; “and yet,” says Hugh Miller, “how admirably do they exhibit the articulated type of being, and illustrate that unity of design which pervades all Nature, amid its endless diversity!” Among other beings which have left their traces in the Silurian strata is *Nereites Cambriensis*, a species of annelide, whose articulations are very distinctly marked in the ancient rocks.

Besides the Trilobites, many orders of Mollusca were numerously represented in the Silurian seas. As Sir R. Murchison has observed, no zoological feature in the Upper Silurian rocks is more striking than the great increase and profusion of Cephalopods, many of them of great size, which appear in strata of the age immediately antecedent to the dawn of vertebrated life. Among the Cephalopods we have *Gyroceras* and *Lituites cornu-arietis* (Fig. 21), whose living representatives are the Nautilus and Cuttlefish of every sea. The genus *Bellerophon* (Figs. 54 and 56), with many others, represented the Gasteropods, and like the living carinaria sailed freely over the sea by [109] means of its fleshy parts. The Gasteropods, with the Lamellibranchs, of which the Oyster is a living type, and the Brachiopods, whose congeners may still be detected in the *Terebratula* of our Highland lochs and bays, and the *Lingulæ* of the southern hemisphere, were all then represented. The Lamellibranchiata are without a head, and almost entirely destitute of power of locomotion. Among the Echinodermata we may cite the *Hemiscosmites*, of which *H. pyriformis* (Fig. 22) may be considered an example.

The rocks of the Lower Silurian age in France are found in Languedoc, in the environs of Neffiez and of Bédarrieux. They occupy, also, great part of Brittany. They occur in Bohemia, also in Spain, Russia, and in the New World. Limestones, sandstones, and schists (slates of Angers) form the chief part of this series. The Cambrian slates are largely represented in Canada and the United States.

Lower Silurian Group.

Formation.	Prevailing Rocks.	Thickness.	Fossils.
Lower Llandovery	Hard sandstones, conglomerates, and flaggy shaly beds	600 to 1,000	Pentamerus lens.
Caradoc or Bala	Shelly sandstones, shales, and slaty beds, with grits, conglomerates, and occasional calcareous bands (Bala limestone)	12,000	Brachiopods; Lamellibranchs; Pteropods; Cystideans; Graptolites; Trilobites.
Llandeilo Flags	Dark-grey flagstones, occasionally calcareous sandstones, with black slates, containing Graptolites	1,000 to 1,500	Trilobites (Fig. 36); Graptolites; Heteropods; large Cephalopods.
Lower Llandeilo Tremadoc Slates	Dark-grey and ferruginous slates, sandy shales, and bluish flags, with occasional beds of pisolitic iron-ore		
Lingula Flags	Black and dark shaly, grey and brown slaty flagstones and sandstones, with siliceous grits and quartzites	6,000	Trilobites (Olenus, Conocoryphe, Paradoxides, Fig. 17); Brachiopods; Cystideans.
Cambrian Group.			
Cambrian	Llanberis slates, with sandy strata	3,000	Annelides.
	Harlech grits	6,000	Oldhamia.
Laurentian Group.			
Upper Laurentian	Stratified, highly-crystalline, and felspathic rocks	12,060	Eozoon.
Lower Laurentian	Gneiss, quartzite, hornblende and mica-schists	18,000	None.

Upper Silurian Period. [110]

Upper Silurian Group.

	Lithological Characters.	Thickness.	Fossils.
Ludlow Rocks	Passage Beds, Tile-stones, and Downton sandstones, at the base of the bone-bed	80	Sea-weeds, Lingulæ, Mollusca.
	Micaceous, yellowish and grey, sandy mudstone	700	Crustacea and Fish-remains.

	Argillaceous (Aymestry) limestone	50	Crinoids.
	Argillaceous Shale with impure limestones	1000	Mollusca of many genera.
Wenlock Rocks	Argillaceous or semi-crystalline limestone Argillaceous shales, in places slaty Woolhope Limestone and occasional bands of argillaceous nodules	3000	Mollusca of many genera. Echinodermata; Actinozoa; Trilobites. Graptolites.
Upper Llandovery Rocks	Grey and yellowish sandstones (occasionally conglomerates) with bands of limestone	800	Pentamerus oblongus, Rhynchonella, Orthides, &c.

Among the fossils of this period may be remarked a number of Trilobites, which then attained their greatest development. Among others, *Calymene Blumenbachii* (Fig. 23), some *Cephalopoda*, and *Brachiopoda*, among which last may be named *Pentamerus Knightii*, *Orthis*, &c., and some Corals, as *Halysites catenularius* (Fig. 26), or the chain coral.

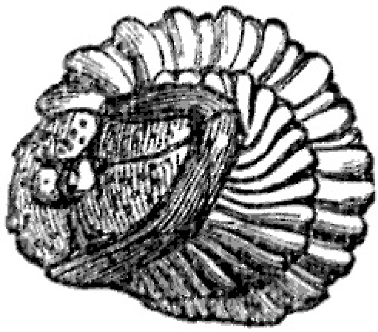


Fig. 23.—Calymene Blumenbachii partially rolled up.

The Trilobites, we have already said, were able to coil themselves into a ball, like the wood-louse, doubtless as a means of defence. In Fig. 23, one of these creatures, *Calymene Blumenbachii*, is represented in that form, coiled upon itself. (See also *Illænus Barriensis*, Fig. 25.)

Crustaceans of a very strange form, and in no respects resembling the Trilobites, have been met with in the Silurian rocks of England and America—the *Pterygotus* (Fig. 27) and the *Eurypterus*, (Fig. 24). They are supposed to have been the inhabitants of fresh water. They were called "Seraphim" by the Scotch quarrymen, from the winged form and feather-like ornamentation upon the thoracic appendage, the part most usually met with. Agassiz figured them in his work on the 'Fossil Fishes of the Old Red Sandstone,' but, subsequently recognising their crustacean [111] character, removed them from the Class of Fishes, and placed them with the *Pœcilipod Crustacea*. The *Eurypteridæ* and *Pterygoti* in England almost exclusively belong to the passage beds—the Downton sandstone and the Upper Ludlow rocks.

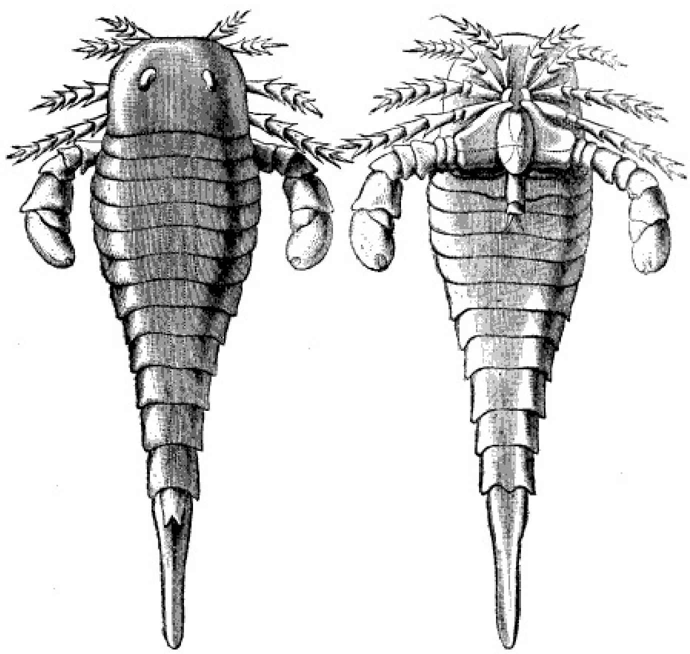


Fig. 24.—Eurypterus remipes. Natural size.

Among the marine plants which have been found in the rocks corresponding with this sub-period are some species of Algæ, and others belonging to the Lycopodiaceæ, which become still more abundant in the Old Red Sandstone and Carboniferous Periods. Fig. 28 represents some examples of the impressions they have left.

The seas were, evidently, abundantly inhabited at the end of the Upper Silurian period, for naturalists have examined nearly 1,500 species belonging to these beds, and the number of British species, classified and arranged for public inspection in our museums cannot be much short of that number. [112]

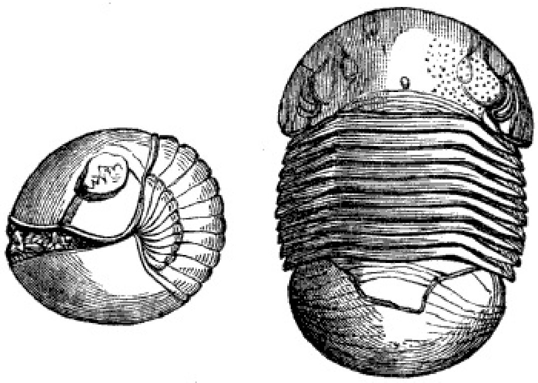


Fig. 25.—Illænus Barriensis.—Dudley, Walsall.

Towards the close of the Upper Silurian sub-period, the argillaceous beds pass upwards into more sandy and shore-like deposits, in which the most ancient known fossil Fishes occur, and then usher us into the first great ichthyic period of the Old Red Sandstone, or Devonian, so well marked by its fossil fishes in Britain, Russia, and North America. The so-called fish-bones have been the subject of considerable doubt. Between the Upper Ludlow rocks opposite Downton Castle and the next overlying stratum, there occurs a thin bed of soft earthy shale, and fine, soft, yellowish greenstone, immediately overlying the Ludlow rock: just below this a remarkable fish-deposit occurs, called the Ludlow bone-bed, because the bones of animals are found in this stratum in great quantities. Old Drayton treats these bones as a great marvel:—

"With strange and sundry tales
Of all their wondrous things; and not the least in Wales,
Of that prodigious spring (him neighbouring as he past),
That little fishes' bones continually doth cast."

Polyolbion.

Above the yellow beds, or Downton sandstone, as they are called, organic remains are extensively diffused through the argillaceous strata, which have yielded fragments of fishes' bones (being the earliest trace yet found of vertebrate life), with seeds and land-plants, the latter clearly indicating the neighbourhood of land, and the poverty of numbers and the small size of the shells, a change [113] of condition in the nature of the waters in which they lived. "It was the central part only," says Sir R. Murchison, "of this band, or a ginger-bread-coloured layer of a thickness of three or four inches, and dwindling away to a quarter of an inch, exhibiting, when my attention was first directed to it, a matted mass of bony fragments, for the most part of small size and of very peculiar character. Some of the fragments of fish are of a mahogany hue, but others of so brilliant a black that when first discovered they conveyed the impression that the bed was a heap of broken beetles."[39]

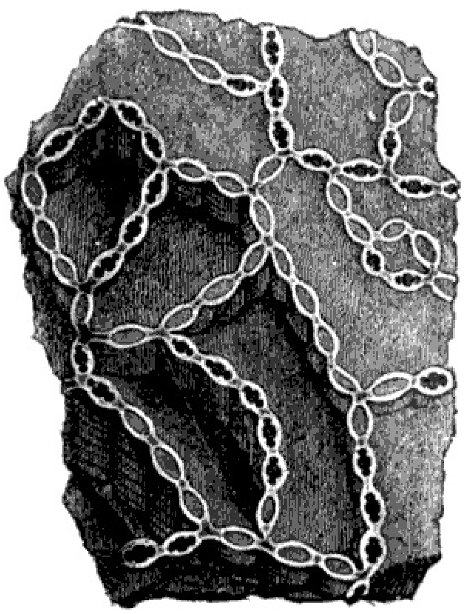


Fig. 26.—Halysites catenularius.

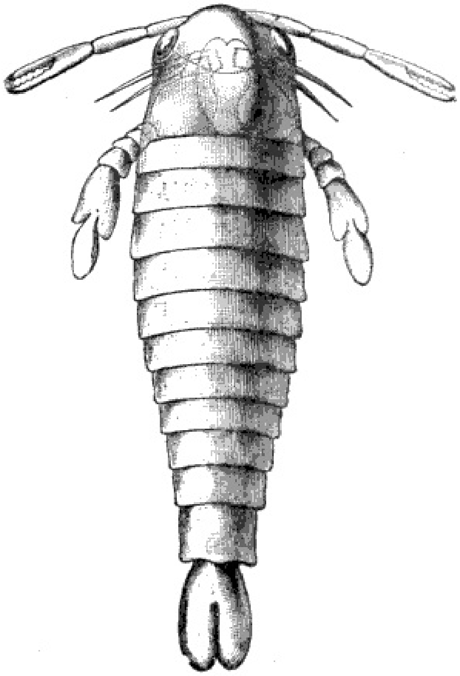


Fig. 27.—Pterygotus bilobatus.

The fragments thus discovered were, after examination on the spot, supposed to be those of fishes, but, upon further investigation, many of them were found to belong to Crustaceans. The ichthyic nature of some of them is, however, now well established.

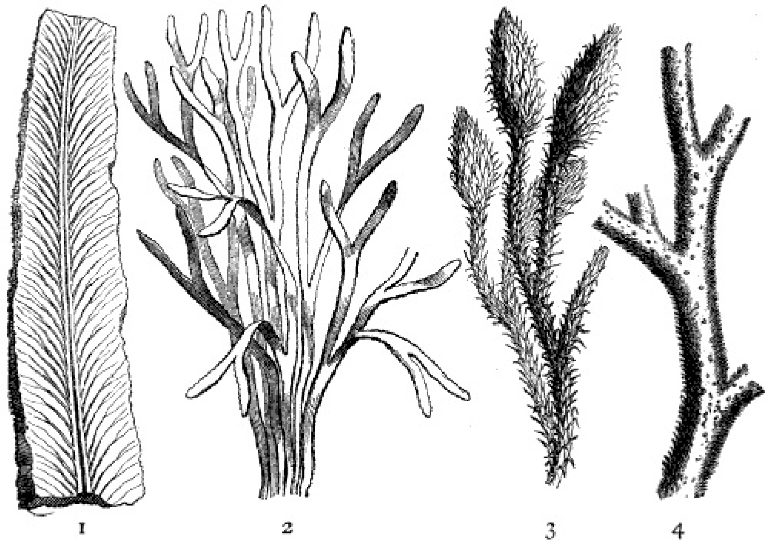


Fig. 28.—Plants of the Palæozoic Epoch.—1 and 2, Algæ; 3 and 4, Lycopods.

Silurian Rocks are found in France in the departments of La Manche, Calvados, and of the Sarthe, and in Languedoc the Silurian formation has occupied the attention of Messrs. Graff and Fournet, who have traced along the base of the Espinouse, the green, primordial chlorite-schists, surmounted by clay-slates, which become more and more pure as the distance from the masses of granite and gneiss increases, and the valley of the Jour is approached. Upon these last the Silurian system rests, sinking towards the plain under Secondary and Tertiary formations. In Great Britain, Silurian strata are found enormously developed in the West and South Highlands of Scotland, on the western slopes of the Pennine chain and the mountains of Wales, and in the adjoining counties of Shropshire—their most typical region—and Worcestershire. In Spain; in Germany (on the banks of the Rhine); in Bohemia—where, also, they are largely developed, especially in the neighbourhood of Prague—in Sweden, where they compose the entire island of Gothland; in Norway; in Russia, especially in the Ural Mountains; and in America, in the neighbourhood of New York, and half way across the continent—in all these countries they are more or less developed. [114] [115]

We may add, as a general characteristic of the Silurian system as a whole, that of all formations it is the most disturbed. In the countries where it prevails, it only appears as fragments which have escaped destruction amid the numerous changes that have affected it during the earlier ages of the world. The beds, originally horizontal, are turned up, contorted, folded over, and sometimes become even vertical, as in the slates of Angers, Llanberis, and Ireleth. D’Orbigny found the

Silurian beds with their fossils in the American Andes, at the height of 16,000 feet above the level of the sea. What vast upheavals must have been necessary to elevate these fossils to such a height!

In the Silurian period the sea still occupied the earth almost entirely; it covered the greater part of Europe: all the area comprised between Spain and the Ural was under water. In France only two islands had emerged from the primordial ocean. One of them was formed of the granitic rocks of what are now Brittany and La Vendée; the other constituted the great central plateau, and consisted of the same rocks. The northern parts of Norway, Sweden, and of Russian Lapland formed a vast continental surface. In America the emerged lands were more extensive. In North America an island extended over eighteen degrees of latitude, in the part now called New Britain. In South America, in the Pacific, Chili formed one elongated island. Upon the Atlantic, a portion of Brazil, to the extent of twenty degrees of latitude, was raised above water. Finally, in the equatorial regions, Guiana formed a later island in the vast ocean which still covered most other parts of the New World.

There is, perhaps, no scene of greater geological confusion than that presented by the western flanks of the Pennine chain. A line drawn longitudinally from about three degrees west of Greenwich, would include on its western side Cross Fell, in Cumberland, and the greater part of the Silurian rocks belonging to the Cambrian system, in which the Cambrian and Lower Silurian rocks are now well determined; while the upper series are so metamorphosed by eruptive granite and the effects of denudation, as to be scarcely recognisable. “With the rare exception of a seaweed and a zoophyte,” says the author of ‘Siluria,’ “not a trace of a fossil has been detected in the thousands of feet of strata, with interpolated igneous matter, which intervene between the slates of Skiddaw and the Coniston limestone, with its overlying flags; at that zone only do we begin to find anything like a fauna: here, judging from its fossils, we find representations of the [116] Caradoc and Bala rocks.” This much-disturbed district Professor Sedgwick, after several years devoted to its study, has attempted to reconstruct, the following being a brief summary of his arguments. The region consists of:—

I. Beds of mudstone and sandstone, deposited in an ancient sea, apparently without the calcareous matter necessary to the existence of shells and corals, and with numerous traces of organic forms of Silurian age—these were the elements of the Skiddaw slates.

II. Plutonic rocks were, for many ages, poured out among the aqueous sedimentary deposits; the beds were broken up and re-cemented—plutonic silt and other finely comminuted matter were deposited along with the igneous rocks: the process was again and again repeated, till a deep sea was filled up with a formation many thousands of feet thick by the materials forming the middle Cambrian rocks.

III. A period of comparative repose followed. Beds of shells and bands of coral were formed upon the more ancient rocks, interrupted with beds of sand and mud; processes many times repeated: and thus, in a long succession of ages, were the deposits of the upper series completed.

IV. Towards the end of the period, mountain-masses and eruptive rocks were pushed up through the older deposits. After many revolutions, all the divisions of the slate-series were upheaved and contorted by movements which did not affect the newer formations.

V. The conglomerates of the Old Red Sandstone were now spread out by the beating of an ancient surf, continued through many ages, against the upheaved and broken slates.

VI. Another period of comparative repose followed: the coral-reefs of the mountain limestone, and the whole carboniferous series, were formed, but not without any oscillations between the land and sea-levels.

VII. An age of disruption and violence succeeded, marked by the discordant position of the rocks, and by the conglomerate of the New Red Sandstone. At the beginning of this period the great north and south “Craven fault,” which rent off the eastern calcareous mountains from the old slates, was formed. Soon afterwards the disruption of the great “Pennine fault,” which ranges from the foot of Stanmore to the coast of North Cumberland, occurred, lifting up the terrace of Cross Fell above the plain of the Eden. About the same time some of the north and south fissures, which now form the valleys leading into Morecambe Bay, may have been formed.

VIII. The more tranquil period of the New Red Sandstone now dawns, but here our facts fail us on [117] the skirts of the Lake Mountains.

IX. Thousands of ages rolled away during the Secondary and Tertiary periods, in which we can trace no movement. But the powers of Nature are never still: during this age of apparent repose many a fissure may have started into an open chasm, many a valley been scooped out upon the lines of “fault.”

X. Close to the historic times we have evidence of new disruptions and violence, and of vast changes of level between land and sea. Ancient valleys probably opened out anew or extended, and fresh ones formed in the changes of the oceanic level. Cracks among the strata may now have become open fissures, vertical escarpments formed by unequal elevations along the lines of fault; and subsidence may have given rise to many of the tarns and lakes of the district.

Such is the picture which one of our most eminent geologists gives as the probable process by which this region has attained its present appearance, after he had devoted years of study and observation to its peculiarities; and his description of one spot applies in its general scope to the whole district. At the close of the Silurian period our island was probably an archipelago, ranging over ten degrees of latitude, like many of the island groups now found in the great Pacific Ocean; the old gneissic hills of the western coast of Scotland, culminating in the granite range of Ben Nevis, and stretching to the southern Grampians, forming the nucleus of one island group; the south Highlands of Scotland, ranging from the Lammermoor hills, another; the Pennine chain and the Malvern hills, the third, and most easterly group; the Shropshire and Welsh mountains, a fourth; and Devon and Cornwall stretching far to the south and west. The basis of the calculation being, that every spot of this island lying now at a lower elevation than 800 feet above the sea, was under water at the close of the Silurian period, except in those instances where depression by subsidence has since occurred.

There is, however, another element to be considered, which cannot be better stated than in the picturesque language of M. Esquiros, an eminent French writer, who has given much attention to British geology. "The Silurian mountains," he says, "ruins in themselves, contain other ruins. In the bosom of the Longmynd rocks, geologists discover conglomerates of rounded stones which bear no resemblance to any rocks now near them. These stones consequently prove the existence of rocks more ancient still; they are fragments of other mountains, of other shores, perhaps even of continents, broken up, destroyed, and crumbled by earlier seas. There is, then, little hope of [118]
one discovering the origin of life on the globe, since this page of the Genesis of the facts has been torn. For some years geologists loved to rest their eyes, in this long night of ages, upon an ideal limit beyond which plants and animals would begin to appear. Now, this line of demarcation between the rocks which are without vestiges of organised beings, and those which contain fossils, is nearly effaced among the surrounding ruins. On the horizon of the primitive world we see vaguely indicated a series of other worlds which have altogether disappeared; perhaps it is necessary to resign ourselves to the fact that the dawn of life is lost in this silent epoch, where age succeeds age, till they are clothed in the garb of eternity. The river of creation is like the Nile, which, as Bossuet says, hides its head—a figure of speech which time has falsified—but the endless speculations opened up by these and similar considerations led Lyell to say, 'Here I am almost prepared to believe in the ancient existence of the Atlantis of Plato.'"

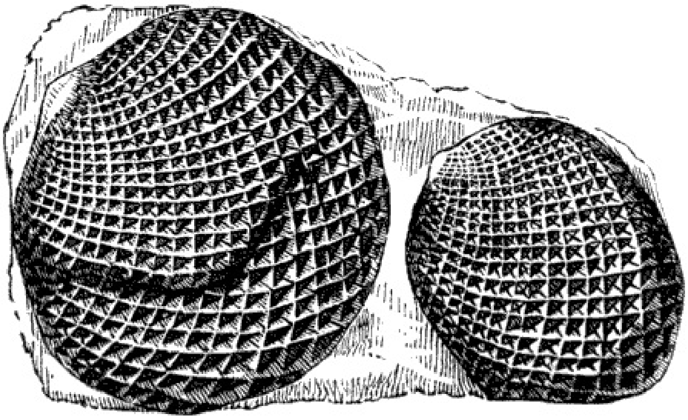


Fig. 29.—Ischadites Kœnigii. Upper Ludlow Rocks.

Note.—For accurate representations of the typical fossils of the Palæozoic strata of Britain, the reader may consult, with advantage, the carefully executed "Figures of Characteristic British Fossils," by W. H. Baily, F.G.S. (Van Voorst).

[119]

OLD RED SANDSTONE AND DEVONIAN PERIOD.

Another great period in the Earth's history opens on us—the Devonian or "Old Red Sandstone," so called, because the formation is very clearly displayed over a great extent of country in the county of Devon. The name was first proposed by Murchison and Sedgwick, in 1837, for these strata, which had previously been referred to the "transition" or Silurian series.

The circumstances which marked the passage of the uppermost Silurian rocks into Old Red Sandstone seem to have been:—First, a shallowing of the sea, followed by a gradual alteration in the physical geography of the district, so that the area became changed into a series of mingled fresh and brackish lagoons, which, finally, by continued terrestrial changes, were converted into a great fresh-water lake; or, if we take the whole of Britain and lands beyond, into a series of lakes.[40]

Mr. Godwin Austen has, also, stated his opinion that the Old Red Sandstone, as distinct from the Devonian rocks, was of lacustrine origin.

The absence of marine shells helps to this conclusion, and the nearest living analogues of some of the fishes are found in the fresh water of Africa and North America. Even the occurrence in the Devonian rocks of Devonshire and Russia of some Old Red Sandstone fishes along with marine shells, merely proves that some of them were fitted to live in either fresh or salt water, like various existing fishes. At the present day animals that are commonly supposed to be essentially marine, are occasionally found inhabiting fresh water, as is the case in some of the lakes of Sweden, where it is said marine crustacea are found. Mr. Alexander Murray also states that in the inland fresh-water lakes of Newfoundland seals are common, living there without even visiting the sea. And the same is the case in Lake Baikal, in Central Asia. [120]

The red colour of the Old Red Sandstone of England and Scotland, and the total absence of fossils, except in the very uppermost beds, are considered by Professor Ramsay to indicate that the strata were deposited in inland waters. These fossils are terrestrial ferns, *Adiantites* (Pecopteris) *Hibernicus*, and a fresh-water shell, *Anodon Jukesii*, together with the fish *Glyptolepis*.[41]

The rocks deposited during the Devonian period exhibit some species of animals and plants of a much more complex organisation than those which had previously made their appearance. We have seen, during the Silurian epoch, organisms appearing of very simple type; namely, zoophytes, articulated and molluscous animals, with algæ and lycopods, among plants. We shall see, as the globe grows older, that organisation becomes more complex. Vertebrated animals, represented by numerous Fishes, succeed Zoophytes, Trilobites, and Molluscs. Soon afterwards Reptiles appear, then Birds and Mammals; until the time comes when man, His supreme and last work, issues from the hands of the Creator, to be king of all the earth—man, who has for the sign of his superiority, intelligence—that celestial gift, the emanation from God.

Vast inland seas, or lakes covered with a few islets, form the ideal of the Old Red Sandstone period. Upon the rocks of these islets the mollusca and articulata of the period exhibit themselves, as represented on the opposite page (Plate IX.). Stranded on the shore we see armour-coated Fishes of strange forms. A group of plants (*Asterophyllites*) covers one of the islets, associated with plants nearly herbaceous, resembling mosses, though the true mosses did not appear till a much later period. *Encrinites* and *Lituites* occupy the rocks in the foreground of the left hand.

The vegetation is still simple in its development, for forest-trees seem altogether wanting. The Asterophyllites, with tall and slender stems, rise singly to a considerable height. Cryptogams, of which our mushrooms convey some idea, would form the chief part of this primitive vegetation; but in consequence of the softness of their tissues, their want of consistence, and the absence of much woody fibre, these earlier plants have come down to us only in a fragmentary state.

[121]

IX.—Ideal Landscape of the Devonian Period.

The plants belonging to the Devonian period differ much from the vegetation of the present day. They resembled both mosses and lycopods, which are flowerless cryptogamic plants of a low organisation. The Lycopods are herbaceous plants, playing only a secondary part in the vegetation of the globe; but in the earlier ages of organic creation they were the predominant forms in the vegetable kingdom, both as to individual size and the number and variety of their species. [123]

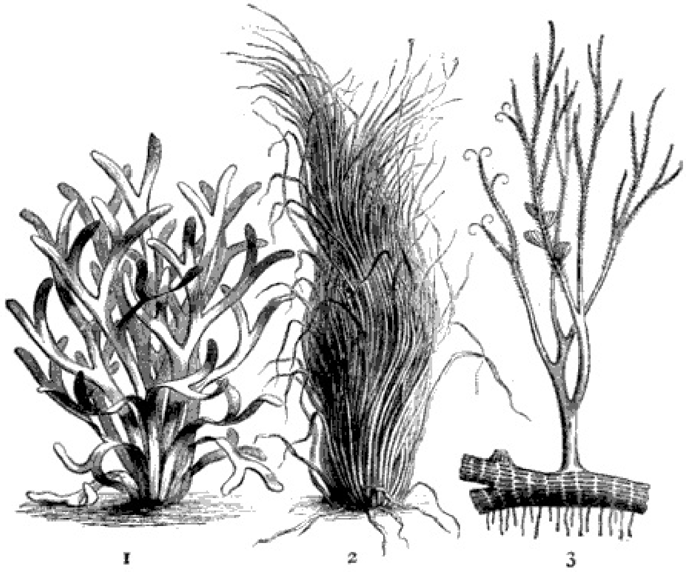


Fig. 30.—Plants of the Devonian Epoch. 1. Algæ. 2. Zostera. 3. Psilophyton, natural size.

In the woodcut (Fig. 30) we have represented three species of aquatic plants belonging to the Devonian period; they are—1, *Fucoids* (or *Algæ*); 2, *Zostera*; 3, *Psilophyton*. The Fucoid closely resembles its modern ally; but with the first indications of terrestrial vegetation we pass from the *Thallogens*, to which the *Algæ* belong (plants of simple organisation, without flower or stem), to the *Acrogens*, which throw out their leaves and branches at the extremity, and bear in the axils of [124] their leaves minute circular cases, which form the receptacles of their spore-like seeds. "If we stand," says Hugh Miller, "on the outer edge of one of those iron-bound shores of the Western Highlands, where rock and skerries are crowned with sea-weeds; the long cylindrical lines of *chorda-filum*, many feet in length, lying aslant in the tideway; long shaggy bunches of *Fucus serratus* and *F. nodosus* drooping from the sides of the rock; the flat ledges bristling with the stiff cartilaginous many-cleft fronds of at least two species of *Chondrus*; now, in the thickly-spread Fucoids of this Highland scene we have a not very improbable representation of the Thallogenous vegetation. If we add to this rocky tract, so rich in Fucoids, a submarine meadow of pale shelly sand, covered by a deep-green swathe of *Zosteræ*, with jointed root and slim flowers, unfurnished with petals, it would be more representative still."

Let us now take a glance at the animals belonging to this period.

The class of Fishes seem to have held the first rank and importance in the Old Red Sandstone *fauna*; but their structure was very different from that of existing fishes: they were provided with a sort of cuirass, and from the nature of the scales were called *Ganoid* fishes. Numerous fragments of these curious fishes are now found in geological collections; they are of strange forms, some being completely covered with a cuirass of many pieces, and others furnished with wing-like pectoral fins, as in *Pterichthys*.

Let any one picture to himself the surprise he would feel should he, on taking his first lesson in geology, and on first breaking a stone—a pebble, for instance, exhibiting every external sign of a water-worn surface—find, to appropriate Archdeacon Paley's illustration, a watch, or any other delicate piece of mechanism, in its centre. Now, this, thirty years ago, is exactly the kind of surprise that Hugh Miller experienced in the sandstone quarry opened in a lofty wall of cliff overhanging the northern shore of the Moray Frith. He had picked up a nodular mass of blue Lias-limestone, which he laid open by a stroke of the hammer, when, behold! an exquisitely shaped Ammonite was displayed before him. It is not surprising that henceforth the half-mason, half-sailor, and poet, became a geologist. He sought for information, and found it; he found that the rocks among which he laboured swarmed with the relics of a former age. He pursued his investigations, and found, while working in this zone of strata all around the coast, that a certain class of fossils abounded; but that in a higher zone these familiar forms disappeared, and others made their appearance.

He read and learned that in other lands—lands of more recent formation—strange forms of [125] animal life had been discovered; forms which in their turn had disappeared, to be succeeded by others, more in accordance with beings now living. He came to know that he was surrounded, in his native mountains, by the sedimentary deposits of other ages; he became alive to the fact that these grand mountain ranges had been built up grain by grain in the bed of the ocean, and the mountains had been subsequently raised to their present level by the upheaval of one part of its bed, or by the subsidence of another. The young geologist now ceased to wonder that each bed, or series of beds, should contain in its bosom records of its own epoch; it seemed to him as if it had been the object of the Creator to furnish the inquirer with records of His wisdom and power, which could not be misinterpreted.

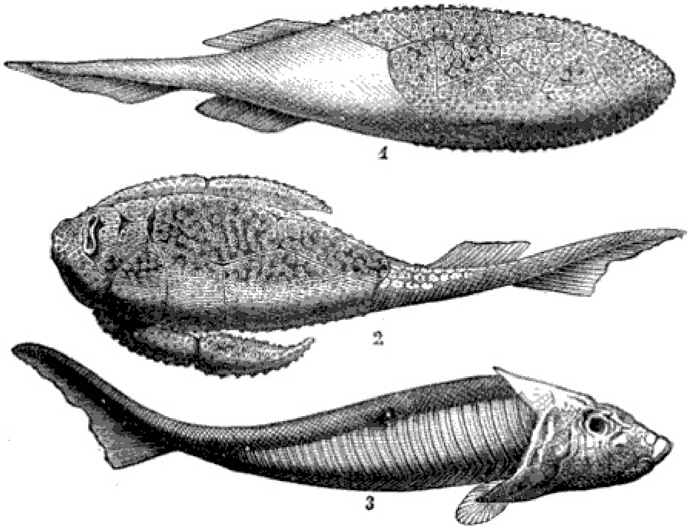


Fig. 31.—Fishes of the Devonian Epoch. 1. Coccosteus, one-third natural size. 2. Pterichthys, one-fourth natural size. 3. Cephalaspis, one-fourth natural size.

Among the Fishes of Old Red Sandstone, the *Coccosteus* (Fig. 31, No. 1) was only partially cased in a defensive armour; the upper part of the body down to the fins was defended by scales. *Pterichthys* (No. 2), a strange form, with a very small head, furnished with two powerful paddles, [126] or arms, like wings, and a mouth placed far behind the nose, was entirely covered with scales. The *Cephalaspis* (No. 3), which has a considerable outward resemblance to some fishes of the present time, was nevertheless mail-clad, only on the anterior part of the body.

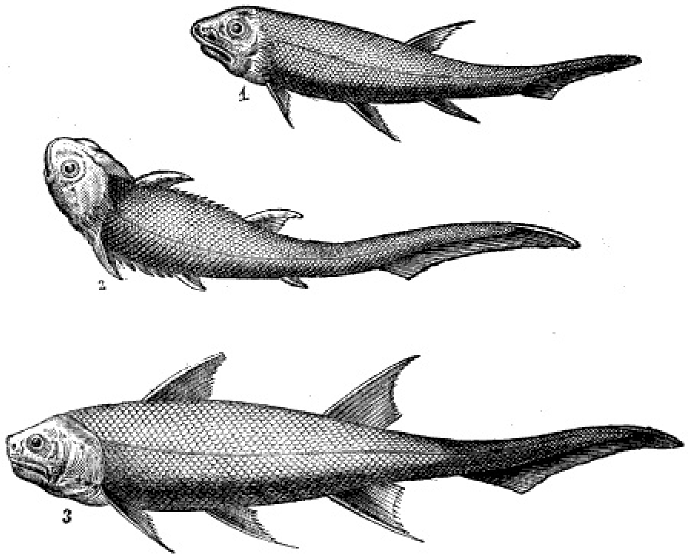


Fig. 32.—Fishes of the Devonian epoch. 1. Acanthodes. 2. Climatius. 3. Diplacanthus.

Other fishes were provided with no such cuirass, properly so called, but were protected by strong resisting scales, enveloping the whole body. Such were the *Acanthodes* (1), the *Climatius* (2), and the *Diplacanthus* (3), represented in Fig. 32.

Among the organic beings of the Devonian rocks we find worm-like animals, such as the *Annelides*, protected by an external shell, and which at the present day are probably represented by the *Serpulæ*. Among Crustaceans the *Trilobites* are still somewhat numerous, especially in the middle rocks of the period. We also find there many different groups of Mollusca, of which the *Brachiopoda* form more than one-half. We may say of this period that it is the reign of [127] Brachiopoda; in it they assumed extraordinary forms, and the number of their species was very great. Among the most curious we may instance the enormous *Stringocephalus Burtini*, *Davidsonia Verneuilli*, *Uncites gryphus*, and *Calceola Sandalina*, shells of singular and fantastic shape, differing entirely from all known forms. Amongst the most characteristic of these Mollusca, *Atrypa reticularis* (Fig. 33) holds the first rank, with *Spirifera concentrica*, *Leptæna Murchisoni*, and *Productus subaculeatus*. Among the Cephalopoda we have *Clymenia Sedgwickii* (Fig. 34), including the *Goniatites*, illustrating the Ammonites, which so distinctly characterise the Secondary epoch, but which were only foreshadowed in the Devonian period.

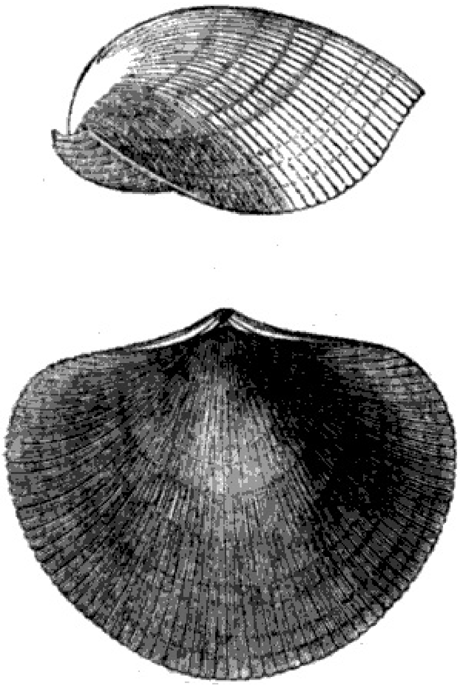


Fig. 33.—Atrypa reticularis.

Among the Radiata of this epoch, the order Crinoidea are abundantly represented. We give as an example *Cupressocrinus crassus* (Fig. 35). The Encrinites, under which name the whole of these animals are sometimes included, lived attached to rocky places and in deep water, as they now do in the Caribbean sea.

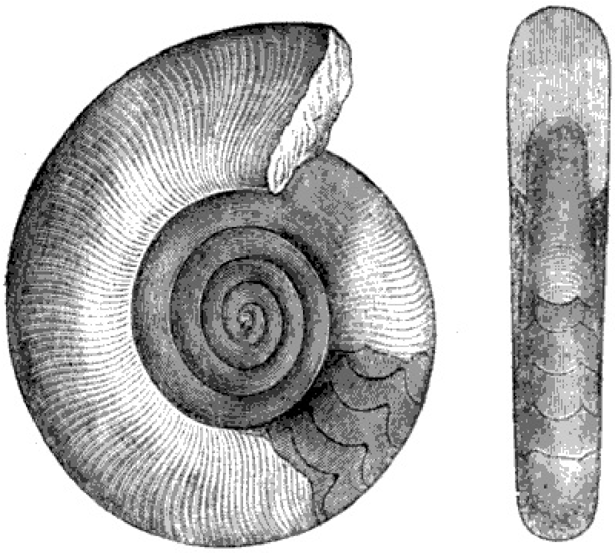


Fig. 34.—Clymenia Sedgwickii.

The Encrinites, as we have seen, were represented during the Silurian period in a simple genus, *Hemicosmites*, but they greatly increased in numbers in the seas of the Devonian period. They diminish in numbers, as we retire from that geological age; until those forms, which were so numerous and varied in the earliest seas, are now only represented by two genera.

The Old Red Sandstone rocks are composed of schists, sandstone, and limestones. The line of [128] demarcation between the Silurian rocks and those which succeed them may be followed, in many places, by the eye; but, on a closer examination, the exact limits of the two systems become more difficult to fix. The beds of the one system pass into the other by a gradual passage, for Nature rarely admits of violent contrasts, and shows few sudden transitions. By-and-by, however, the change becomes very decided, and the contrast between the dark grey masses at the base and the superincumbent yellow and red rocks become sufficiently striking. In fact, the uppermost beds of the Silurian rocks are the passage-beds of the overlying system, consisting of flagstones, occasionally reddish, and called in some districts “tile-stones.” Over these lie the Old Red Sandstone conglomerate, the Caithness flags, and the great superincumbent mass which forms the upper portion of the system. Though less abrupt than the eruptive and Silurian mountains, the Old Red Sandstone scenery is, nevertheless, distinguished by its imposing outline, assuming bold and lofty escarpments in the Vans of Brecon, in Grongar Hill, near Caermarthen, and in the Black Mountain of Monmouthshire, in the centre of a landscape which, wood, rock, and river combine to render perfect. But it is in the north of Scotland where this rock assumes its grandest aspect, wrapping its mantle round the loftiest mountains, and rising out of the sea in rugged and fantastic masses, as far north as the Orkneys. In Devon and Cornwall, where the rocks are of a calcareous, and sometimes schistose or slaty character, they are sufficiently extensive to have given a name to the series, which is recognised all over the world.

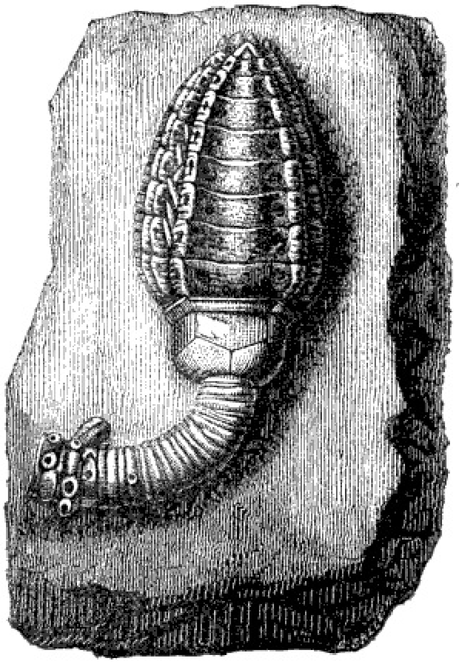


Fig. 35.—Cupressocrinus crassus.

In Herefordshire, Worcestershire, Shropshire, Gloucestershire, and South Wales, the Old Red Sandstone is largely developed, and sometimes attains the thickness of from 8,000 to 10,000 feet, divided into: 1. Conglomerate; 2. Brown stone, with *Eurypterus*; 3. Marl and cornstones, with [129] irregular courses of concrete limestone, in which are spines of Fishes and remains of *Cephalaspis* and *Pteraspis*; 4. Thin olive-coloured shales and sandstone, intercalated with beds of red marl, containing *Cephalaspis* and *Auchenaspis*. In Scotland, south of the Grampians, a yellow sandstone occupies the base of the system; conglomerate, red shales, sandstone and cornstones, containing *Holoptychius* and *Cephalaspis*, and the Arbroath paving-stone, containing what Agassiz recognised as a huge Crustacean.

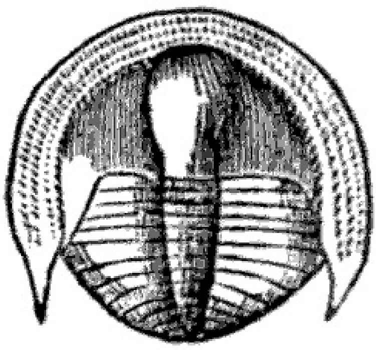


Fig. 36.—Trinucleus Lloydii.
(Llandeilo Flags.)

Some of the phenomena connected with the older rocks of Devonshire are difficult to unravel. The Devonian, it is now understood, is the equivalent, in another area, of the Old Red Sandstone, and in Cornwall and Devonshire lie directly on the Silurian strata, while elsewhere the fossils of the Upper Silurian are almost identical with those in the Devonian beds. The late Professor Jukes, with some other geologists, was of opinion that the Devonian rocks of Devonshire only represented the Old Red Sandstone of Scotland and South Wales in part; the Upper Devonian rocks lying between the acknowledged Old Red Sandstone and the Culm-measures being the representatives of the lower carboniferous rocks of Ireland.

Mr. Etheridge, on the other hand, in an elaborate memoir upon the same subject, has endeavoured to prove that the Devonian and Old Red Sandstone, though contemporaneous in point of time, were deposited in different areas and under widely different conditions—the one strictly marine, the other altogether fresh-water—or, perhaps, partly fresh-water and partly estuarine. This supposition is strongly supported by his researches into the mollusca of the Devonian system, and also by the fish-remains of the Devonian and Old Red Sandstone of Scotland and the West of England and Wales.[42] The difficulty of drawing a sharply-defined line of demarcation between different systems is sufficient to dispel the idea which has sometimes been entertained that special *faunæ* were created and annihilated in the mass at the close of each epoch. There was no close: each epoch disappears or merges into that which succeeds it, and with it the animals belonging to it, much as we have seen them disappear from our own fauna almost within recent times.

[130]

CARBONIFEROUS PERIOD.

In the history of our globe the Carboniferous period succeeds to the Devonian. It is in the formations of this latter epoch that we find the fossil fuel which has done so much to enrich and civilise the world in our own age. This period divides itself into two great sub-periods: 1. The *Coal-measures*; and 2. The *Carboniferous Limestone*. The first, a period which gave rise to the great deposits of coal; the second, to most important marine deposits, most frequently underlying the coal-fields in England, Belgium, France, and America.

The limestone-mountains which form the base of the whole system, attain in places, according to Professor Phillips, a thickness of 2,500 feet. They are of marine origin, as is apparent by the multitude of fossils they contain of Zoophytes, Radiata, Cephalopoda, and Fishes. But the chief characteristic of this epoch is its strictly terrestrial flora—remains of plants now become as common as they were rare in all previous formations, announcing a great increase of dry land. In older geological times the present site of our island was covered by a sea of unlimited extent; we now approach a time when it was a forest, or, rather, an innumerable group of islands, and marshes covered with forests, which spread over the surface of the clusters of islands which thickly studded the sea of the period.

[132]

Fig. 37.—Ferns restored. 1 and 2. Arborescent Ferns. 3 and 4. Herbaceous Ferns.

The monuments of this era of profuse vegetation reveal themselves in the precious Coal-measures of England and Scotland. These give us some idea of the rich verdure which covered the surface of the earth, newly risen from the bosom of its parent waves. It was the paradise of terrestrial vegetation. The grand *Sigillaria*, the *Stigmaria*, and other fern-like plants, were especially typical of this age, and formed the woods, which were left to grow undisturbed; for as yet no living Mammals seem to have appeared; everything indicates a uniformly warm, humid temperature, the only climate in which the gigantic ferns of the Coal-measures could have attained their magnitude. In Fig. 37 the reader has a restoration of the arborescent and herbaceous Ferns of the period. Conifers have been found of this period with concentric rings, [131] but these rings are more slightly marked than in existing trees of the same family, from which it is reasonable to assume that the seasonal changes were less marked than they are with us.

Everything announces that the time occupied in the deposition of the Carboniferous Limestone was one of vast duration. Professor Phillips calculates that, at the ordinary rate of progress, it would require 122,400 years to produce only sixty feet of coal. Geologists believe, moreover, that the upper coal-measures, where bed has been deposited upon bed, for ages upon ages, were accumulated under conditions of comparative tranquillity, but that the end of this period was marked by violent convulsions—by ruptures of the terrestrial crust, when the carboniferous rocks were upturned, contorted, dislocated by faults, and subsequently partially denuded, and thus appear now in depressions or basin-shaped concavities; and that upon this deranged and disturbed foundation a fourth geological system, called Permian, was constructed.

The fundamental character of the period we are about to study is the immense development of a vegetation which then covered much of the globe. The great thickness of the rocks which now represent the period in question, the variety of changes which are observed in these rocks wherever they are met with, lead to the conclusion that this phase in the Earth’s history involved a long succession of time.

Coal, as we shall find, is composed of the mineralised remains of the vegetation which flourished in remote ages of the world. Buried under an enormous thickness of rocks, it has been preserved to our days, after being modified in its inward nature and external aspect. Having lost a portion of its elementary constituents, it has become transformed into a species of carbon, impregnated with those bituminous substances which are the ordinary products of the slow decomposition of vegetable matter.

Thus, coal, which supplies our manufactures and our furnaces, which is the fundamental agent of our productive and economic industry—the coal which warms our houses and furnishes the gas which lights our streets and dwellings—is the substance of the plants which formed the forests, the vegetation, and the marshes of the ancient world, at a period too distant for human chronology to calculate with anything like precision. We shall not say—with some persons, who believe that all in Nature was made with reference to man, and who thus form a very imperfect idea of the vast immensity of creation—that the vegetables of the ancient world have lived and multiplied only, some day, to prepare for man the agents of his economic and industrial occupations. We shall rather direct the attention of our young readers to the powers of modern
science, which can thus, after such a prodigious interval of time, trace the precise origin, and [133]
state with the utmost exactness, the genera and species of plants, of which there are now no identical representatives existing on the face of the earth.

Let us pause for a moment, and consider the general characters which belonged to our planet during the Carboniferous period. Heat—though not necessarily excessive heat—and extreme humidity were then the attributes of its atmosphere. The modern allies of the species which formed its vegetation are now only found under the burning latitudes of the tropics; and the enormous dimensions in which we find them in the fossil state prove, on the other hand, that the atmosphere was saturated with moisture. Dr. Livingstone tells us that continual rains, added to intense heat, are the climatic characteristic of Equatorial Africa, where the vigorous and tufted vegetation flourishes which is so delightful to the eye.

It is a remarkable circumstance that conditions of equable and warm climate, combined with humidity, do not seem to have been limited to any one part of the globe, but the temperature of the whole globe seems to have been nearly the same in very different latitudes. From the Equatorial regions up to Melville Island, in the Arctic Ocean, where in our days eternal frost prevails—from Spitzbergen to the centre of Africa, the carboniferous flora is identically the same. When nearly the same plants are found in Greenland and Guinea; when the same species, now extinct, are met with of equal development at the equator as at the pole, we cannot but admit that at this epoch the temperature of the globe was nearly alike everywhere. What we now call *climate* was unknown in these geological times. There seems to have been then only one climate over the whole globe. It was at a subsequent period, that is, in later Tertiary times, that the cold began to make itself felt at the terrestrial poles. Whence, then, proceeded this general superficial warmth, which we now regard with so much surprise? It was a consequence of the greater or nearer influence of the interior heat of the globe. The earth was still so hot in itself, that the heat which reached it from the sun may have been inappreciable.

Another hypothesis, which has been advanced with much less certainty than the preceding, relates to the chemical composition of the air during the Carboniferous period. Seeing the enormous mass of vegetation which then covered the globe, and extended from one pole to the other; considering, also, the great proportion of carbon and hydrogen which exists in the bituminous matter of coal, it has been thought, and not without reason, that the atmosphere of
the period might be richer in carbonic acid than the atmosphere of the present day. It has even [134]
been thought that the small number of (especially air-breathing) animals, which then lived, might be accounted for by the presence of a greater proportion of carbonic acid gas in the atmosphere than is the case in our own times. This, however, is pure assumption, totally deficient in proof. Nothing proves that the atmosphere of the period in question was richer in carbonic acid than is the case now. Since we are only able, then, to offer vague conjectures on this subject, we cannot profess with any confidence to entertain the opinion that the atmospheric air of the Carboniferous period contained more carbonic acid gas than that which we now breathe. What we can remark, with certainty, as a striking characteristic of the vegetation of the globe during this phase of its history, was the prodigious development which it assumed. The Ferns, which in our days and in our climate, are most commonly only small perennial plants, in the Carboniferous age sometimes presented themselves under lofty and even magnificent forms.

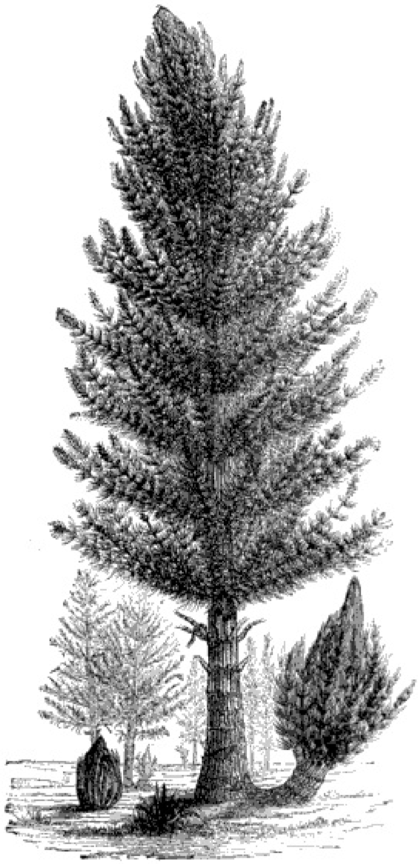


Fig. 38.—Calamite restored. Thirty to forty feet high.

Every one knows those marsh-plants with hollow, channelled, and articulated cylindrical stems; whose joints are furnished with a membranous, denticulated sheath, and which bear the vulgar name of "mare's-tail;" their fructification forming a sort of catkin composed of many rings of scales, carrying on their lower surface sacs full of *spores* or seeds. These humble *Equiseta* were represented during the Coal-period by herbaceous trees from twenty to thirty feet high and four to six inches in diameter. Their trunks, channelled longitudinally, and divided transversely by lines of articulation, have been preserved to us: they bear the name of *Calamites*. The engraving (Fig. 38) represents one of these gigantic mare's-tails, or Calamites, of the Coal-period, restored under the directions of M. Eugene Deslongchamps. It is represented with its fronds of leaves, and its organs of fructification. They seem to have grown by means of an underground stem, while new buds issued from the ground at intervals, as represented in the engraving.

The *Lycopods* of our age are humble plants, scarcely a yard in height, and most commonly creepers; but the Lycopodiaceæ of the ancient world were trees of eighty or ninety feet in height. It was the *Lepidodendrons* which filled the forests. Their leaves were sometimes twenty inches long, and their trunks a yard in diameter. Such are the dimensions of some specimens of *Lepidodendron carinatum* which have been found. Another Lycopod of this period, the *Lomatophloyos crassicaule*, attained dimensions still more colossal. The *Sigillarias* sometimes exceeded 100 feet in height. Herbaceous Ferns were also exceedingly abundant, and grew [135] beneath the shade of these gigantic trees. It was the combination of these lofty trees with such shrubs (if we may so call them), which formed the forests of the Carboniferous period. The trunks of two of the gigantic trees, which flourished in the forests of the Carboniferous period, are represented in Figs. 39 and 40, reduced respectively to one-fifth and one-tenth the natural size.

What could be more surprising than the aspect of this exuberant vegetation!—these immense Sigillarias, which reigned over the forest! these Lepidodendrons, with flexible and slender stems! these Lomatophloyos, which present themselves as *herbaceous* trees of gigantic height, furnished with verdant leaflets! these Calamites, forty feet high! these elegant arborescent Ferns, with airy [136] foliage, as finely cut as the most delicate lace! Nothing at the present day can convey to us an idea of the prodigious and immense extent of never-changing verdure which clothed the earth, from pole to pole, under the high temperature which everywhere prevailed over the whole terrestrial globe. In the depths of these inextricable forests parasitic plants were suspended from the trunks of the great trees, in tufts or garlands, like the wild vines of our tropical forests. They were nearly all pretty, fern-like plants—*Sphenopteris*, *Hymenophyllites*, &c.; they attached themselves to the stems of the great trees, like the orchids and *Bromeliaceæ* of our times.

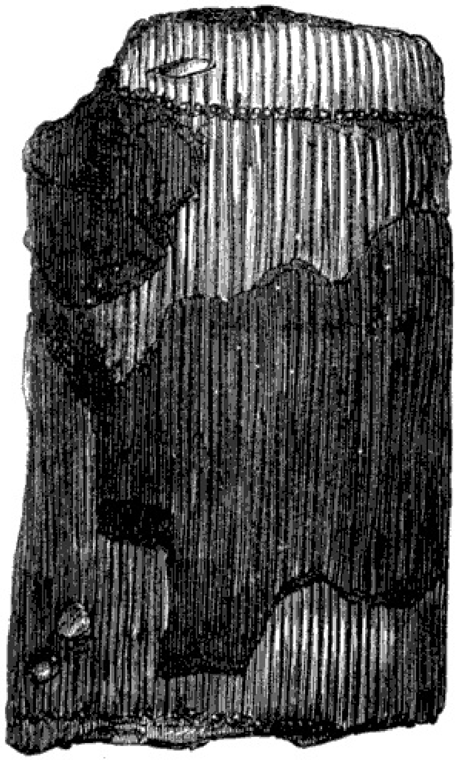


Fig. 39.—Trunk of Calamites. One-fifth natural size.

The margin of the waters would also be covered with various plants with light and whorled leaves, belonging, perhaps, to the Dicotyledons; *Annularia fertilis*, *Sphenophyllites*, and *Asterophyllites*.

How this vegetation, so imposing, both on account of the dimensions of the individual trees and the immense space which they occupied, so splendid in its aspect, and yet so simple in its [137] organisation, must have differed from that which now embellishes the earth and charms our eyes! It certainly possessed the advantage of size and rapid growth; but how poor it was in species—how uniform in appearance! No flowers yet adorned the foliage or varied the tints of the forests. Eternal verdure clothed the branches of the Ferns, the Lycopods, and Equiseta, which composed to a great extent the vegetation of the age. The forests presented an innumerable collection of individuals, but very few species, and all belonging to the lower types of vegetation. No fruit appeared fit for nourishment; none would seem to have been on the branches. Suffice it to say that few terrestrial animals seem to have existed yet; animal life was apparently almost wholly confined to the sea, while the vegetable kingdom occupied the land, which at a later period was more thickly inhabited by air-breathing animals. Probably a few winged insects (some coleoptera, orthoptera, and neuroptera) gave animation to the air while exhibiting their variegated colours; and it was not impossible but that many pulmoniferous mollusca (such as land-snails) lived at the same time.

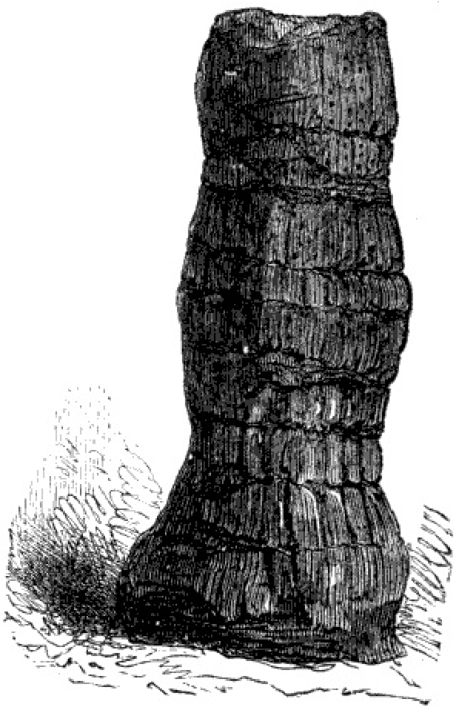


Fig. 40.—Trunk of Sigillaria. One-tenth natural size.

But, we might ask, for what eyes, for whose thoughts, for whose wants, did the solitary forests grow? For whom these majestic and extensive shades? For whom these sublime sights? What mysterious beings contemplated these marvels? A question which cannot be solved, and one before which we are overwhelmed, and our powerless reason is silent; its solution rests with Him who said, "Before the world was, I am!"

The vegetation which covered the numerous islands of the Carboniferous sea consisted, then, of Ferns, of Equisetaceæ, of Lycopodiaceæ, and dicotyledonous Gymnosperms. The Annularia and Sigillariæ belong to families of the last-named class, which are now completely extinct.

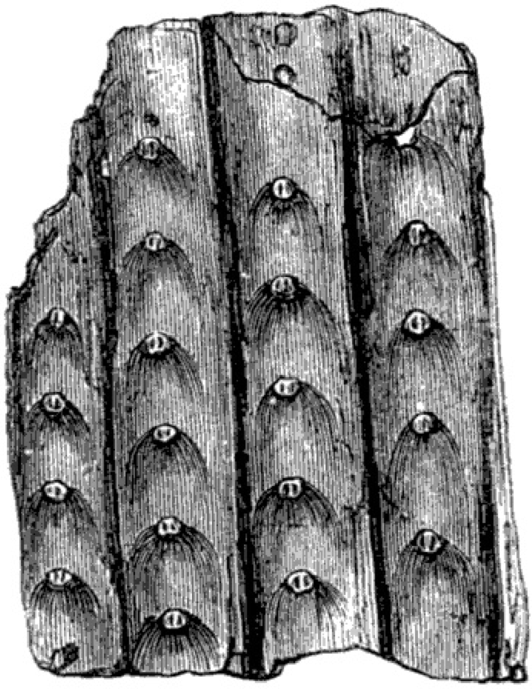


Fig. 41.—Sigillaria lævigata. One-third natural size.

The *Annulariæ* were small plants which floated on the surface of fresh-water lakes and ponds; their leaves were verticillate, that is, arranged in a great number of whorls, at each articulation of the stem with the branches. The *Sigillariæ* were, on the contrary, great trees, consisting of a simple trunk, surmounted with a bunch or panicle of slender drooping leaves, with the bark often channelled, and displaying impressions or scars of the old leaves, which, from their resemblance to a seal, *sigillum*, gave origin to their name. Fig. 41 represents the bark of one of these Sigillariæ, which is often met with in coal-mines.

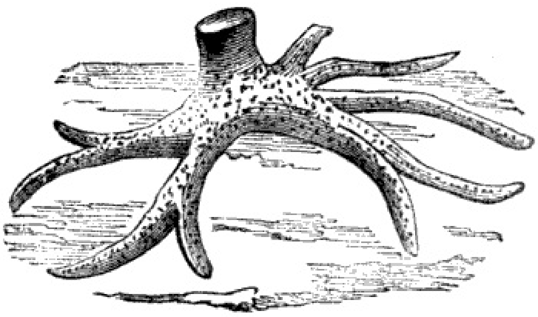


Fig. 42.—Stigmaria. One-tenth natural size.

The *Stigmariæ* (Fig. 42), according to palæontologists, were roots of Sigillariæ, with a subterranean fructification; all that is known of them is the long roots which carry the [138] reproductive organs, and in some cases are as much as sixteen feet long. These were suspected by Brongniart, on botanical grounds, to be the roots of Sigillaria, and recent discoveries have confirmed this impression. Sir Charles Lyell, in company with Dr. Dawson, examined several erect *Sigillariæ* in the sea-cliffs of the South Joggins in Nova Scotia, and found that from the lower extremities of the trunk they sent out *Stigmariæ* as roots, which divided into four parts, and these again threw out eight continuations, each of which again divided into pairs. Twenty-one specimens of Sigillaria have been described by Dr. Dawson from the Coal-measures of Nova Scotia; but the differences in the markings in different parts of the same tree are so great, that Dr. Dawson regards the greater part of the recognised species of *Sigillariæ* as merely provisional. [43]

Two other gigantic trees grew in the forests of this period: these were *Lepidodendron carinatum* and *Lomatophloyos crassicaule*, both belonging to the family of Lycopodiaceæ, which now includes only very small species. The trunk of the Lomatophloyos threw out numerous branches, which terminated in thick tufts of linear and fleshy leaves.

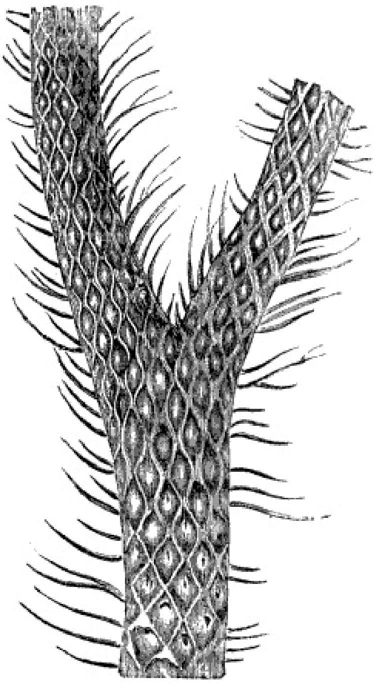


Fig. 43.—Lepidodendron Sternbergii.

The *Lepidodendrons*, of which there are about forty known species, have cylindrical bifurcated branches; that is, the branches were evolved in pairs, or were *dichotomous* to the top. The [139] extremities of the branches were terminated by a fructification in the form of a cone, formed of linear scales, to which the name of *Lepidostrobus* (Fig. 45) has been given. Nevertheless, many of these branches were sterile, and terminated simply in fronds (elongated leaves). In many of the coal-fields fossil cones have been found, to which this name has been given by earlier palæontologists. They sometimes form the nucleus of nodular, concretionary balls of clay-ironstone, and are well preserved, having a conical axis, surrounded by scales compactly imbricated. The opinion of Brongniart is now generally adopted, that they are the fruit of the Lepidodendron. At Coalbrookdale, and elsewhere, these have been found as terminal tips of a branch of a well-characterised Lepidodendron. Both Hooker and Brongniart place them with the Lycopods, having cones with similar spores and sporangia, like that family. Most of them were large trees. One tree of *L. Sternbergii*, nearly fifty feet long, was found in the Jarrow Colliery, near Newcastle, lying in the shale parallel to the plane of stratification. Fragments of others found in the same shale indicated, by the size of the rhomboidal scars which covered them, a still greater size. Lepidodendron Sternbergii (Fig. 43) is represented as it is found beneath the shales in the collieries of Swina, in Bohemia. Fig. 46 represents a portion of a branch of *L. elegans* furnished with leaves. M. Eugene Deslongchamps has drawn the restoration of the Lepidodendron Sternbergii, represented in Fig. 47, which is shown entire in Fig. 44, with its stem, its branches, fronds, and organs of fructification. The Ferns composed a great part of the vegetation of the Coal-measure period.

[140]

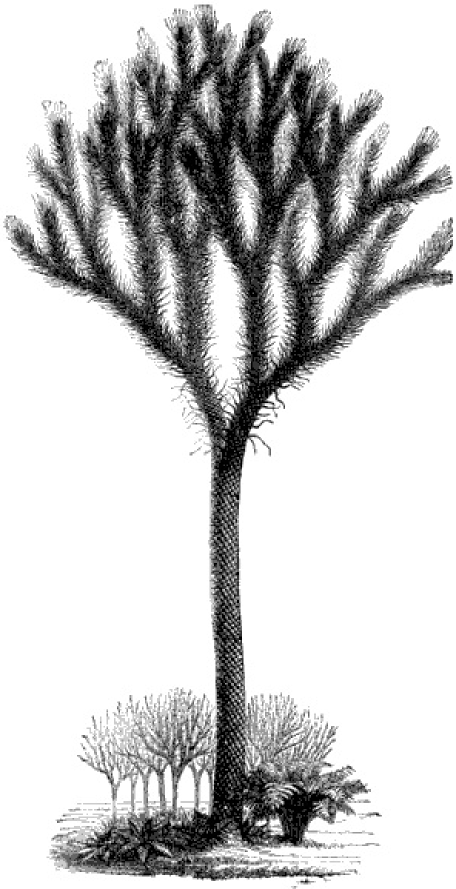


Fig. 44.—Lepidodendron Sternbergii restored. Forty feet high.

The Ferns differ chiefly in some of the details of the leaf. *Pecopteris*, for instance (Fig. 48), have the leaves once, twice, or thrice pinnatifid with the leaflets adhering either by their whole base or by the centre only; the midrib running through to the point. *Neuropteris* (Fig. 49) has leaves divided like Pecopteris, but the midrib does not reach the apex of the leaflets, but divides right and left into veins. *Odontopteris* (Fig. 51) has pinnatifid leaves, like the last, but its leaflets adhere by their whole base to the stalk. *Lonchopteris* (Fig. 50) has the leaves several times pinnatifid, the leaflets more or less united to one another, and the veins reticulated. Among the most numerous species of forms of the Coal-measure period was *Sphenopteris artemisiæfolia* (Fig. 52), of which a magnified leaf is represented. Sphenopteris has twice or thrice pinnatifid leaves, the leaflets narrow at the base, and the veins generally arranged as if they radiated from the base; the leaflets are frequently wedge-shaped. [141]

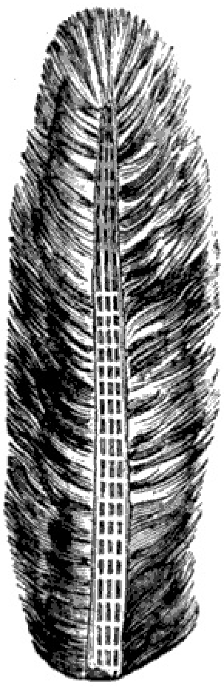


Fig. 45.—Lepidostrobus variabilis.

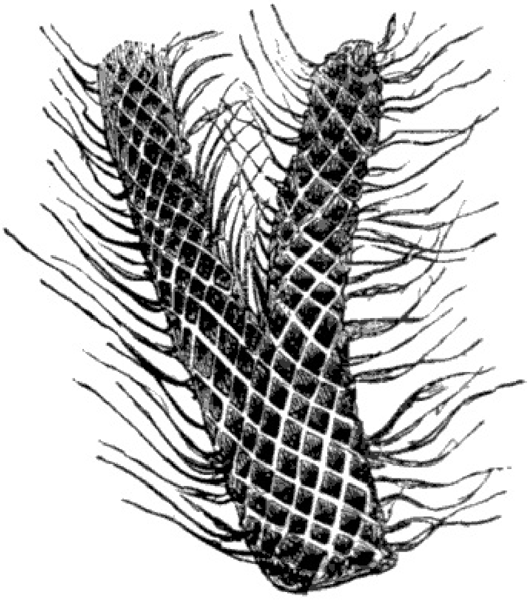


Fig. 46.—Lepidodendron elegans.

Carboniferous Limestone. (Sub-period.)

The seas of this epoch included an immense number of Zoophytes, nearly 400 species of Mollusca, and a few Crustaceans and Fishes. Among the Fishes, *Psammodus* and *Coccosteus*, whose massive teeth inserted in the palate were suitable for grinding; and the *Holoptychius* and *Megalichthys*, are the most important. The Mollusca are chiefly Brachiopods of great size. The Productæ attained here exceptional development, *Producta Martini* (Fig. 53), *P. semi-reticulata* and *P. gigantea*, being the most remarkable. Spirifers, also, were equally abundant, as *Spirifera trigonalis* and *S. glabra*. In *Terebratula hastata* the coloured bands, which adorned the shell of the living animal, have been preserved to us. The *Bellerophon*, whose convoluted shell in some respects resembles the Nautilus of our present seas, but without its chambered shell, were then represented by many species, among others by *Bellerophon costatus* (Fig. 54), and *B. hiulcus* (Fig. 56). Again, among the Cephalopods, we find the *Orthoceras* (Fig. 57), which resembled a straight Nautilus; and Goniatites (*Goniatites evolutus*, Fig. 55), a chambered shell allied to the Ammonite, which appeared in great numbers during the Secondary epoch. [142]

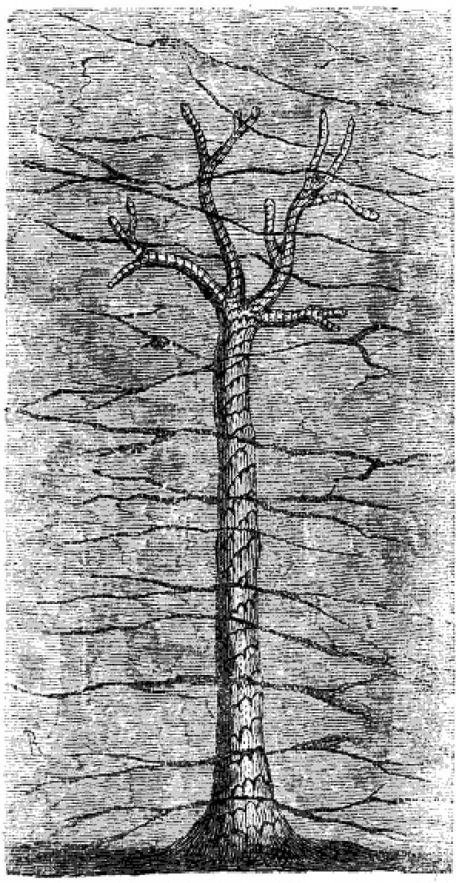


Fig. 47.—Lepidodendron Sternbergii.

Crustaceans are rare in the Carboniferous Limestone strata; the genus Phillipsia is the last of the

Trilobites, all of which became extinct at the close of this period. As to the Zoophytes, they consist chiefly of Crinoids and Corals. The Crinoids were represented by the genera *Platycrinus* and *Cyathocrinus*. We also have in these rocks many Polyzoa.

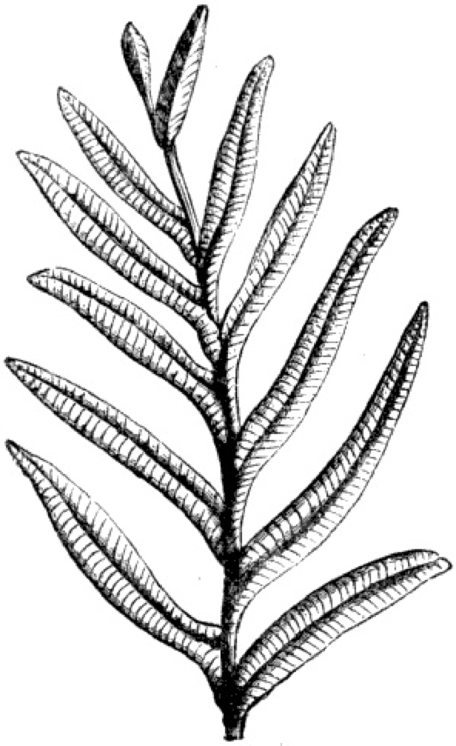


Fig. 48.—Pecopteris lonchitica, a little magnified.

Fig. 49.—Neuropteris gigantea.

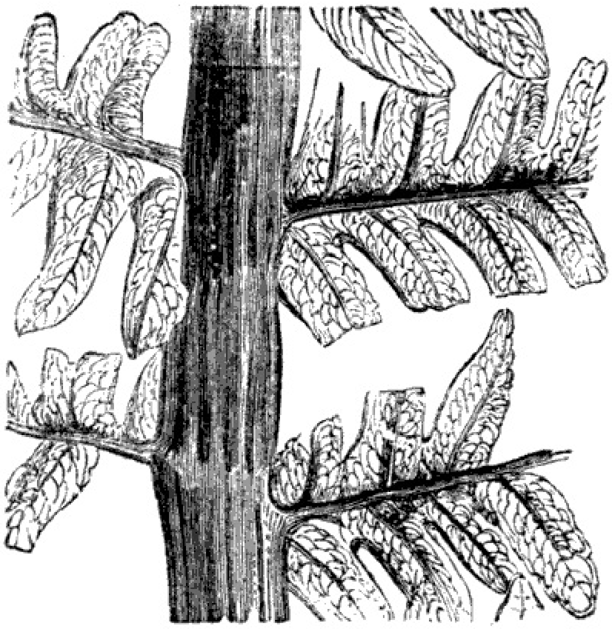


Fig. 50.—Lonchopteris Bricii.

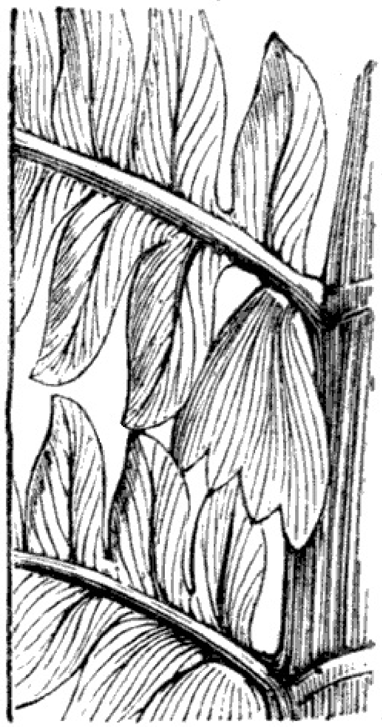


Fig. 51.—Odontopteris Brardii.

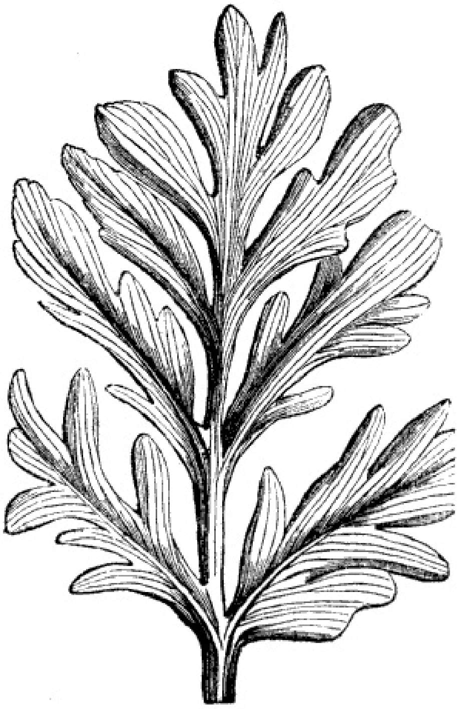


Fig. 52.—Sphenopteris artemisiæfolia, magnified.

Among the corals of the period, we may include the genera *Lithostrotion* and *Lonsdalea*, of which *Lithostrotion basaltiforme* (Fig. 58), and *Lonsdalea floriformis* (Fig. 59), are respectively the representatives, with *Amplexus coralloïdes*. Among the Polyzoa are the genera *Fenestrella* and *Polypora*. Lastly, to these we may add a group of animals which will play a very important part and become abundantly represented in the beds of later geological periods, but which already abounded in the seas of the Carboniferous period. We speak of the *Foraminifera* (Fig. 60), microscopic animals, which clustered either in one body, or divided into segments, and covered with a calcareous, many-chambered shell, as in Fig. 60, *Fusulina cylindrica*. These little creatures, which, during the Jurassic and Cretaceous periods, formed enormous banks and entire masses of rock, began to make their appearance in the period which now engages our attention. [143]

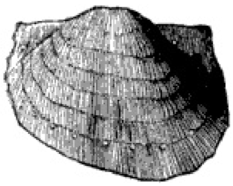


Fig. 53.—Producta Martini. One-third nat. size.

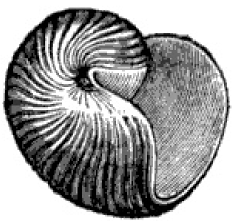


Fig. 54.—Bellerophon costatus. Half nat. size.

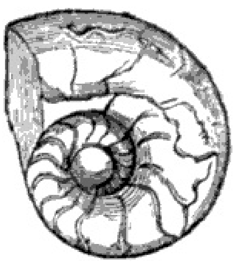


Fig. 55.—Goniatites evolutus. Nat. size.

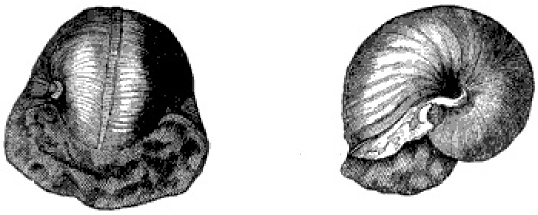


Fig. 56.—Bellerophon hiulcus.

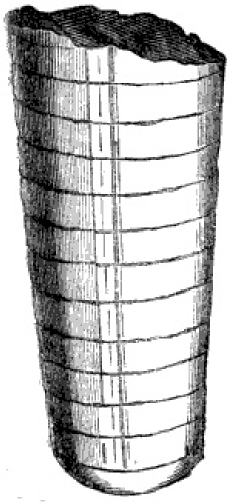


Fig. 57.—Orthoceras laterale.

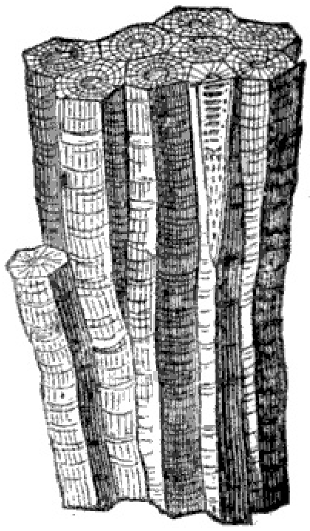


Fig. 58.—Lithostrotion basaltiforme.

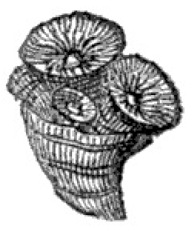
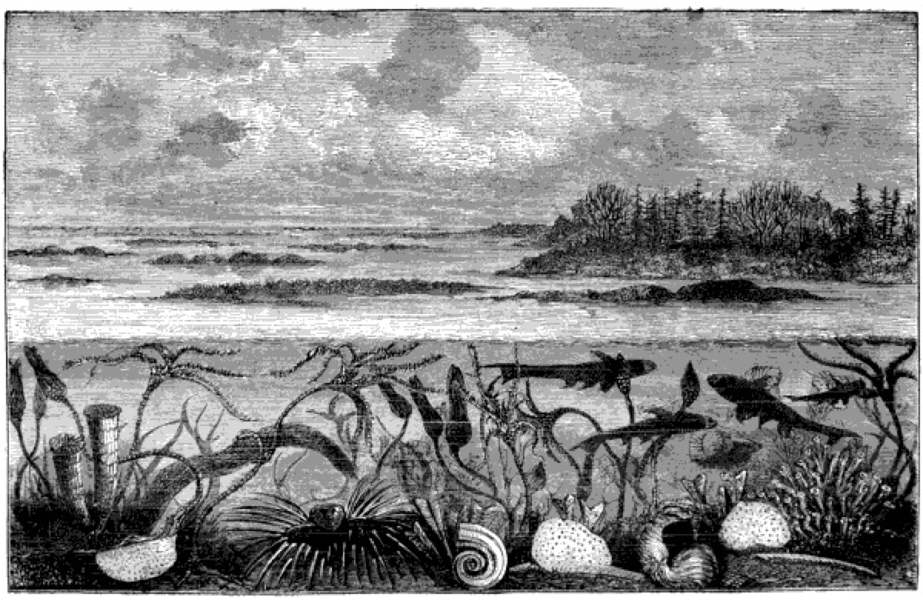


Fig. 59.—Lonsdalea floriformis.

The plate opposite (Plate X.) is a representation of an ideal aquarium, in which some of the more prominent species, which inhabited the seas during the period of the Carboniferous Limestone, are represented. On the right is a tribe of corals, with reflections of dazzling white: the species represented are, nearest the edge, the *Lasmocyathus*, the *Chætetes*, and the *Ptylopora*. The Mollusc which occupies the extremity of the elongated and conical tube in the shape of a sabre is an *Aploceras*. It seems to prepare the way for the Ammonite; for if this elongated shell were coiled round itself it would resemble the Ammonite and Nautilus. In the centre of the foreground we have *Bellerophon hiulcus* (Fig. 56), the *Nautilus Koninckii*, and a *Producta*, with the numerous spines which surround the shell. (See Fig. 62.) [146]

[147]



X.—Ideal view of marine life in the Carboniferous Period.

On the left are other corals: the *Cyathophyllum* with straight cylindrical stems; some Encrinites (*Cyathocrinus* and *Platycrinus*) wound round the trunk of a tree, or with their flexible stem floating in the water. Some Fishes, *Amblypterus*, move about amongst these creatures, the greater number of which are immovably attached, like plants, to the rock on which they grow.

In addition, this engraving shows us a series of islets, rising out of a tranquil sea. One of these is occupied by a forest, in which a distant view is presented of the general forms of the grand vegetation of the period. [149]

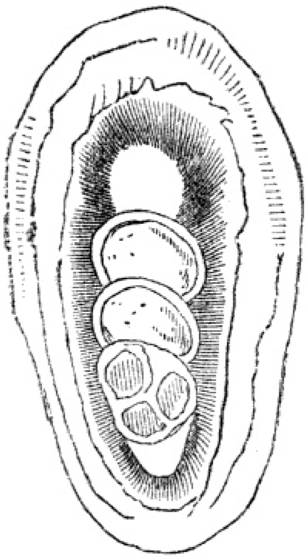


Fig. 60.—Foraminifera of the Mountain Limestone, forming the centre of an oolitic grain. Power 120.

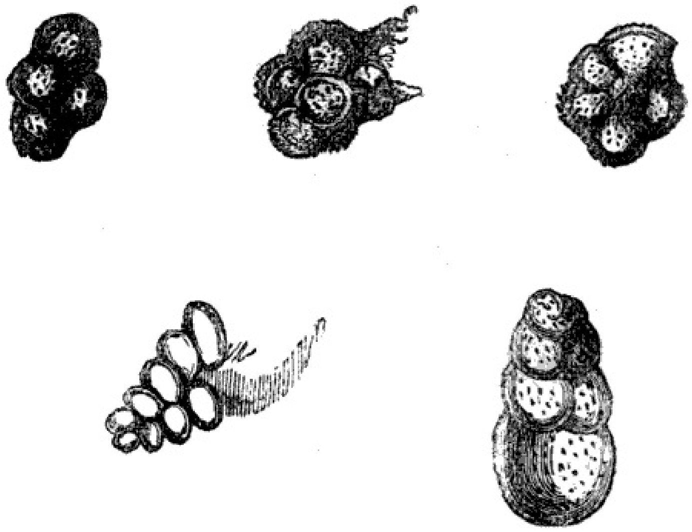


Fig. 61.—Foraminifera of the Chalk, obtained by brushing it in water. Power 120.

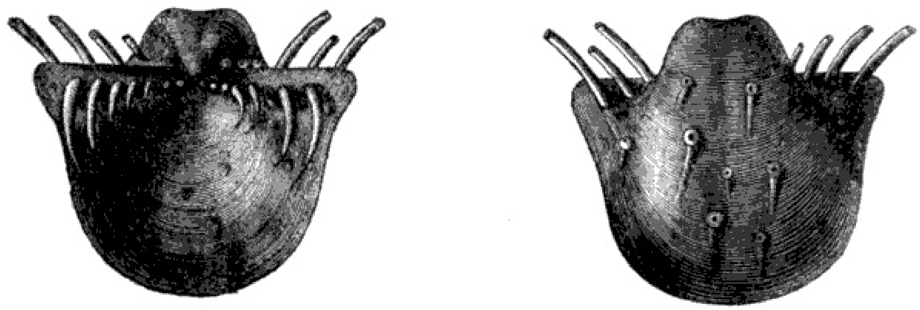


Fig. 62.—Producta horrida. Half natural size.

It is of importance to know the rocks formed by marine deposits during the era of the Carboniferous Limestone, inasmuch as they include coal, though in much smaller quantities than in the succeeding sub-period of the true coal-deposit. They consist essentially of a compact limestone, of a greyish-blue, and even black colour. The blow of the hammer causes them to exhale a somewhat fetid odour, which is owing to decomposed organic matter—the modified substance of the molluscs and zoophytes—of which it is to so great an extent composed, and whose remains are still easily recognised.

In the north of England, and many other parts of the British Islands, the Carboniferous Limestone forms, as we have seen, lofty mountain-masses, to which the term *Mountain Limestone* is sometimes applied.

In Derbyshire the formation constitutes rugged, lofty, and fantastically-shaped mountains, whose summits mingle with the clouds, while its picturesque character appears here, as well as farther north, in the *dales* or valleys, where rich meadows, through which the mountain streams force their way, seem to be closed abruptly by masses of rock, rising above them like the grey ruins of some ancient tower; while the mountain bases are pierced with caverns, and their sides covered with mosses and ferns, for the growth of which the limestone is particularly favourable.

The formation is *metalliferous*, and yields rich veins of lead-ore in Derbyshire, Cumberland, and [150]
other counties of Great Britain. The rock is found in Russia, in the north of France, and in Belgium, where it furnishes the common marbles, known as Flanders marble (*Marbre de Flandres* and *M. de petit granit*). These marbles are also quarried in other localities, such as Regneville (La Manche), either for the manufacture of lime or for ornamental stonework; one of the varieties quarried at Regneville, being black, with large yellow veins, is very pretty.

In France, the *Carboniferous Limestone*, with its sandstones and conglomerates, schists and limestones, is largely developed in the Vosges, in the Lyonnais, and in Languedoc, often in contact with syenites and porphyries, and other igneous rocks, by which it has been penetrated and disturbed, and even *metamorphosed* in many ways, by reason of the various kinds of rocks of which it is composed. In the United States the Carboniferous Limestone formation occupies a somewhat grand position in the rear of the Alleghanies. It is also found forming considerable ranges in our Australian colonies.

In consequence of their age, as compared with the Secondary and Tertiary limestones, the Carboniferous rocks are generally more marked and varied in character. The valley of the Meuse, from Namur to Chockier, above Liège, is cut out of this formation; and many of our readers will remember with delight the picturesque character of the scenery, especially that of the left bank of the celebrated river in question.

Coal Measures. (Sub-period.)

This terrestrial period is characterised, in a remarkable manner, by the abundance and strangeness of the vegetation which then covered the islands and continents of the whole globe. Upon all points of the earth, as we have said, this flora presented a striking uniformity. In comparing it with the vegetation of the present day, the learned French botanist, M. Brongniart, who has given particular attention to the flora of the Coal-measures, has arrived at the conclusion that it presented considerable analogy with that of the islands of the equatorial and torrid zone, in which a maritime climate and elevated temperature exist in the highest degree. It is believed that islands were very numerous at this period; that, in short, the dry land formed a sort of vast archipelago upon the general ocean, of no great depth, the islands being connected together and formed into continents as they gradually emerged from the ocean.

This flora, then, consists of great trees, and also of many smaller plants, which would form a [151] close, thick turf, or sod, when partially buried in marshes of almost unlimited extent. M. Brongniart indicates, as characterising the period, 500 species of plants belonging to families which we have already seen making their first appearance in the Devonian period, but which now attain a prodigious development. The ordinary dicotyledons and monocotyledons—that is, plants having seeds with two lobes in germinating, and plants having one seed-lobe—are almost entirely absent; the cryptogamic, or flowerless plants, predominate; especially Ferns, Lycopodiaceæ and Equisetaceæ—but of forms insulated and actually extinct in these same families. A few dicotyledonous gymnosperms, or naked-seed plants forming genera of Conifers, have completely disappeared, not only from the present flora, but since the close of the period under consideration, there being no trace of them in the succeeding Permian flora. Such is a general view of the features most characteristic of the Coal period, and of the Primary epoch in general. It differs, altogether and absolutely, from that of the present day; the climatic condition of these remote ages of the globe, however, enables us to comprehend the characteristics which distinguish its vegetation. A damp atmosphere, of an equable rather than an intense heat like that of the tropics, a soft light veiled by permanent fogs, were favourable to the growth of this peculiar vegetation, of which we search in vain for anything strictly analogous in our own days. The nearest approach to the climate and vegetation proper to the geological period which now occupies our attention, would probably be found in certain islands, or on the littoral of the Pacific Ocean—the island of Chloë, for example, where it rains during 300 days in the year, and where the light of the sun is shut out by perpetual fogs; where arborescent Ferns form forests, beneath whose shade grow herbaceous Ferns, which rise three feet and upwards above a marshy soil; which gives shelter also to a mass of cryptogamic plants, greatly resembling, in its main features, the flora of the Coal-measures. This flora was, as we have said, uniform and poor in its botanic genera, compared to the abundance and variety of the flora of the present time; but the few families of plants, which existed then, included many more species than are now produced in the same countries. The fossil Ferns of the coal-series in Europe, for instance, comprehend about 300 species, while all Europe now only produces fifty. The gymnosperms, which now muster only twenty-five species in Europe, then numbered more than 120.

It will simplify the classification of the flora of the Carboniferous epoch if we give a tabular arrangement adopted by the best authorities:—

[152]

	Dr. Lindley.	Brongniart.	
I.	Thallogens	Cryptogamous Amphigens, or Cellular Cryptogams	Lichens, Sea-weeds, Fungi.
II.	Acrogens	Cryptogamous Acrogens	Club-mosses, Equiseta, Ferns, Lycopods, Lepidodendra.
III.	Gymnogens	Dicotyledonous Gymnosperms	Conifers and Cycads.
IV.	Exogens	Dicotyledonous Angiosperms	Compositæ, Leguminosæ, Umbelliferæ, Cruciferæ, Heaths. All European except Conifers.
V.	Endogens	Monocotyledons	Palms, Lilies, Aloes, Rushes, Grasses.

Calamites are among the most abundant fossil plants of the Carboniferous period, and occur also in the Devonian. They are preserved as striated, jointed, cylindrical, or compressed stems, with fluted channels or furrows at their sides, and sometimes surrounded by a bituminous coating, the remains of a cortical integument. They were originally hollow, but the cavity is usually filled up with a substance into which they themselves have been converted. They were divided into joints or segments, and when broken across at their articulations they show a number of striæ, originating in the furrows of the sides, and turning inwards towards the centre of the stem. It is not known whether this structure was connected with an imperfect diaphragm stretched across the hollow of the stem at each joint, or merely represented the ends of woody plates of which the solid part of the stem is composed. Their extremities have been discovered to taper gradually to a point, as represented in *C. cannæformis* (Fig. 64), or to end abruptly, the intervals becoming shorter and smaller. The obtuse point is now found to be the root. Calamites are regarded as Equisetaceous plants; later botanists consider that they belong to an extinct family of plants. *Sigillariæ* are the most abundant of all plants in the coal formation, and were those principally concerned in the accumulation of the mineral fuel of the Coal-measures. Not a mine is opened, nor a heap of shale thrown out, but there occur fragments of its stem, marked externally with small rounded impressions, and in the centre slight tubercles, with a quincuncial arrangement. From the tubercles arise long ribbon-shaped bodies, which have been traced in some instances to the length of twenty feet.

[153]

Fig. 63.—Sphenophyllum restored.

In the family of the Sigillarias we have already presented the bark of *S. lævigata*, at page 138; on page 157 we give a drawing of the bark of *S. reniformis*, one-third the natural size (Fig. 65). [154]

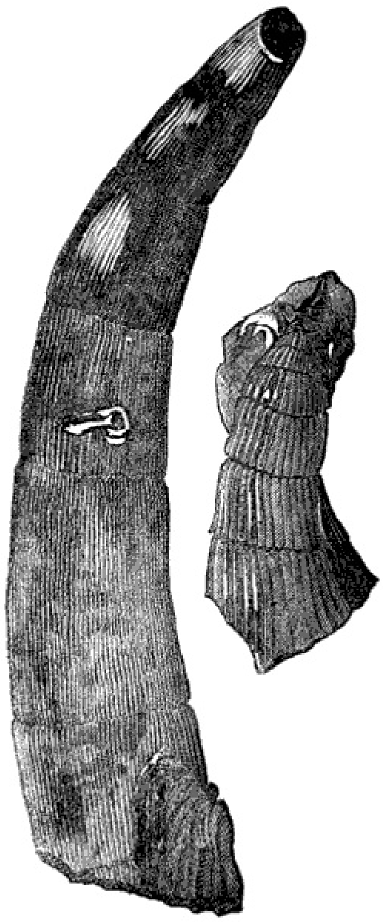


Fig. 64.—Calamites cannæformis.
One-third natural size.

In the family of the Asterophyllites, the leaf of *A. foliosa* (Fig. 66); and the foliage of *Annularia orifolia* (Fig. 67) are remarkable. In addition to these, we present, in Fig. 63, a restoration of one of these Asterophyllites, the *Sphenophyllum*, after M. Eugene Deslongchamps. This herbaceous tree, like the Calamites, would present the appearance of an immense asparagus, twenty-five to thirty feet high. It is represented here with its branches and *fronds*, which bear some resemblance to the leaves of the ginkgo. The bud, as represented in the figure, is terminal, and not axillary, as in some of the Calamites.

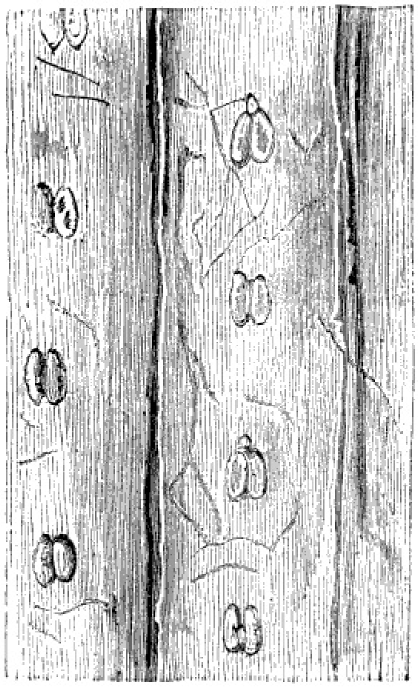


Fig. 65.—Sigillaria reniformis.

If, during the Coal-period, the vegetable kingdom had reached its maximum, the animal kingdom, on the contrary, was poorly represented. Some remains have been found, both in America and Germany, consisting of portions of the skeleton and the impressions of the footsteps of a Reptile, which has received the name of Archegosaurus. In Fig. 68 is represented the head and neck of *Archegosaurus minor*, found in 1847 in the coal-basin of Saarbruck between Strasbourg and Trèves. Among the animals of this period we find a few Fishes, analogous to those of the Devonian formation. These are the *Holoptychius* and *Megalichthys*, having jaw-bones armed with [157] enormous teeth. Scales of *Pygopterus* have been found in the Northumberland Coal-shale at Newsham Colliery, and also in the Staffordshire Coal-shale. Some winged insects would probably join this slender group of living beings. It may then be said with truth that the immense forests and marshy plains, crowded with trees, shrubs, and herbaceous plants, which formed on the the innumerable isles of the period a thick and tufted sward, were almost destitute of animals.

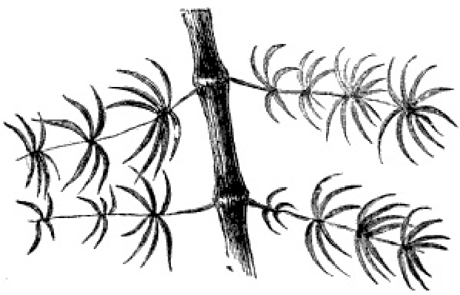


Fig. 66.—Asterophyllites foliosa.

XI.—Ideal view of a marshy forest of the Coal Period.

On the opposite page (Pl. XI.) M. Riou has attempted, under the directions of M. Deslongchamps, to reproduce the aspect of Nature during the period. A marsh and forest of the Coal-period are here represented, with a short and thick vegetation, a sort of grass composed of herbaceous Fern and mare’s-tail. Several trees of forest-height raise their heads above this lacustrine vegetation.

On the left are seen the naked trunk of a *Lepidodendron* and a *Sigillaria*, an arborescent Fern rising between the two trunks. At the foot of these great trees an herbaceous Fern and a *Stigmaria* appear, whose long ramification of roots, provided with reproductive spores, extend to [158] the water. On the right is the naked trunk of another *Sigillaria*, a tree whose foliage is altogether unknown, a *Sphenophyllum*, and a *Conifer*. It is difficult to describe with precision the species of this last family, the impressions of which are, nevertheless, very abundant in the Coal-measures.

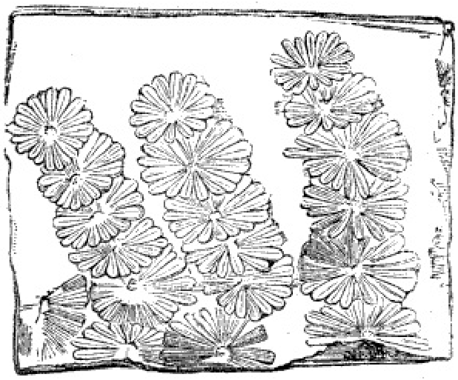


Fig. 67.—Annularia orifolia.

In front of this group we see two trunks broken and overthrown. These are a *Lepidodendron* and *Sigillaria*, mingling with a heap of vegetable débris in course of decomposition, from which a rich humus will be formed, upon which new generations of plants will soon develop themselves. Some herbaceous Ferns and buds of *Calamites* rise out of the waters of the marsh.

A few Fishes belonging to the period swim on the surface of the water, and the aquatic reptile *Archegosaurus* shows its long and pointed head—the only part of the animal which has hitherto been discovered (Fig. 68). A *Stigmaria* extends its roots into the water, and the pretty *Asterophyllites*, with its finely-cut stems, rises above it in the foreground.

A forest, composed of *Lepidodendra* and *Calamites*, forms the background to the picture.

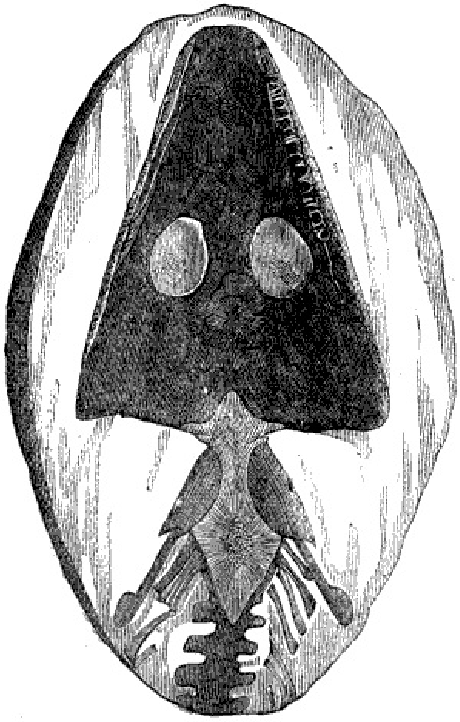


Fig. 68.—Head and neck of Archegosaurus minor.

Formation of Beds of Coal.

Coal, as we have said, is only the result of a partial decomposition of the plants which covered the earth during a geological period of immense duration. No one, now, has any doubt that this is its origin. In coal-mines it is not unusual to find fragments of the very plants whose trunks and leaves characterise the Coal-measures, or Carboniferous era. Immense trunks of trees have also been met with in the middle of a seam of coal. In the coal-mines of Treuil,[44] at St. Etienne, for instance, vertical trunks of fossil trees, resembling bamboos or large Equiseta, are not only mixed with the coal, but stand erect, traversing the overlying beds of micaceous sandstone in the manner represented in the engraving, which has been reproduced from a drawing by M. Ad. Brongniart (Fig. 69).

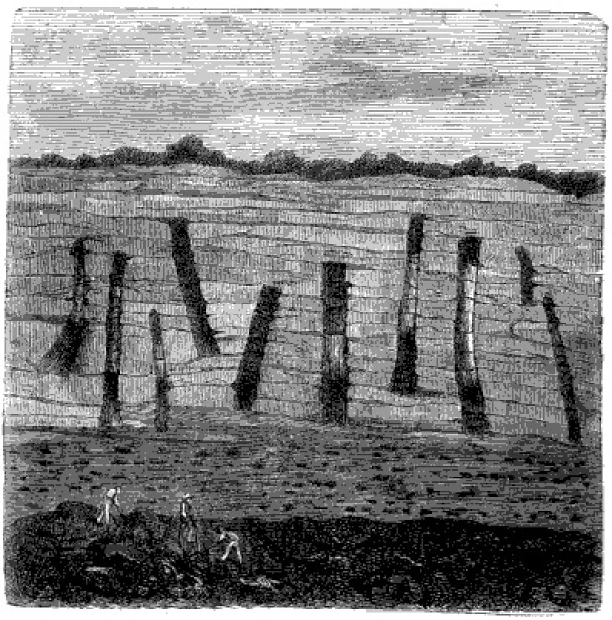


Fig. 69.—Treuil coal-mine, at St. Etienne.

In England it is the same; entire trees are found lying across the coal-beds. Sir Charles Lyell tells us[45] that in Parkfield Colliery, South Staffordshire, there was discovered in 1854, upon a surface of about a quarter of an acre, a bed of coal which has furnished as many as seventy-three stumps of trees with their roots attached, some of the former measuring more than eight feet in circumference; their roots formed part of a seam of coal ten inches thick, resting on a layer of clay two inches thick, under which was a second forest resting on a band of coal from two to five feet thick. Underneath this, again, was a third forest, with large stumps of *Lepidodendra*, *Calamites*, and other trees.[46]

In the lofty cliffs of the South Joggins, in the Bay of Fundy, in Nova Scotia, Sir Charles Lyell found in one portion of the coal-field 1,500 feet thick, as many as sixty-eight different surfaces, presenting evident traces of as many old soils of forests, where the trunks of the trees were still furnished with roots.[47]

We will endeavour to establish here the true geological origin of coal, in order that no doubt may exist in the minds of our readers on a subject of such importance. In order to explain the presence of coal in the depths of the earth, there are only two possible hypotheses. This vegetable débris may either result from the burying of plants brought from afar and transported by river or maritime currents, forming immense rafts, which may have grounded in different places and been covered subsequently by sedimentary deposits; or the trees may have grown on the spot where they perished, and where they are now found. Let us examine each of these [160]
theories.

Can the coal-beds result from the transport by water, and burial underground, of immense rafts formed of the trunks of trees? The hypothesis has against it the enormous height which must be conceded to the raft, in order to form coal-seams as thick as some of those which are worked in our collieries. If we take into consideration the specific gravity of wood, and the amount of carbon it contains, we find that the coal-deposits can only be about seven-hundredths of the [161]
volume of the original wood and other vegetable materials from which they are formed. If we take into account, besides, the numerous voids necessarily arising from the loose packing of the materials forming the supposed raft, as compared with the compactness of coal, this may fairly be reduced to five-hundredths. A bed of coal, for instance, sixteen feet thick, would have required a raft 310 feet high for its formation. These accumulations of wood could never have arranged themselves with sufficient regularity to form those well-stratified coal-beds, maintaining a uniform thickness over many miles, and that are seen in most coal-fields to lie one above another in succession, separated by beds of sandstone or shale. And even admitting the possibility of a slow and gradual accumulation of vegetable débris, like that which reaches the mouth of a river, would not the plants in that case be buried in great quantities of mud and earth? Now, in most of our coal-beds the proportion of earthy matter does not exceed fifteen per cent. of the entire mass. If we bear in mind, finally, the remarkable parallelism existing in the stratification of the coal-formation, and the state of preservation in which the impressions of the most delicate vegetable forms are discovered, it will, we think, be proved to demonstration, that those coal-seams have been formed in perfect tranquillity. We are, then, forced to the conclusion that coal results from the mineralisation of plants which has taken place on the spot; that is to say, in the very place where the plants lived and died.

It was suggested long ago by Bakewell, from the occurrence of the same peculiar kind of fireclay under each bed of coal, that it was the soil proper for the production of those plants from which coal has been formed.[48]

It has, also, been pointed out by Sir William Logan, as the result of his observations in the South Wales coal-field, and afterwards by Sir Henry De la Beche, and subsequently confirmed by the observations of Sir Charles Lyell in America, that not only in this country, but in the coal-fields of Nova Scotia, the United States, &c., every layer of true coal is co-extensive with and invariably underlaid by a marked stratum of arenaceous clay of greater or less thickness, which, from its position relatively to the coal has been long known to coal-miners, among other terms, by the name of *under-clay*.

The clay-beds, “which vary in thickness from a few inches to more than ten feet, are penetrated in all directions by a confused and tangled collection of the roots and leaves, as they may be, of [162]
the *Stigmaria ficoides*, these being frequently traceable to the main stem (*Sigillaria*), which varies in diameter from about two inches to half a foot. The main stems are noticed as occurring nearer the top than the bottom of the bed, as usually of considerable length, the leaves or roots radiating from them in a tortuous irregular course to considerable distances, and as so mingled with the under-clay that it is not possible to cut out a cubic foot of it which does not contain portions of the plant.” (Logan “On the Characters of the Beds of Clay immediately below the Coal-seams of South Wales,” Geol. Transactions, Second Series, vol. vi., pp. 491-2. An account of these beds had previously been published by Mr. Logan in the Annual Report of the Royal Institution of South Wales for 1839.)

From the circumstance of the main stem of the Sigillaria, of which the *Stigmaria ficoides* have been traced to be merely a continuation, it was inferred by the above-mentioned authors, and has subsequently been generally recognised as probably the truth, that the roots found in the underclay are merely those of the plant (*Sigillaria*), the stem of which is met with in the overlying coal-beds—in fact, that the *Stigmaria ficoides* is only the root of the *Sigillaria*, and not a distinct plant, as was once supposed to be the case.

This being granted, it is a natural inference to suppose that the present indurated under-clay is only another condition of that soft, silty soil, or of that finely levigated muddy sediment—most likely of still and shallow water—in which the vegetation grew, the remains of which were afterwards carbonised and converted into coal.[49]

In order thoroughly to comprehend the phenomena of the transformation into coal of the forests and of the herbaceous plants which filled the marshes and swamps of the ancient world, there is another consideration to be presented. During the coal-period, the terrestrial crust was subjected to alternate movements of elevation and depression of the internal liquid mass, under the impulse of the solar and lunar attractions to which they would be subject, as our seas are now, giving rise to a sort of subterranean tide, operating at intervals, more or less widely apart, upon the weaker parts of the crust, and producing considerable subsidences of the ground. It might, perhaps, happen that, in consequence of a subsidence produced in such a manner, the vegetation of the coal-period would be submerged, and the shrubs and plants which covered the surface of [163] the earth would finally become buried under water. After this submergence new forests sprung up in the same place. Owing to another submergence, the second forests were depressed in their turn, and again covered by water. It is probably by a series of repetitions of this double phenomenon—this submergence of whole regions of forest, and the development upon the same site of new growths of vegetation—that the enormous accumulations of semi-decomposed plants, which constitute the Coal-measures, have been formed in a long series of ages.

But, has coal been produced from the larger plants only—for example, from the great forest-trees of the period, such as the Lepidodendra, Sigillariæ, Calamites, and Sphenophylla? That is scarcely probable, for many coal-deposits contain no vestiges of the great trees of the period, but only of Ferns and other herbaceous plants of small size. It is, therefore, presumable that the larger vegetation has been almost unconnected with the formation of coal, or, at least, that it has played a minor part in its production. In all probability there existed in the coal-period, as at the present time, two distinct kinds of vegetation: one formed of lofty forest-trees, growing on the higher grounds; the other, herbaceous and aquatic plants, growing on marshy plains. It is the latter kind of vegetation, probably, which has mostly furnished the material for the coal; in the same way that marsh-plants have, during historic times and up to the present day, supplied our existing peat, which may be regarded as a sort of contemporaneous incipient coal.

To what modification has the vegetation of the ancient world been subjected to attain that carbonised state, which constitutes coal? The submerged plants would, at first, be a light, spongy mass, in all respects resembling the peat-moss of our moors and marshes. While under water, and afterwards, when covered with sediment, these vegetable masses underwent a partial decomposition—a moist, putrefactive fermentation, accompanied by the production of much carburetted hydrogen and carbonic acid gas. In this way, the hydrogen escaping in the form of carburetted hydrogen, and the oxygen in the form of carbonic acid gas, the carbon became more concentrated, and coal was ultimately formed. This emission of carburetted hydrogen gas would, probably, continue after the peat-beds were buried beneath the strata which were deposited and accumulated upon them. The mere weight and pressure of the superincumbent mass, continued at an increasing ratio during a long series of ages, have given to the coal its density and compact state.

The heat emanating from the interior of the globe would, also, exercise a great influence upon [164] the final result. It is to these two causes—that is to say, to pressure and to the central heat—that we may attribute the differences which exist in the mineral characters of various kinds of coal. The inferior beds are *drier* and more compact than the upper ones; or less bituminous, because their mineralisation has been completed under the influence of a higher temperature, and at the same time under a greater pressure.

An experiment, attempted for the first time in 1833, at Sain-Bel, afterwards repeated by M. Cagniard de la Tour, and completed at Saint-Etienne by M. Baroulier in 1858, fully demonstrates the process by which coal was formed. These gentlemen succeeded in producing a very compact coal artificially, by subjecting wood and other vegetable substances to the double influence of heat and pressure combined.

The apparatus employed for this experiment by M. Baroulier, at Saint-Etienne, allowed the exposure of the strongly compressed vegetable matter enveloped in moist clay, to the influence of a long-continued temperature of from 200° to 300° Centigrade. This apparatus, without being absolutely closed, offered obstacles to the escape of gases or vapours in such a manner that the decomposition of the organic matters took place in the medium saturated with moisture, and under a pressure which prevented the escape of the elements of which it was composed. By placing in these conditions the sawdust of various kinds of wood, products were obtained which resembled in many respects, sometimes brilliant shining coal, and at others a dull coal. These differences, moreover, varied with the conditions of the experiment and the nature of the wood employed; thus explaining the striped appearance of coal when composed alternately of shining and dull veins.

When the stems and leaves of ferns are compressed between beds of clay or pozzuolana, they are decomposed by the pressure only, and form on these blocks a carbonaceous layer, and impressions bearing a close resemblance to those which blocks of coal frequently exhibit. These last-mentioned experiments, which were first made by Dr. Tyndall, leave no room for doubt that coal has been formed from the plants of the ancient world.

Passing from these speculations to the Coal-measures:—

This formation is composed of a succession of beds, of various thicknesses, consisting of sandstones or gritstones, of clays and shales, sometimes so bituminous as to be inflammable—and passing, in short, into an imperfect kind of *coal*. These rocks are interstratified with each other in such a manner that they may consist of many alterations. Carbonate of protoxide of iron (clay-ironstone) may also be considered a constituent of this formation; its extensive [165] dissemination in connection with coal in some parts of Great Britain has been of immense advantage to the ironworks of this country, in many parts of which blast-furnaces for the manufacture of iron rise by hundreds alongside of the coal-pits from which they are fed. In France, as is frequently the case in England, this argillaceous iron-ore only occurs in nodules or lenticular masses, much interrupted; so that it becomes necessary in that country, as in this, to find other ores of iron to supply the wants of the foundries. Fig. 70 gives an idea of the ordinary arrangement of the coal-beds, one of which is seen interstratified between two parallel and nearly horizontal beds of argillaceous shale, containing nodules of clay iron-ore—a disposition very common in English collieries. The coal-basin of Aveyron, in France, presents an analogous mode of occurrence.

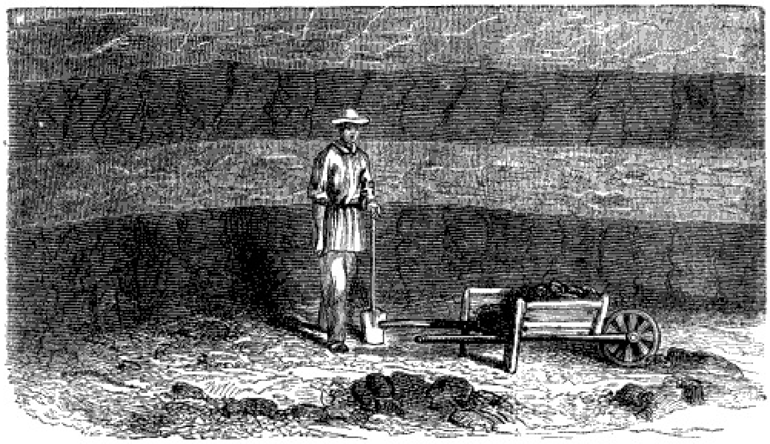


Fig. 70.—Stratification of coal-beds.

The frequent presence of carbonate of iron in the coal-measures is a most fortunate circumstance for mining industry. When the miner finds, in the same spot, the ore of iron and the fuel required for smelting it, arrangements for working them can be established under the most favourable conditions. Such is the case in the coal-fields of Great Britain, and also in France to a less extent—that is to say, only at Saint-Etienne and Alais.

The extent of the Coal-measures, in various parts of the world, may be briefly and approximately stated as follows:— [166]

ESTIMATED AREA OF THE COAL-MEASURES OF THE WORLD.

		Square Miles.
United States	220,166	420,166
„ Lignites and inferior Coals	200,000	
British Possessions in North America		2,200
Great Britain		3,000
France		2,000
Belgium		468
Rhenish Prussia and Saarbrück		1,550
Westphalia		400
Bohemia		620
Saxony		66
The Asturias, in Spain		310
Russia		11,000
Islands of the Pacific and Indian Ocean		Unknown.

The American continent, then, contains much more extensive coal-fields than Europe; it possesses very nearly two square miles of coal-fields for every five miles of its surface; but it must be added that these immense fields of coal have not, hitherto, been productive in proportion to their extent. The following Table represents the annual produce of the collieries of America and Europe:—

		Tons.
British Islands	(in 1870)	110,431,192
United States		14,593,659
Belgium	(in 1870)	13,697,118
France	(in 1864)	10,000,000
„	(in 1866)	11,807,142
Prussia	(in 1864)	21,197,266
Nassau	(in 1864)	2,345,459
Netherlands	(in 1864)	24,815
Austria	(in 1864)	4,589,014
Spain		500,000

We thus see that the United States holds a secondary place as a coal-producing country; raising one-eleventh part of the out-put of the whole of Europe, and about one-eighth part of the quantity produced by Great Britain.

The Coal-measures of England and Scotland cover a large area; and attempts have been made to

estimate the quantity of fuel they contain. The estimate made by the Royal Commission on the [167]
coal in the United Kingdom may be considered as the nearest; and, in this Report, lately published, it is stated that in the ascertained coal-fields of the United Kingdom there is an aggregate quantity of 146,480,000,000 tons of coal, which may be reasonably expected to be available for use. In the coal-field of South Wales, ascertained by actual measurement to attain the extraordinary thickness of 11,000 feet of Coal-measures, there are 100 different seams of coal, affording an aggregate thickness of 120 feet, mostly in thin beds, but varying from six inches to more than ten feet. Professor J. Phillips estimates the thickness of the coal-bearing strata of the north of England at 3,000 feet; but these, in common with all other coal-fields, contain, along with many beds of the mineral in a more or less pure state, interstratified beds of sandstones, shales, and limestone; the real coal-seams, to the number of twenty or thirty, not exceeding sixty feet in thickness in the aggregate. The Scottish Coal-measures have a thickness of 3,000 feet, with similar intercalations of other carboniferous rocks.

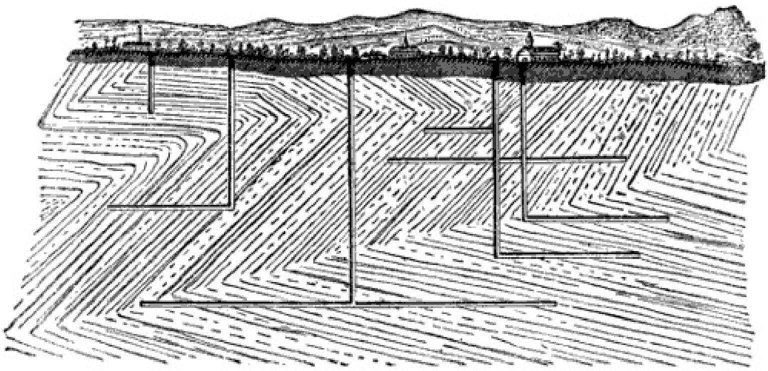


Fig. 71.—Contortions of Coal-beds.

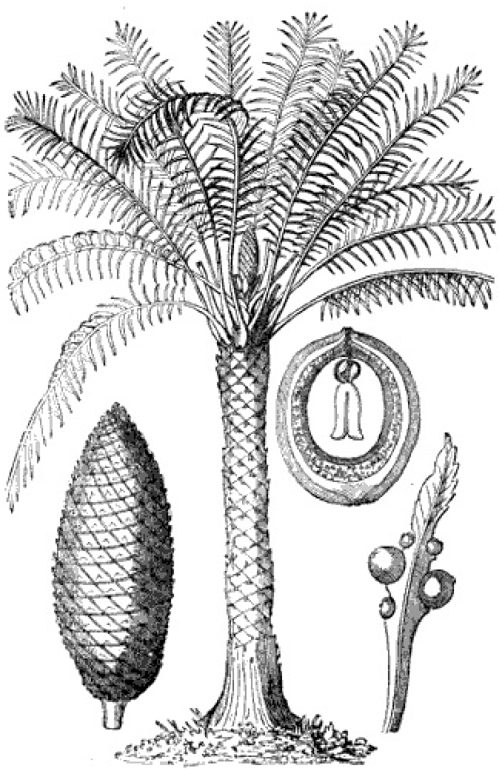


Fig. 72.—Cycas circinalis (living form).

The coal-basin of Belgium and of the north of France forms a nearly continuous zone from Liége, Namur, Charleroi, and Mons, to Valenciennes, Douai, and Béthune. The beds of coal there are from fifty to one hundred and ten in number, and their thickness varies from ten inches to six feet. Some coal-fields which are situated beneath the Secondary formations of the centre and
south of France possess beds fewer in number, but individually thicker and less regularly [168]
stratified. The two basins of the Saône-et-Loire, the principal mines of which are at Creuzot, Blanzy, Montchanin, and Epinac, only contain ten beds; but some of these (as at Montchanin)
attain 30, 100, and even 130 feet in thickness. The coal-basin of the Loire is that which contains [169]
the greatest total thickness of coal-beds: the seams there are twenty-five in number. After those of the North—of the Saône-et-Loire and of the Loire—the principal basins in France are those of the Allier, where very important beds are worked at Commentry and Bezenet; the basin of Brassac, which commences at the confluence of the Allier and the Alagnon; the basin of the Aveyron, known by the collieries of Decazeville and Aubin; the basin of the Gard, and of Grand'-Combe. Besides these principal basins, there are a great many others of scarcely less importance, which yield annually to France from six to seven million tons of coal.

The seams of coal are rarely found in the horizontal position in which their original formation took place. They have been since much crumpled and distorted, forced into basin-shaped cavities, with minor undulations, and affected by numerous flexures and other disturbances. They are frequently found broken up and distorted by faults, and even folded back on themselves into zigzag forms, as represented in the engraving (Fig. 71, p. 167), which is a mode of occurrence common in all the Coal-measures of Somersetshire and in the basins of Belgium and the north of France. Vertical pits, sunk on coal which has been subjected to this kind of contortion and disturbance, sometimes traverse the same beds many times.

PERMIAN PERIOD. [170]

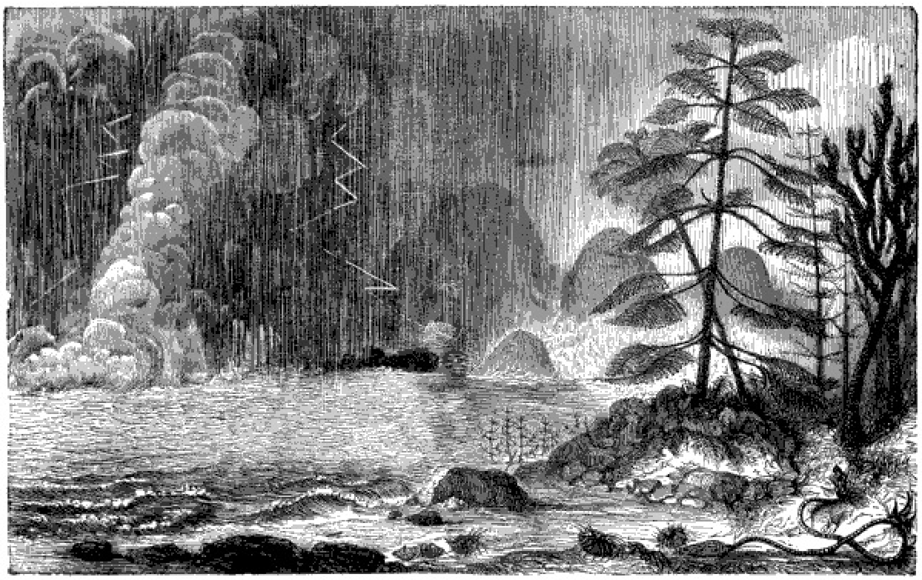
The name "Permian" was proposed by Sir Roderick I. Murchison, in the year 1841, for certain deposits which are now known to terminate upwards the great primeval or Palæozoic Series.[50]

This natural group consists, in descending order, in Germany, of the Zechstein, the Kupfer-schiefer, Roth-liegende, &c. In England it is usually divided into Magnesian Limestone or Zechstein, with subordinate Marl-slate or Kupfer-schiefer, and Rothliegende. The chief calcareous member of this group of strata is termed in Germany the "Zechstein," in England the "Magnesian Limestone;" but, as magnesian limestones have been produced at many geological periods, and as the German Zechstein is only a part of a group, the other members of which are known as "Kupfer-schiefer" ("copper-slate"), "Roth-todt-liegende" (the "Lower New Red" of English geologists), &c., it was manifest that a single name for the whole was much needed. Finding, in his examination of Russia in Europe, that this group was a great and united physical series of marls, limestones, sandstones, and conglomerates, occupying a region much larger than France, and of which the Government of Perm formed a central part, Sir Roderick proposed that the name of Permian, now in general use, should be thereto applied.

Extended researches have shown, from the character of its embedded organic remains, that it is closely allied to, but distinct from, the carboniferous strata below it, and is entirely distinct from the overlying Trias, or New Red Sandstone, which forms the base of the great series of the Secondary rocks.

Geology is, however, not only indebted to Sir Roderick Murchison for this classification and nomenclature, but also to him, in conjunction with Professor Sedgwick, for the name "*Devonian*," as an equivalent to "Old Red Sandstone;" whilst every geologist knows that Sir R. Murchison is the sole author of the Silurian System.

[172]



XII.—Ideal landscape of the Permian Period.

The Permian rocks have of late years assumed great interest, particularly in England, in consequence of the evidence their correct determination affords with regard to the probable extent, beneath them, of the coal-bearing strata which they overlie and conceal; thus tending to throw a light upon the duration of our coal-fields, one of the most important questions of the day in connection with our industrial resources and national prosperity. [173]

On the opposite page an ideal view of the earth during the Permian period is represented (Pl. XII.). In the background, on the right, is seen a series of syenitic and porphyritic domes, recently thrown up; while a mass of steam and vapour rises in columns from the midst of the sea, resulting from the heat given out by the porphyries and syenites. Having attained a certain height in the cooler atmosphere, the columns of steam become condensed and fall in torrents of rain. The evaporation of water in such vast masses being necessarily accompanied by an enormous disengagement of electricity, this imposing scene of the primitive world is illuminated by brilliant flashes of lightning, accompanied by reverberating peals of thunder. In the foreground, on the right, rise groups of Tree-ferns, Lepidodendra, and Walchias, of the preceding period. On the sea-shore, and left exposed by the retiring tide, are Molluscs and Zoophytes peculiar to the period, such as *Producta*, *Spirifera*, and *Encrinites*; pretty plants—the *Asterophyllites*—which we have noticed in our description of the Carboniferous age, are growing at the water's edge, not far from the shore.

During the Permian period the species of plants and animals were nearly the same as those already described as belonging to the Carboniferous period. Footprints of reptilian animals have been found in the Permian beds near Kenilworth, in the red sandstones of that age in the Vale of Eden, and in the sandstones of Corncockle Moor, and other parts of Dumfriesshire. These footprints, together with the occurrence of current-markings or ripplings, sun-cracks, and the pittings of rain-drops impressed on the surfaces of the beds, indicate that they were made upon damp surfaces, which afterwards became dried by the sun before the flooded waters covered them with fresh deposits of sediment, in the way that now happens during variations of the seasons in many salt lakes.[51] M. Ad. Brongniart has described the forms of the Permian flora as being intermediate between those of the Carboniferous period and of that which succeeds it.

Although the Permian flora indicates a climate similar to that which prevailed during the Carboniferous period, it has been pointed out by Professor Ramsay, as long ago as 1855, that the Permian breccia of Shropshire, Worcestershire, &c., affords strong proofs of being the result of direct glacial action, and of the consequent existence at the period of glaciers and icebergs. [174]

That such a state of things is not inconsistent with the prevalence of a moist, equable, and temperate climate, necessary for the preservation of a luxuriant flora like that of the period in question, is shown in New Zealand; where, with a climate and vegetation approximating to those of the Carboniferous period, there are also glaciers at the present day in the southern island.

Professor King has published a valuable memoir on the Permian fossils of England, in the Proceedings of the Palæontographical Society, in which the following Table is given (in descending order) of the Permian system of the North of England, as compared with that of Thuringia:—

North of England.	Thuringia.	Mineral Character.
1. Crystalline, earthy, compact, and oolitic limestones	1. Stinkstein	1. Oolitic limestones.
2. Brecciated and pseudo-brecciated limestones	2. Rauchwacke	2. Conglomerates.
3. Fossiliferous limestone	3. Upper Zechstein, or Dolomit-Zechstein	3. Marlstones.
4. Compact limestone	4. Lower Zechstein	4. Magnesian limestones.
5. Marl-slate	5. Mergel-Schiefer or Kupferschiefer	5. Red and green grits with copper-ore.
6. Lower sandstones, and sands of various colours	6. Todteliegende	6. White limestone with gypsum and white salt.

At the base of the system lies a band of *lower sandstone* (No. 6) of various colours, separating the Magnesian Limestone from the coal in Yorkshire and Durham; sometimes associated with red marl and gypsum, but with the same obscure relations in all these beds which usually attend the close of one series and the commencement of another; the imbedded plants being, in some cases, stated to be identical with those of the Carboniferous series. In Thuringia the *Rothliegende*, or *red-lyer*, a great deposit of red sandstone and conglomerate, associated with porphyry, basaltic trap, and amygdaloid, lies at the base of the system. Among the fossils of this age are the silicified trunks of Tree-ferns (*Psaronius*), the bark of which is surrounded by dense masses of air- [175]
roots, which often double or quadruple the diameter of the original stem; in this respect bearing a strong resemblance to the living arborescent ferns of New Zealand.

The marl-slate (No. 5) consists of hard calcareous shales, marl-slates, and thin-bedded limestone, the whole nearly thirty feet thick in Durham, and yielding many fine specimens of Ganoid and Placoid fishes—*Palæoniscus*, *Pygopterus*, *Cœlacanthus*, and *Platysomus*—genera which all belong to the Carboniferous system, and which Professor King thinks probably lived at no great distance from the shore; but the Permian species of the marl-slate of England are identical with those of the copper-slate of Thuringia. Agassiz was the first to point out a remarkable peculiarity in the forms of the fishes which lived before and after this period. In most living fishes the trunk seems to terminate in the middle of the root of the tail, whose free margin is "homocercal" (even-tail), that is, either rounded, or, if forked, divided into two equal lobes. In Palæoniscus, and most Palæozoic fishes, the axis of the body is continued into the upper lobe of the tail, which is thus rendered unsymmetrical, as in the living sharks and sturgeons. The latter form, which Agassiz termed "heterocercal" (unequal-tail) is only in a very general way distinctive of Palæozoic fishes, since this asymmetry exists, though in a minor degree, in many living genera besides those just mentioned. The compact limestone (No. 4) is rich in Polyzoa. The fossiliferous limestone (No. 3), Mr. King considers, is a deep-water formation, from the numerous Polyzoa which it contains. One of these, *Fenestella retiformis*, found in the Permian rocks of England and Germany, sometimes measures eight inches in width.

Many species of Mollusca, and especially Brachiopoda, appear in the Permian seas of this age, *Spirifera* and *Producta* being the most characteristic.

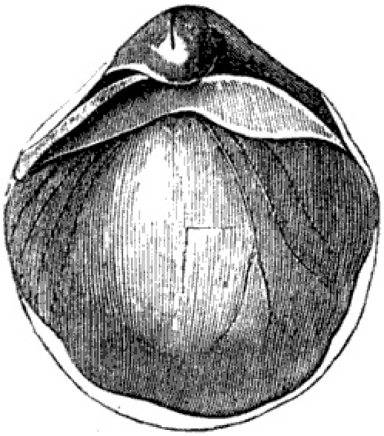


Fig. 73.—Strophalosia Morrisiana.

Other shells now occur, which have not been observed in strata newer than the Permian. *Strophalosia* (Fig. 73) is abundantly represented in the Permian rocks of Germany, Russia, and England, and much more sparingly in the yellow magnesian limestone, accompanied by *Spirifera undulata*, &c. *S. Schlotheimii* is widely disseminated both in England, Germany, and Russia, with *Lingula Credneri*, and other Palæozoic Brachiopoda. Here also we note the first appearance of the Oyster, but still in small numbers. *Fenestella* represents the Polyzoa. *Schizodus* has been found by Mr. Binney in the Upper Red Permian Marls of Manchester; but no shells of any kind have hitherto been met with in the Rothliegende of Lancashire, or in the Vale of Eden.

The brecciated limestone (No. 2) and the concretionary masses (No. 1) overlying it (although Professor King has attempted to separate them) are considered by Professor Sedgwick as different forms of the same rock. They contain no foreign elements, but seem to be composed of fragments of the underlying limestone, No. 3. Some of the angular masses at Tynemouth cliff are two feet in diameter, and none of them are water-worn. [176]

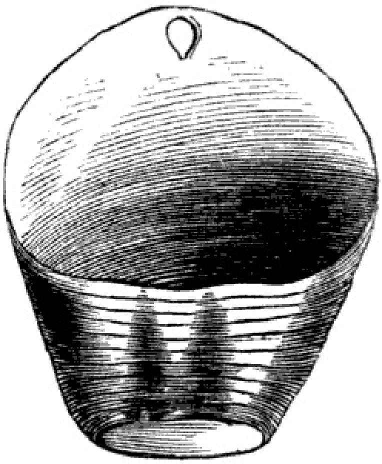


Fig. 74.—Cyrtoceras depressum.

The crystalline or concretionary limestone (No. 1) formation is seen upon the coast of Durham and Yorkshire, between the Wear and the Tees; and Mr. King thinks that the character of the shells and the absence of corals indicate a deposit formed in shallow water.

The plants also found in some of the Permian strata indicate the neighbourhood of land. These are land species, and chiefly of genera common in the Coal-measures. Fragments of supposed coniferous wood (generally silicified) are occasionally met with in the Permian red beds of many parts of England.

Fig. 75.—Walchia Schlotheimii.

Among the Ferns characteristic of the period may be mentioned *Sphenopteris dichotoma* and *S. Artemisiæfolia*; *Pecopteris lonchitica* and *Neuropteris gigantea*, figured on pp. 143, 144. “If we are,” says Lyell, “to draw a line between the Secondary and Primary fossiliferous strata, it must [177] be run through the middle of what was once called the ‘New Red.’ The inferior half of this group will rank as Primary or Palæozoic, while its upper member will form the base of the Secondary or Mesozoic series.”[52] Among the *Equiseta* of the Permian formation of Saxony, Colonel Von Gutbier found *Calamites gigas* and sixty species of fossil plants, most of them Ferns, forty of which have not been found elsewhere. Among these are several species of *Walchia*, a genus of Conifers, of which an example is given in Fig. 75.

In their stems, leaves, and cones, they bear some resemblance to the *Araucarias*, which have been introduced from North America into our pleasure-grounds during the last half-century.

Fig. 76.—Trigonocarpum Nöggerathii.

Among the genera enumerated by Colonel Von Gutbier are some fruits called *Cardiocarpon*, and *Asterophyllites* and *Annularia*, so characteristic of the Carboniferous age. The Lepidodendron is also common to the Permian rocks of Saxony, Russia, and Thuringia; also the *Nöggerathia*, a family of large trees, intermediate between Cycads (Fig. 72) and the Conifers. The fruit of one of these is represented in Fig 76.

Permian Rocks.—We now give a sketch of the physiognomy of the earth in Permian times. Of what do the beds consist? What is the extent, and what is the mineralogical constitution of the rocks deposited in the seas of the period? The Permian formation consists of three members, which are in descending order—

1. Upper Permian sandstone, or Grès des Vosges; 2. Magnesian Limestone, or Zechstein; 3. Lower Red Sandstone, Marl-slate or Kupferschiefer, and Rothliegende.

The *grès des Vosges*, usually of a red colour, and from 300 to 450 feet thick, composes all the southern part of the Vosges Mountains, where it forms frequent level summits, which are evidences of an ancient plain that has been acted on by running water. It only contains a few vegetable remains.

The *Magnesian Limestone*, Pierre de mine, or Zechstein, so called in consequence of the numerous metalliferous deposits met with in its diverse beds, presents in France only a few insignificant fragments; but in Germany and England it attains the thickness of 450 feet. It is [178] composed of a diversified mass of Magnesian Limestone, generally of a yellow colour, but sometimes red and brown, and bituminous clay, the last black and fetid. The subordinate rocks consist of marl, gypsum, and inflammable bituminous schists. The beds of marl slate are remarkable for the numbers of peculiar fossil fishes which they contain; and from the occurrence of small proportions of argentiferous grey copper-ore, met with in the bituminous shales which are worked in the district of Mansfeld, in Thuringia—the latter are called *Kupferschiefer* in Germany.

The *Lower Red Sandstone*, which attains a thickness of from 300 to 600 feet, is found over great part of Germany, in the Vosges, and in England. Its fossil remains are few and rare; they include silicified trunks of Conifers, some impressions of Ferns, and Calamites.

In England the Permian strata, to a great extent, consist of red sandstones and marls; and the Magnesian Limestone of the northern counties is also, though to a less degree, associated with red marls.

In Lancashire thin beds of Magnesian Limestone are interstratified with red marls in the upper Permian strata, beneath which there are soft Red Sandstones, estimated by Mr. Hull to be about 1,500 feet thick. These are supposed to represent the Rothliegende, and no shells of any kind have been found in them. The upper Permian beds, however, contain a few Magnesian Limestone species, such as *Gervillia antiqua*, *Pleurophorus costatus*, *Schizodus obscurus*, and some others, but all small and dwarfed.

The coal-fields of North and South Staffordshire, Tamworth, Coalbrook Dale, and of the Forest of Wyre, are partly bordered by Permian rocks, which lie unconformably on the Coal-measures; as is the case, also, in the immediate neighbourhood of Manchester, where they skirt the borders of the main coal-field, and consist of the Lower Red Sandstone, resting unconformably on different parts of the Coal-measures, and overlaid by the pebble-beds of the Trias.

At Stockport the Permian strata are stated by Mr. Hull to be more than 1,500 feet thick.

In Yorkshire, Nottinghamshire, and Derbyshire, the Permian strata are stated by Mr. Aveline to be divided into two chief groups: the Roth-liegende, of no great thickness, and the Magnesian Limestone series; the latter being the largest and most important member of the Permian series in the northern counties of England. The Magnesian Limestone consists there of two great bands, separated by marls and sandstone, and quarried for building and for lime. In Derbyshire and Yorkshire the magnesian limestone, under the name of Dolomite, forms an excellent building-stone, which has been used in the construction of the Houses of Parliament.

In the midland counties and on the borders of Wales, the Permian section is different from that of [179]
Nottinghamshire and the North of England. The Magnesian Limestones are absent, and the rocks consist principally of dark-red marl, brown and red sandstones, and calcareous conglomerates and breccias, which are almost entirely unfossiliferous. In Warwickshire, where they rest conformably on the Coal-measures, they occupy a very considerable tract of country, and are of very great thickness, being estimated by Mr. Howell to be 2,000 feet thick.

In the east of England the Magnesian Limestone contains a numerous marine fauna, but much restricted when compared with that of the Carboniferous period. The shells of the former are all small and dwarfed in size when compared with their congeners of Carboniferous times, when such there are, and in this respect, and the small number of genera, they resemble the living mollusca of the still less numerous fauna of the Caspian Sea.

Besides the poverty and small size of the mollusca, the later strata of the true Magnesian Limestone seem to afford strong indications that they may have been deposited in a great inland salt-lake subject to evaporation.

The absence of fossils in much of the formation may be partly accounted for by its deposition in great measure from solution, and the uncongenial nature of the waters of a salt-lake may account for the poverty-stricken character of the whole molluscan fauna.

The red colouring-matter of the Permian sandstones and marls is considered, by Professor Ramsay, to be due to carbonate of iron introduced into the waters, and afterwards precipitated as peroxide through the oxidising action of the air and the escape of the carbonic acid which held it in solution. This circumstance of the red colour of the Permian beds affords an indication that the red Permian strata were deposited in inland waters unconnected with the main ocean, which waters may have been salt or fresh as the case may be.

“The Magnesian Limestone series of the east of England may, possibly, have been connected directly with an open sea at the commencement of the deposition of these strata, whatever its subsequent history may have been; for the fish of the marl strata have generically strong affinities with those of Carboniferous age, some of which were truly marine, while others certainly penetrated shallow lagoons bordered by peaty flats.”[53]

There is indisputable evidence that the Permian ocean covered an immense area of the globe. In [180]
the Permian period this ocean extended from Ireland to the Ural mountains, and probably to Spitzbergen, with its northern boundary defined by the Carboniferous, Devonian, Silurian, and Igneous regions of Scotland, Scandinavia, and Northern Russia; and its southern boundaries apparently stretching far into the south of Europe (King). The chain of the Vosges, stretching across Rhenish Bavaria, the Grand Duchy of Baden, as far as Saxony and Silesia, would be under water. They would communicate with the ocean, which covered all the midland and western counties of England and part of Russia. In other parts of Europe the continent has varied very little since the preceding Devonian and Carboniferous ages. In France the central plateaux would form a great island, which extended towards the south, probably as far as the foot of the Pyrenees; another island would consist of the mass of Brittany. In Russia the continent would have extended itself considerably towards the east; finally, it is probable that, at the end of the Carboniferous period, the Belgian continent would stretch from the Departments of the Pas-de-Calais and Du Nord, in France, and would extend up to and beyond the Rhine.

In England, the Silurian archipelago, now filled up and occupied by deposits of the Devonian and Carboniferous systems, would be covered with carboniferous vegetation; dry land would now extend, almost without interruption, from Cape Wrath to the Land’s End; but, on its eastern shore, the great mass of the region now lying less than three degrees west of Greenwich would, in a general sense, be under water, or form islands rising out of the sea. Alphonse Esquiros thus eloquently closes the chapter of his work in which he treats of this formation in England: “We have seen seas, vast watery deserts, become populated; we have seen the birth of the first land

and its increase; ages succeeding each other, and Nature in its progress advancing among ruins; the ancient inhabitants of the sea, or at least their spoils, have been raised to the summit of lofty mountains. In the midst of these vast cemeteries of the primitive world we have met with the remains of millions of beings; entire species sacrificed to the development of life. Here terminates the first mass of facts constituting the infancy of the British Islands. But great changes are still to produce themselves on this portion of the earth's surface."

Having thus described the *Primary Epoch*, it may be useful, before entering on what is termed by geologists the *Secondary Epoch*, to glance backwards at the facts which we have had under consideration.

In this Primary period plants and animals appear for the first time upon the surface of the cooling [181] globe. We have said that the seas of the epoch were then dominated by the fishes known as *Ganoids* (from γανος, *glitter*), from the brilliant polish of the enamelled scales which covered their bodies, sometimes in a very complicated and fantastic manner; the *Trilobites* are curious Crustaceans, which appear and altogether disappear in the Primary epoch; an immense quantity of Mollusca, Cephalopoda, and Brachiopoda; the *Encrinites*, animals of curious organisation, which form some of the most graceful ornaments of our Palæontological collections.

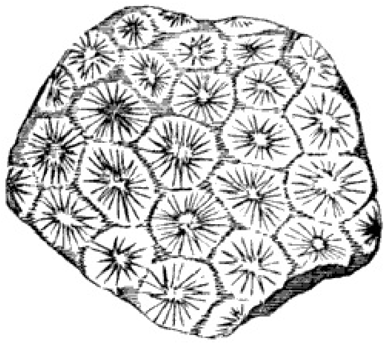


Fig. 77.—Lithostrotion. (Fossil Coral.)

But, among all these beings, those which prevailed—those which were truly the kings of the organic world—were the Fishes, and, above all, the *Ganoids*, which have left no animated being behind them of similar organisation. Furnished with a sort of defensive armour, they seem to have received from Nature this means of protection to ensure their existence, and permit them to triumph over all the influences which threatened them with destruction in the seas of the ancient world.

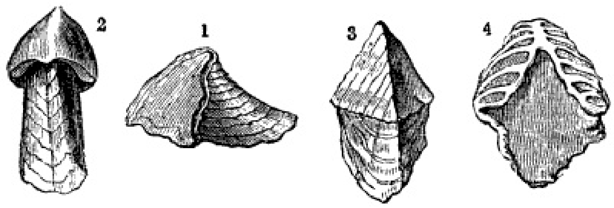


Fig. 78.—Rhyncholites, upper, side, and internal views. 1, Side view (Muschelkalk of Luneville); 2, Upper view (same locality); 3, Upper view (Lias of Lyme Regis); 4, Calcareous point of an under mandible, internal view, from Luneville. (Buckland.)

In the Primary epoch the living creation was in its infancy. No Mammals then roamed the forests; no bird had yet displayed its wings. Without Mammals, therefore, there was no maternal instinct; none of the soft affections which are, with animals, as it were, the precursors of intelligence. Without birds, also, there could be no songs in the air. Fishes, Mollusca, and Crustacea silently ploughed their way in the depths of the sea, and the immovable Crinoid lived there. On the land we only find a few marsh-frequenting Reptiles, of small size—forerunners of those monstrous [182] Saurians which make their appearance in the Secondary epoch.

The vegetation of the Primary epoch is chiefly of inferior organisation. With a few plants of a higher order, that is to say, Dicotyledons, Calamites, Sigillarias, it was the Cryptogamia (also several species of Ferns, the Lepidodendra, Lycopodiaceæ, and the Equisetaceæ, and some doubtfully allied forms, termed Nöggerathia), then at their maximum of development, which formed the great mass of the vegetation.

Let us also consider, in this short analysis, that during the epoch under consideration, what we call *climate* may not have existed. The same animals and the same plants then lived in the polar regions as at the equator. Since we find, in the Primary formations of the icy regions of Spitzbergen and Melville Islands, nearly the same fossils which we meet with in these same rocks in the torrid zone, we must conclude that the temperature at this epoch was uniform all over the globe, and that the heat of the earth itself was sufficiently high to render inappreciable the calorific influence of the sun.

During this same period the progressive cooling of the earth occasioned frequent ruptures and dislocations of the ground; the terrestrial crust, in opening, afforded a passage for the rocks called *igneous*, such as granite, afterwards to the porphyries and syenites, which poured slowly through these immense fissures, and formed mountains of granite and porphyry, or simple clefts, which subsequently became filled with oxides and metallic sulphides, forming what are now designated metallic veins. The great mountain-range of Ben Nevis offers a striking example of the first of these phenomena; through the granite base a distinct natural section can be traced of porphyry ejected through the granite, and of syenite through the porphyry. These geological commotions (which occasioned, not over the whole extent of the earth, but only in certain places, great movements of the surface) would appear to have been more frequent at the close of the Primary epoch; during the interval which forms the passage between the Primary and Secondary epochs; that is to say, between the Permian and the Triassic periods. The phenomena of eruptions, and the character of the rocks called eruptive, are treated of in a former chapter.

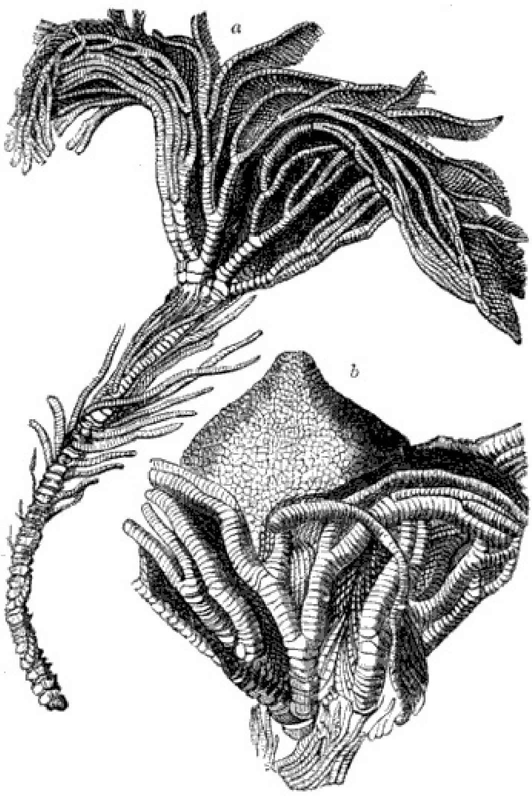


Fig. 79. *a*, Pentacrinites Briareus, reduced; *b*, the same from the Lias of Lyme Regis; natural size.

The convulsions and disturbances by which the surface of the earth was agitated did not extend, let it be noted, over the whole of its circumference; the effects were partial and local. It would, then, be wrong to affirm, as is asserted by many modern geologists, that the dislocations of the crust and the agitations of the surface of the globe extended to both hemispheres, resulting in [183] the destruction of all living creatures. The Fauna and Flora of the Permian period did not differ essentially from the Fauna and Flora of the Coal-measures, which shows that no general revolution occurred to disturb the entire globe between these two epochs. Here, then, as in all analogous cases, it is unnecessary to recur to any general cataclysm to explain the passage from [184] one epoch to another. Have we not, almost in our our own day, seen certain species of animals die out and disappear, without the least geological revolution? Without speaking of the Beaver, which abounded two centuries ago on the banks of the Rhône, and in the Cévennes, which still lived at Paris in the little river Bièvre in the middle ages, its existence being now unknown in these latitudes, although it is still found in America and other countries, we could cite many examples of animals which have become extinct in times by no means remote from our own. Such are the *Dinornis* and the *Epyornis*, colossal birds of New Zealand and Madagascar, and the *Dodo*, which lived in the Isle of France in 1626. *Ursus spelæus*, *Cervus Megaceros*, *Bos primigenius*, are species of Bear, Deer, and Ox which were contemporary with man, but have now become extinct. In France we no longer know the gigantic wood-stag, figured by the Romans on their monuments, and which they had brought from England for the fine quality of its flesh. The Erymanthean boar, so widely dispersed during the ancient historical period, no longer exists among our living races, any more than the Crocodiles *lacunosus* and *laciniatus* found by Geoffroy St.-Hilaire in the catacombs of ancient Egypt. Many races of animals figured in the mosaics of Palestrina, engraved and painted along with species now actually existing, are no longer found living in our days any more than are the Lions with curly manes, which formerly existed in Syria, and perhaps even in Thessaly and the northern parts of Greece. From what happens in our own time, we may infer what has taken place in times antecedent to the appearance of man; and the idea of successive cataclysms of the globe, must be restrained within bounds. Must we imagine a series of geological revolutions to account for the disappearance of animals which have evidently become extinct in a natural way? What has come to pass in our days, it is reasonable to conclude, may have taken place in the times anterior to the appearance of man.

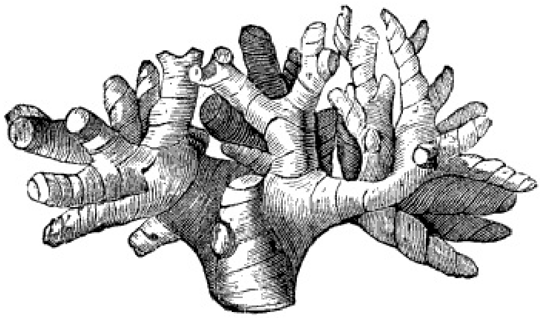


Fig. 80.—Terebellaria ramosissima. (Recent Coral.)

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[34] Trans. Roy. Irish Acad., vol. xxiii., p. 556.

[35] "On the Red Rocks of England," by A. C. Ramsay. *Quart. Jour. Geol. Soc.*, vol. xxvii., p. 250.

[36] *Quart. Jour. Geol. Soc.*, vol. iii., p. 159.

[37] "The Flora and Fauna of the Silurian Period," by John T. Bigsby, M.A., F.G.S. 4to, 1868.

[38] Ibid, p. vi.

[39] "Siluria," p. 148.

[40] "On the Red Rocks of England," by A. C. Ramsay. *Quart. Jour. Geol. Soc.*, vol. xxvii., p. 243.

[41] "On the Red Rocks of England," by A. C. Ramsay. *Quart. Jour. Geol. Soc.*, vol. xxvii., p. 247.

[42] For fuller details on this subject, see J. B. Jukes' "Manual of Geology," 3rd ed., p. 762. Also, R. Etheridge, *Quart. Journ. Geol. Soc.*, vol. 23, p. 251.

[43] *Quart. Jour. Geol. Soc.*, vol. xxii., p. 129.

[44] "Elements of Geology," p. 480.

[45] Ibid, p. 479.

[46] Ibid, p. 479.

[47] Ibid, p. 483.

[48] "Introduction to Geology," by Robert Bakewell, 5th ed., p. 179. 1838.

[49] For the opinions respecting the *Stigmaria ficoides*, see a Memoir on "The Formation of the Rocks in South Wales and South-Western England," by Sir Henry T. De la Beche, F.R.S., in the "Memoirs of the Geological Survey of Great Britain," vol. i., p. 149.

[50] See "Siluria," p. 14. *Philosophical Mag.*, 3rd series, vol. xix., p. 419.

[51] A. C. Ramsay, "On the Red Rocks of England." *Quart. Jour. Geol. Soc.*, vol. xxvii., p. 246.

[52] "Elements of Geology," p. 456.

[53] "On the Red Rocks of England," by A. C. Ramsay. *Quart. Jour. Geol. Soc.*, vol. xxvii., p. 246.

SECONDARY EPOCH. [185]

During the *Primary Epoch* our globe would appear to have been chiefly appropriated to beings which lived in the waters—above all, to the Crustaceans and Fishes; during the *Secondary Epoch* Reptiles seem to have been its prevailing inhabitants. Animals of this class assumed astonishing dimensions, and would seem to have multiplied in a most singular manner; they were, apparently, the kings of the earth. At the same time, however, that the animal kingdom thus developed itself, the vegetation lost much of its importance.

Geologists have agreed among themselves to divide the Secondary epoch into three periods: 1, the *Cretaceous*; 2, the *Jurassic*; 3, the *Triassic*—a division which it is convenient to adopt.

The Triassic, or New Red Period.

This period has received the name of Triassic because the rocks of which it is composed, which are more fully developed in Germany than either in England or France, were called the Trias (or Triple Group), by German writers, from its division into three groups, as follows, in descending order:—

England.	France.	Germany.
Saliferous and gypseous shales and		

sandstone	Marnes irisées	Keuper. 1,000 feet.
Wanting	Muschelkalk or Calcaire coquillier	Muschelkalk. 600 feet.
Sandstone and quartzose conglomerate	Grès bigarré	Bunter-Sandstein. 1,500 ft.

The following has been shown by Mr. Ed. Hull to be the general succession of the Triassic formation in the midland and north-western counties of England, where it attains its greatest vertical development, thinning away in the direction of the mouth of the Thames:—

[186]

			Foreign Equivalents.	
TRIASSIC SERIES.	New Red Marl.	Red and grey shales and marls, sometimes micaceous, with beds of rock-salt and gypsum, containing *Estheria* and *Foraminifera* (Chellaston).	Keuper.	Marnes irisées.
	Lower Keuper Sandstone.	Thinly-laminated micaceous sandstones and marls (waterstones); passing downwards into white, brown, or reddish sandstone, with a base of calcareous conglomerate or breccia.	Letten Kohle (?)	„
	Wanting in England.	...	Muschelkalk.	Calcaire coquillier.
	Upper Mottled Sandstone.	Soft, bright-red and variegated sandstone (without pebbles).	Bunter Sandstein.	Grès bigarré, or Grès des Vosges (in part).
	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).		
PERMIAN SERIES.	Upper Permian.	Red marls, with thin-bedded fossiliferous limestones (Manchester).	Zechstein.	
	Lower	Red and variegated sandstone (Collyhurst, Manchester) represented by [...].	Rothe-todte-liegende.	Grès des Vosges (in part).
		Reddish-brown and purple sandstones and marls, with calcareous conglomerates and trappoid breccia. (Central counties).		

New Red Sandstone. [187]

In this new phase of the revolutions of the globe, the animated beings on its surface differ much from those which belonged to the Primary epoch. The curious Crustaceans which we have described under the name of *Trilobites* have disappeared; the molluscous Cephalopods and Brachiopods are here few in number, as are the Ganoid and Placoid Fishes, whose existence also seems to have terminated during this period, and vegetation has undergone analogous changes. The cryptogamic plants, which reached their maximum in the Primary epoch, become now less numerous, while the Conifers experienced a certain extension. Some kinds of terrestrial animals have disappeared, but they are replaced by genera as numerous as new. For the first time the Turtle appears in the bosom of the sea, and on the borders of lakes. The Saurian reptiles acquire a great development; they prepare the way for those enormous Saurians, which appear in the following period, whose skeletons present such vast proportions, and such a strange aspect, as to strike with astonishment all who contemplate their gigantic, and, so to speak, awe-inspiring remains.

The *Variegated Sandstone*, or Bunter, contains many vegetable, but few animal, remains, although we constantly find imprints of the footsteps of the Labyrinthodon.

The lowest Bunter formation shows itself in France, in the Pyrenees, around the central plateau in the Var, and upon both flanks of the Vosges mountains. It is represented in south-western and central Germany, in Belgium, in Switzerland, in Sardinia, in Spain, in Poland, in the Tyrol, in Bohemia, in Moravia, and in Russia. M. D’Orbigny states, from his own observation, that it covers vast surfaces in the mountainous regions of Bolivia, in South America. It is recognised in the United States, in Columbia, in the Great Antilles, and in Mexico.

The Bunter in France is reduced to the variegated sandstone, except around the Vosges, in the Var, and the Black Forest, where it is accompanied by the Muschelkalk. In Germany it furnishes building-stone of excellent quality; many great edifices, in particular the cathedrals, so much admired on the Rhine—such, for example, as those of Strasbourg and Fribourg—are constructed of this stone, the sombre tints of which singularly relieve the grandeur and majesty of the Gothic architecture. Whole cities in Germany are built of the brownish-red stones drawn from its mottled sandstone quarries. In England, in Scotland, and in Ireland this formation extends from north to [188] south through the whole length of the country. “This old land,” says Professor Ramsay,[54] “consisted in great part of what we now know as Wales, and the adjacent counties of Hereford, Monmouth, and Shropshire; of part of Devon and Cornwall, Cumberland, the Pennine chain, and all the mountainous parts of Scotland. Around old Wales, and part of Cumberland, and probably all round and over great part of Devon and Cornwall, the New Red Sandstone was deposited. Part, at least, of this oldest of the Secondary rocks was formed of the material of the older Palæozoic strata, that had then risen above the surface of the water. The New Red Sandstone series consists in its lower members of beds of red sandstone and conglomerate, more than 1,000 feet thick, and above them are placed red and green marls, chiefly red, which in Germany are called the Keuper strata, and in England the New Red Marl. These formations range from the mouth of the Mersey, round the borders of Wales, to the estuary of the Severn, eastwards into Warwickshire, and thence northwards into Yorkshire and Northumberland, along the eastern border of the Magnesian Limestone. They also form the bottom of the valley of the Eden, and skirt Cumberland on the west; in the centre of England the unequal hardness of its sub-divisions sometimes giving rise to minor escarpments, overlooking plains and undulating grounds of softer strata.”

“Different members of the group rest in England, in some region or other,” says Lyell, “on almost every principal member of the Palæozoic series, on Cambrian, Silurian, Devonian, Carboniferous, and Permian rocks; and there is evidence everywhere of disturbance, contortion, partial upheaval into land, and vast denudations which the older rocks underwent before and during the deposition of the successive strata of the New Red Sandstone group.” (“Elements of Geology,” p. 439.)

The *Muschelkalk* consists of beds of compact limestone, often greyish, sometimes black, alternating with marl and clay, and commonly containing such numbers of shells that the name of shelly limestone (*Muschelkalk*) has been given to the formation by the Germans. The beds are sometimes magnesian, especially in the lower strata, which contain deposits of gypsum and rock-salt.

The seas of this sub-period, which is named after the innumerable masses of shells inclosed in the rocks which it represents, included, besides great numbers of Mollusca, Saurian Reptiles of twelve different genera, some Turtles, and six new genera of Fishes clothed with a cuirass. Let us [189] pause at the Mollusca which peopled the Triassic seas.

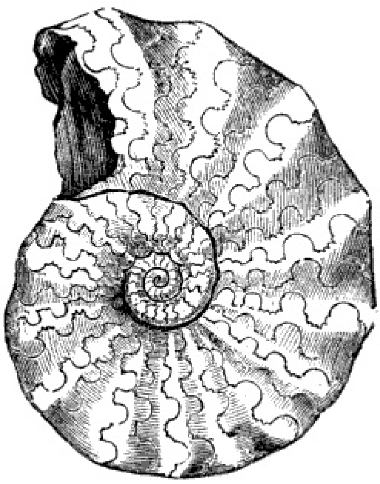
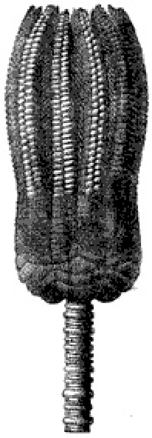


Fig. 81.—Ceratites nodosus.
(Muschelkalk.)

Among the shells characteristic of the Muschelkalk period, we mention *Natica Gaillardoti*, *Rostellaria antiqua*, *Lima striata*, *Avicula socialis*, *Terebratula vulgaris*, *Turbonilla dubia*, *Myophoria vulgaris*, *Nautilus hexagonalis*, and *Ceratites nodosus*. The *Ceratites*, of which a species is here represented (Fig. 81), form a genus closely allied to the *Ammonites*, which seem to have played such an important part in the ancient seas, but which have no existence in those of our era, either in species or even in genus. This Ceratite is found in the Muschelkalk of Germany, a formation which has no equivalent in England, but which is a compact greyish limestone underlying the saliferous rocks in Germany, and including beds of dolomite with gypsum and rock-salt.

The *Mytilus* or *Mussel*, which properly belonged to this age, are acephalous (or headless) Molluscs with elongated triangular shells, of which there are many species found in our existing seas. *Lima*, *Myophoria*, *Posidonia*, and *Avicula*, are acephalous Molluscs of the same period. The two genera *Natica* and *Rostellaria* belong to the Gasteropoda, and are abundant in the Muschelkalk in France, Germany, and Poland.



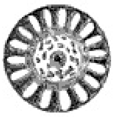


Fig. 82.—
Encrinus
liliiformis.

Among the Echinoderms belonging to this period may be mentioned *Encrinus moniliformis* and *E. liliiformis*, or *lily encrinite* (Fig. 82), whose remains, constituting in some localities whole beds of rock, show the slow progress with which this zoophyte formed beds of limestone in the clear seas of the period. To these may be added, among the Mollusca, *Avicula subcostata* and *Myophoria vulgaris*.

In the Muschelkalk are found the skull and teeth of *Placodus gigas*, a reptile which was originally placed by Agassiz among the class of Fishes; but more perfect specimens have satisfied Professor Owen that it was a Saurian Reptile.

It may be added, that the presence of a few genera, peculiar to the Primary epoch, which entirely disappeared during the sub-period, and the appearance for the first time of some other animals [190] peculiar to the Jurassic period, give to the Muschelkalk fauna the appearance of being one of passage from one period to the other.

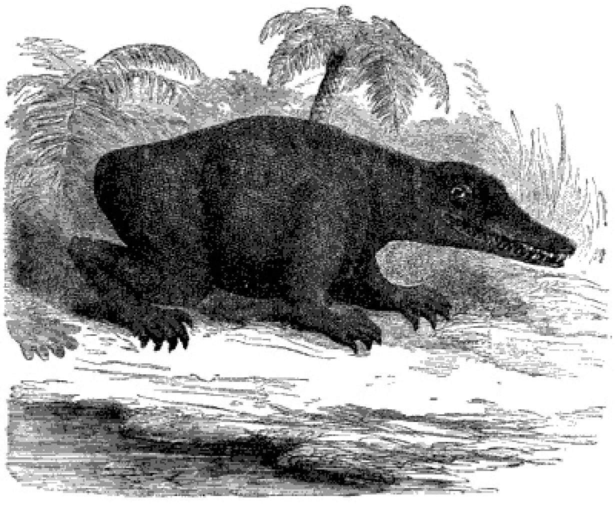
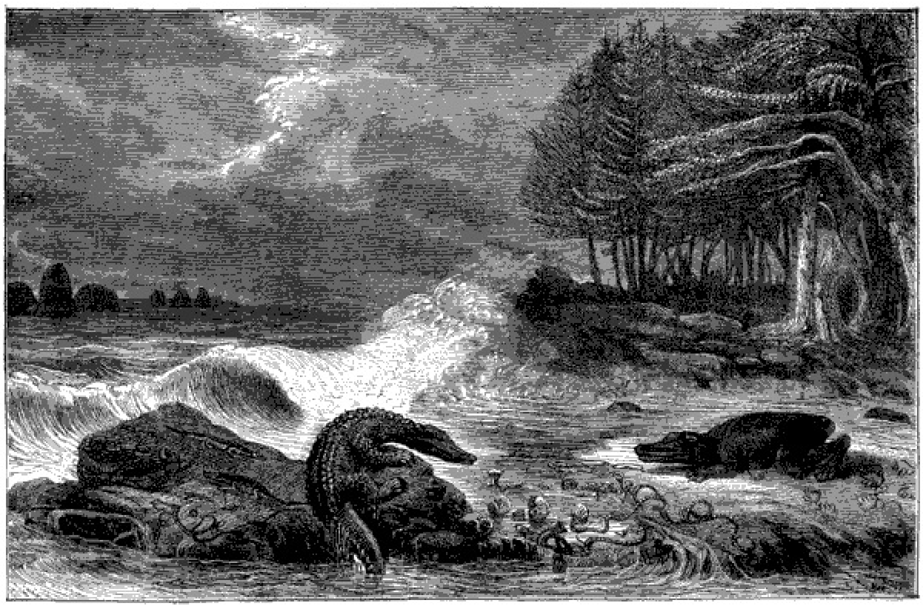


Fig. 83.—Labyrinthodon restored. One-twentieth natural size.

The seas, then, contained a few Reptiles, probably inhabitants of the banks of rivers, as *Phytosaurus*, *Capitosaurus*, &c., and sundry Fishes, as *Sphœrodus* and *Pycnodus*. In this sub-period we shall say nothing of the Land-Turtles, which for the first time now appear; but, we should note, that at the Bunter period a gigantic Reptile appears, on which the opinions of geologists were for a long while at variance. In the argillaceous rocks of the Muschelkalk period imprints of the foot of some animal were discovered in the sandstones of Storeton Hill, in Cheshire, and in the New Red Sandstone of parts of Warwickshire, as well as in Thuringia, and Hesseburg in Saxony, which very much resembled the impression that might be made in soft clay by the outstretched fingers and thumb of a human hand. These traces were made by a species of Reptile furnished with four feet, the two fore-feet being much broader than the hinder two. The head, pelvis, and scapula only of this strange-looking animal have been found, but these are considered to have belonged to a gigantic air-breathing reptile closely connected with the Batrachians. It is thought that the head was not naked, but protected by a bony cushion; that its jaws were armed with conical teeth, of great strength and of a complicated structure. This curious and uncouth-looking creature, of which the woodcut Fig. 83 is a restoration, has been named the *Cheirotherium*, or *Labyrinthodon*, from the complicated arrangement of the cementing layer of the teeth. (See also Fig. 1, p. 12.)

Another Reptile of great dimensions—which would seem to have been intended to prepare the way for the appearance of the enormous Saurians which present themselves in the Jurassic period—was the *Nothosaurus*, a species of marine Crocodile, of which a restoration has been attempted in PLATE XIII. opposite.

[191]



XIII.—Ideal Landscape of the Muschelkalk Sub-period.

It has been supposed, from certain impressions which appear in the Keuper sandstones of the Connecticut river in North America, that Birds made their appearance in the period which now [193] occupies us; the flags on which these occur by thousands show the tracks of an animal of great size (some 20 inches long and 4½ feet apart), presenting the impression of three toes, like some of the Struthionidæ or Ostriches, accompanied by raindrops. No remains of the skeletons of birds have been met with in rocks of this period, and the footprints in question are all that can be alleged in support of the hypothesis.

M. Ad. Brongniart places the commencement of dicotyledonous gymnosperm plants in this age. The characteristics of this Flora consist in numerous Ferns, constituting genera now extinct, such as *Anomopteris* and *Crematopteris*. The true *Equiseta* are rare in it. The Calamites, or, rather, the *Calamodendra*, abound. The gymnosperms are represented by the genera *Conifer*, *Voltzia*, and *Haidingera*, of which both species and individuals are very numerous in the formation of this [194] period.

Among the species of plants which characterise this formation, we may mention *Neuropteris elegans*, *Calamites arenaceus*, *Voltzia heterophylla*, *Haidingera speciosa*. The *Haidingera*, belonging to the tribe of *Abietinæ*, were plants with large leaves, analogous to those of our *Damara*, growing close together, and nearly imbricated, as in the *Araucaria*. Their fruit, which are cones with rounded scales, are imbricated, and have only a single seed, thus bearing out the strong resemblance which has been traced between these fossil plants, and the Damara.

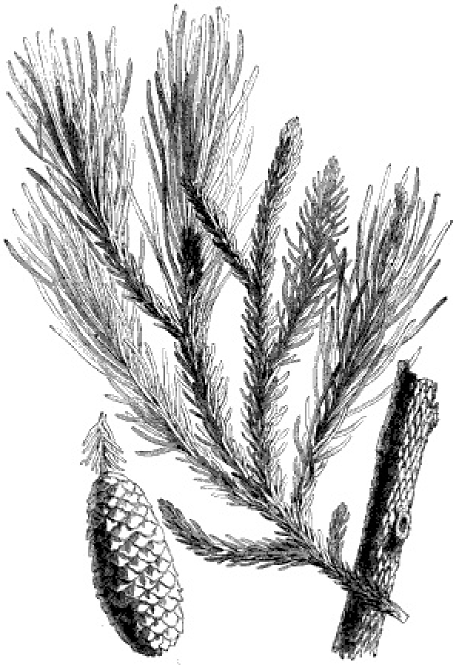


Fig. 84.—Branch and cone of Voltzia restored.

The *Voltzias* (Fig. 84), which seem to have formed the greater part of the forests were a genus of Cupressinaceæ, now extinct, which are well characterised among the fossil Conifers of the period. The alternate spiral leaves, forming five to eight rows sessile, that is, sitting close to the branch and drooping, have much in them analogous to the *Cryptomerias*. Their fruit was an oblong cone with scales, loosely imbricated, cuneiform or wedge-shaped, and, commonly, composed of from three to five obtuse lobes. In Fig. 84 we have a part of the stem, a branch with leaves and cone. In his "Botanic Geography," M. Lecoq thus describes the vegetation of the ancient world in the first period of the Triassic age: "While the variegated sandstone and mottled clays were being slowly deposited in regular beds by the waters, magnificent Ferns still exhibited their light and elegantly-carved leaves. Divers *Protopteris* and majestic *Neuropteris* associated themselves in extensive forests, where vegetated also the *Crematopteris typica* of Schimper, the *Anomopteris Mongeotii* of Brongniart, and the pretty *Trichomanites myriophyllum* (Göppert). The Conifers of this epoch attain a very considerable development, and would form graceful forests of green trees. Elegant monocotyledons, representing the forms of tropical countries, seem to show themselves for the first time, the *Yuccites Vogesiacus* of Schimper constituted groups at once thickly serried and of great extent.

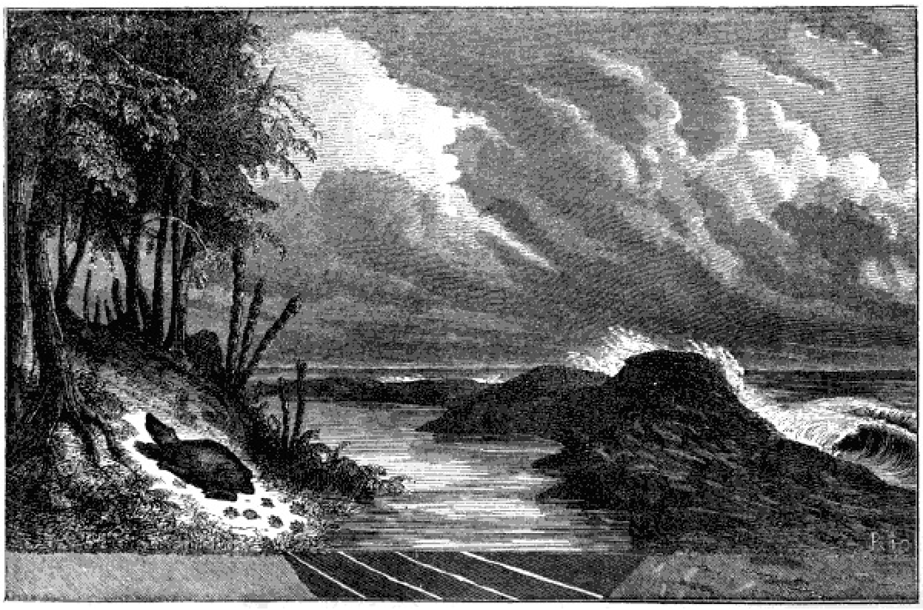
"A family, hitherto doubtful, appears under the elegant form of *Nilssonia Hogardi*, Schimp.; *Ctenis Hogardi*, Brongn. It is still seen in the *Zamites Vogesiacus*, Schimp.; and the group of the Cycads sharing at once in the organisation of the Conifers and the elegance of the Palms, now decorate the earth, which reveals in these new forms its vast fecundity. (See Fig. 72, p. 168.)

"Of the herbaceous plants which formed the undergrowth of the forests, or which luxuriated in its cool marshes, the most remarkable is the *Ætheophyllum speciosum*, Schimp. Their organisation approximates to the Lycopodiaceæ and Thyphaceæ, the *Ætheophyllum stipulare*, Brongn., and the curious *Schizoneura paradoxa*, Schimp. Thus we can trace the commencement of the reign of the Dicotyledons with naked seeds, which afterwards become so widely disseminated, in a few Angiosperms, composed principally of two families, the Conifers and Cycadeaceæ, still represented in the existing vegetation. The former, very abundant at first, associated themselves with the cellular Cryptogams, which still abound, although they are decreasing, then with the Cycadeaceæ, which present themselves slowly, but will soon be observed to take a large part in the brilliant harmonies of the vegetable kingdom." [196]

The engraving at page 191 (Plate XIII.) gives an idealised picture of the plants and animals of the period. The reader must imagine himself transported to the shores of the Muschelkalk sea at a moment when its waves are agitated by a violent but passing storm. The reflux of the tide exposes some of the aquatic animals of the period. Some fine Encrinites are seen, with their long flexible stems, and a few Mytili and Terebratulæ. The Reptile which occupies the rocks, and prepares to throw itself on its prey, is the *Nothosaurus*. Not far from it are other reptiles, its congeners, but of a smaller species. Upon the dune on the shore is a fine group of the trees of the period, that is, of *Haidingeras*, with large trunks, with drooping branches and foliage, of which the cedars of our own age give some idea. The elegant *Voltzias* are seen in the second plane of this curtain of verdure. The Reptiles which lived in these primitive forests, and which would give to it so strange a character, are represented by the *Labyrinthodon*, which descends towards the sea on the right, leaving upon the sandy shore those curious tracks which have been so wonderfully preserved to our days.

The footprints of the reptilian animals of this period prove that they walked over moist surfaces; and, if these surfaces had been simply left by a retiring tide, they would generally have been obliterated by the returning flood, in the same manner that is seen every day on our own sandy shores. It seems more likely that the surfaces, on which fossil footprints are now found, were left bare by the summer evaporation of a lake; that these surfaces were afterwards dried by the sun, and the footprints hardened, so as to ensure their preservation, before the rising waters brought by flooded muddy rivers again submerged the low flat shores and deposited new layers of salt, just as they do at the present day round the Dead Sea and the Salt Lake of Utah.

[198]



XIV.—Ideal Landscape of the Keuper Sub-period.

KEUPER SUB-PERIOD.

[199]

The formation which characterises the Keuper, or saliferous period, is of moderate extent, and derives the latter name from the salt deposits it contains.

These rocks consist of a vast number of argillaceous and marly beds, variously coloured, but chiefly red, with tints of yellow and green. These are the colours which gave the name of *variegatea* (Poikilitic) to the series. The beds of red marl often alternate with sandstones, which are also variegated in colour. As subordinate rocks, we find in this formation some deposits of a poor pyritic coal and of gypsum. But what especially characterises the formation are the important deposits of rock-salt which are included in it. The saliferous beds, often twenty-five to forty feet thick, alternate with beds of clay, the whole attaining a thickness of 160 yards. In Germany in Würtemberg, in France at Vic, at Dieuze, and at Château-Salins, the rock-salt of the saliferous formation has become an important branch of industry. In the Jura, salt is extracted from the water charged with chlorides, which issues from this formation.

Some of these deposits are situated at great depths, and cannot be reached without very considerable labour. The salt-mines of Wieliczka, in Poland, for example, can be procured on the surface, or by galleries of little depth, because the deposit belongs to the Tertiary period; but the deposits of salt, in the Triassic age, lie so much deeper, as to be only approachable by a regular process of mining by galleries, and the ordinary mode of reaching the salt is by digging pits, which are afterwards filled with water. This water, charged with the salt, is then pumped up into troughs, where it is evaporated, and the crystallised mineral obtained.

What is the origin of the great deposits of marine salt which occur in this formation, and which always alternate with thin beds of clay or marl? We can only attribute them to the evaporation of vast quantities of sea-water introduced into depressions, cavities, or gulfs, which the sandy dunes afterwards separated from the great open sea. In PLATE XIV. an attempt is made to represent the natural fact, which must have been of frequent recurrence during the saliferous period, to form the considerable masses of rock-salt which are now found in the rocks of the period. On the right is the sea, with a dune of considerable extent, separating it from a tranquil basin of smooth water. At intervals, and from various causes, the sea, clearing the dune, enters and fills the basin. We may even suppose that a gulf exists here which, at one time, communicated with the sea; the [200] winds having raised this sandy dune, the gulf becomes transformed, by degrees, into a basin or back-water, closed on all sides. However that may be, it is pretty certain that if the waters of the sea were once shut up in this basin, with an argillaceous bottom and without any opening, evaporation from the effects of solar heat would take place, and a bed of salt would be the result of this evaporation, mixed with other mineral salts which accompany chloride of sodium in sea-water, such as sulphate of magnesia, chloride of potassium, &c. This bed of salt, left by the evaporation of the water, would soon receive an argillaceous covering from the clay and silt suspended in the muddy water of the basin, thus forming a first alternation of salt and of clay or marl. The sea making fresh breaches across the barriers, the same process took place with a similar result, until the basin was filled up. By the regular and tranquil repetition of this phenomenon, continued during a long succession of ages, this abundant deposit of rock-salt has been formed, which occupies so important a position in the Secondary rocks.

There is in the delta of the Indus a singular region, called the Runn of Cutch, which extends over an area of 7,000 square miles, which is neither land nor sea, but is under water during the monsoons, and in the dry season is incrusted, here and there, with salt about an inch thick, the result of evaporation. Dry land has been largely increased here, during the present century, by subsidence of the waters and upheavals by earthquakes. "That successive layers of salt may have been thrown down one upon the other on many thousand square miles, in such a region, is undeniable," says Lyell. "The supply of brine from the ocean is as inexhaustible as the supply of heat from the sun. The only assumption required to enable us to explain the great thickness of salt in such an area, is the continuance for an indefinite period of a subsidence, the country preserving all the time a general approach to horizontally." The observations of Mr. Darwin on the atolls of the Pacific, prove that such a continuous subsidence is probable. Hugh Miller, after ably discussing various spots of earth where, as in the Runn of Cutch, evaporation and deposit take place, adds: "If we suppose that, instead of a barrier of lava, sand-bars were raised by the surf on a flat arenaceous coast, during a slow and equable sinking of the surface, the waters of the outer gulf might occasionally topple over the bar and supply a fresh brine when the first stock had been exhausted by evaporation."

Professor Ramsay has pointed out that both the sandstones and marls of the Triassic epoch were formed in lakes. In the latter part of this epoch, he is of opinion, that the Keuper marls of the British Isles were deposited in a large lake, or lakes, which were fresh or brackish at first, but afterwards salt and without outlets to the sea; and that the same was occasionally the case with regard to other portions of northern Europe and its adjoining seas. [201]

By the silting up of such lakes with sediment, and the gradual evaporation of their waters under favourable conditions, such as increased heat and diminished rainfall—where the lakes might cease to have an outflow into the sea and the loss of water by evaporation would exceed the amount flowing into them—the salt or salts contained in solution would, by degrees, become concentrated and finally precipitated. In this way the great deposits of rock-salt and gypsum, common in the Keuper formation, may be accounted for.

Subsequently, by increase of rainfall or decrease of heat, and sinking of the district, the waters became comparatively less salt again; and a recurrence of such conditions lasted until the close of the Keuper period, when a partial influx of the sea took place, and the Rhætic beds of England were deposited.

The red colour of the New Red Sandstones and marls is caused by peroxide of iron, which may also have been carried into the lakes in solution, as a carbonate, and afterwards converted into peroxide by contact with air, and precipitated as a thin pellicle upon the sedimentary grains of sandy mud, of which the Triassic beds more or less consist. Professor Ramsay further considers that all the red-coloured strata of England, including the Permian, Old Red Sandstone, and even the Old Cambrian formation, were deposited in lakes or inland waters.[55]

There is little to be said of the animals which belong to the Saliferous period. They are nearly the same as those of the Muschelkalk, &c.

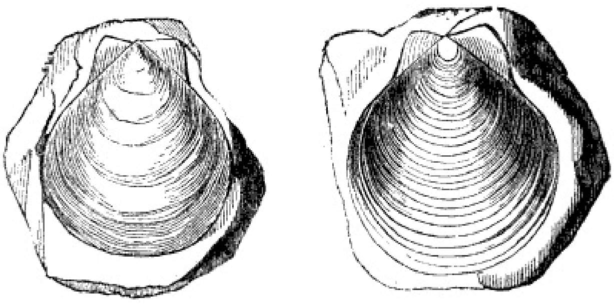


Fig. 85.—Pecten orbicularis.

Among the most abundant of the shells belonging to the upper Trias, in all the countries where it has been examined, are the *Avicula, Cardium*, and *Pecten*, one of which is given in Fig. 85. Foraminifera are numerous in the Keuper marls. The remains of land-plants, and the peculiarities of some of the reptiles of the Keuper period, tend to confirm the opinion of Professor Ramsay, that the strata were deposited in inland salt-lakes.

In the Keuper period the islands and continents presented few mountains; they were intersected here and there by large lakes, with flat and uniform banks. The vegetation on their shores was very abundant, and we possess its remains in great numbers. The Keuper Flora was very analogous to those of the Lias and Oolite, and consisted of Ferns, Equisetaceæ, Cycads, Conifers, and a few plants, which M. Ad. Brongniart classes among the dubious monocotyledons. Among the Ferns may be quoted many species of *Sphenopteris* or *Pecopteris*. Among them, *Pecopteris Stuttgartiensis*, a tree with channelled trunk, which rises to a considerable height without throwing out branches, and terminates in a crown of leaves finely cut and with long petioles; the [202]

Equisetites columnaris, a great Equisetum analogous to the horse-tails of our age, but of infinitely larger dimensions, its long fluted trunk, surmounted by an elongated fructification, towering over all the other trees of the marshy soil.

The *Pterophyllum Jägeri* and *P. Münsteri* represented the Cycads, the *Taxodites Münsterianus* represented the Conifers, and, finally, the trunk of the Calamites was covered with a creeping plant, having elliptical leaves, with a re-curving nervature borne upon its long petioles, and the fruit disposed in bunches; this is the *Preissleria antiqua*, a doubtful monocotyledon, according to Brongniart, but M. Unger places it in the family of *Smilax*, of which it will thus be the earliest representative. The same botanist classes with the canes a marsh-plant very common in this period, the *Palæoxyris Münsteri*, which Brongniart classes with the *Preissleria* among his doubtful Monocotyledons.

The vegetation of the latter part of the Triassic period is thus characterised by Lecoq, in his “Botanical Geography”: “The cellular *Cryptogameæ* predominate in this as they do in the [203] Carboniferous epoch, but the species have changed, and many of the genera also are different; the *Cladephlebis*, the *Sphenopteris*, the *Coniopteris*, and *Pecopteris* predominate over the others in the number of species. The Equisetaceæ are more developed than in any other formation. One of the finest species, the *Calamites arenaceus* of Brongniart, must have formed great forests. The fluted trunks resemble immense columns, terminating at the summit in leafy branches, disposed in graceful verticillated tufts, foreshadowing the elegant forms of *Equisetum sylvaticum*. Growing alongside of these were a curious Equisetum and singular Equisetites, a species of which last, *E. columnaris*, raised its herbaceous stem, with its sterile articulations, to a great height.

“What a singular aspect these ancient rocks would present, if we add to them the forest-trees *Pterophyllum* and the *Zamites* of the fine family of Cycadeaceæ, and the Conifers, which seem to have made their appearance in the humid soil at the same time!

“It is during this epoch, while yet under the reign of the dicotyledonous angiosperms, that we discover the first true monocotyledons. The *Preissleria antiqua*, with its long petals, drooping and creeping round the old trunks, its bunches of bright-coloured berries like the *Smilax* of our own age, to which family it appears to have belonged. Besides, the Triassic marshes gave birth to tufts of *Palæoxyris Münsteri*, a cane-like species of the Gramineæ, which, in all probability, cheered the otherwise gloomy shore.

“During this long period the earth preserved its primitive vegetation; new forms are slowly introduced, and they multiply slowly. But if our present types of vegetation are deficient in these distant epochs, we ought to recognise also that the plants which in our days represent the vegetation of the primitive world are often shorn of their grandeur. Our Equisetaceæ and Lycopodiaceæ are but poor representatives of the Lepidodendrons; the Calamites and Asterophyllites had already run their race before the epoch of which we write.”

The principal features of Triassic vegetation are represented in Plate XIV., page 198. On the cliff, on the left of the ideal landscape, the graceful stems and lofty trees are groups of *Calamites arenaceus*; below are the great “horse-tails” of the epoch, *Equisetum columnare*, a slender tapering species, of soft and pulpy consistence, which, rising erect, would give a peculiar physiognomy to the solitary shore.

The Keuper formation presents itself in Europe at many points, and it is not difficult to trace its [204] course. In France it appears in the department of the Indre, of the Cher, of the Allier, of the Nièvre, of the Saône-et-Loire; upon the western slopes of the Jura its outliers crop out near Poligny and Salins, upon the western slopes of the Vosges; in the Doubs it shows itself; then it skirts the Muschelkalk area in the Haute-Marne; in the Vosges it assumes large proportions in the Meurthe at Luneville and Dieuze; in the Moselle it extends northward to Bouzonville; and on the Rhine to the east of Luxembourg as far as Dockendorf. Some traces of it show themselves upon the eastern slopes of the Vosges, on the lower Rhine.

It appears again in Switzerland and in Germany, in the canton of Basle, in Argovia, in the Grand Duchy of Würtemberg, in the Tyrol, and in Austria, where it gives its name to the city of Salzburg.

In the British Islands the Keuper formation commences in the eastern parts of Devonshire, and a band, more or less regular, extends into Somersetshire, through Gloucestershire, Worcestershire, Warwick, Leicestershire, Nottinghamshire, to the banks of the Tees, in Yorkshire, with a bed, independent of all the others in Cheshire, which extends into Lancashire. “At Nantwich, in the upper Trias of Cheshire,” Sir Charles Lyell states, “two beds of salt, in great part unmixed with earthy matter, attain the thickness of 90 or 100 feet. The upper surface of the highest bed is very uneven, forming cones and irregular figures. Between the two masses there intervenes a bed of indurated clay traversed by veins of salt. The highest bed thins off towards the south-west, losing fifteen feet of its thickness in the course of a mile, according to Mr. Ormerod. The horizontal extent of these beds is not exactly known, but the area containing saliferous clay and sandstones is supposed to exceed 150 miles in diameter, while the total thickness of the Trias in the same region is estimated by Mr. Ormerod at 1,700 feet. Ripple-marked sandstones and the footprints of animals are observed at so many levels, that we may safely assume the whole area to have undergone a slow and gradual depression during the formation of the New Red Sandstone.”

Not to mention the importance of salt as a source of health, it is in Great Britain, and, indeed, all over the world where the saliferous rocks exist, a most important branch of industry. The quantity of the mineral produced in England, from all sources, is between 5,000 and 6,000 tons annually, and the population engaged in producing the mineral, from sources supposed to be inexhaustible, is upwards of 12,000.

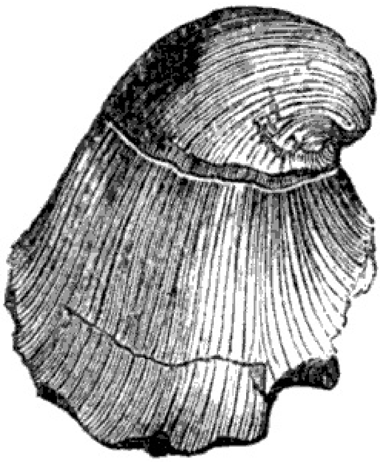


Fig. 86.—Productus Martini.

The lower Keuper sandstones, which lie at the base of the series of red marls, frequently give rise to springs, and are in consequence called “water-stones,” in Lancashire and Cheshire.

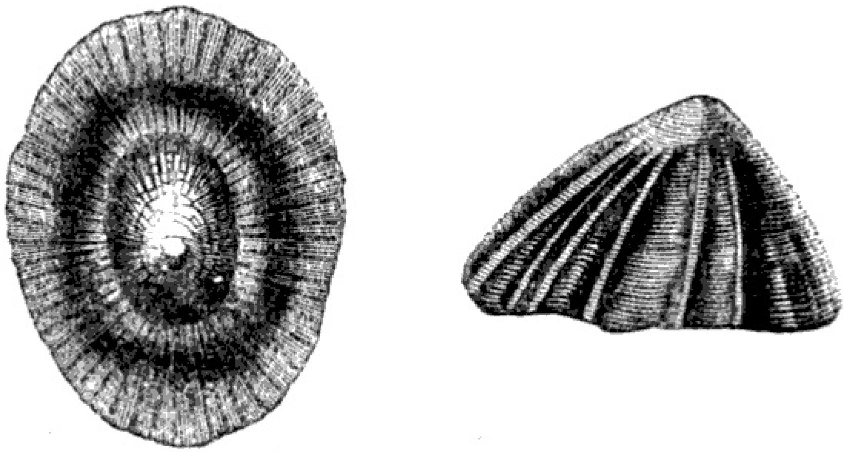


Fig. 87.—Patella vulgata.
(Living.)

If the Keuper formation is poor in organic remains in France, it is by no means so on the other [205]
side of the Alps. In the Tyrol, and in the remarkable beds of Saint Cassian, Aussec, and Hallstadt, the rocks are made up of an immense number of marine fossils, among them Cephalopods, Ceratites, and Ammonites of peculiar form. The Orthoceras, which we have seen abounding in the Silurian period, and continued during the deposit of the Devonian and Carboniferous periods, appears here for the last time. We still find here a great number of Gasteropods and of Lamellibranchs of the most varied form. Sea Urchins—corals of elegant form—appear to have occupied, on the other side of the Alps, the same seas which in France and Germany seem to have been nearly destitute of animals. Some beds are literally formed of accumulated shells belonging to the genus *Avicula*; but these last-mentioned deposits are to be considered as more properly belonging to the Rhætic or Penarth strata, into which the New Red or Keuper Marl gradually passes upwards, and which are more fully described at page 207.

In following the grand mountainous slopes of the Alps and Carpathians we discover the saliferous rocks by this remarkable accumulation of Aviculæ. The same facies presents itself under identical conditions in Syria, in India, in New Caledonia, in New Zealand, and in Australia. It is not the least curious part of this period, that it presents, on one side of the site of the Alps, which were not yet raised, an immense accumulation of sediment, charged with gypsum, rock-salt, &c., without organic remains; while beyond, a region presents itself equally remarkable for the extraordinary accumulation of the remains of marine Mollusca. Among these were *Myophoria lineata*, which is often confounded with Trigonia, and *Stellispongia variabilis*. [206]

France at this period was still the skeleton of what it has since become. A map of that country represents the metamorphic rocks occupying the site of the Alps, the Cévennes, and the Puy-de-Dôme, the country round Nantes, and the Islands of Brittany. The Primary rocks reach the foot of the Pyrenees, the Cotentin, the Vosges, and the Eifel Mountains. Some bands of coal stretch away from Valenciennes to the Rhine, and on the north of the Vosges, these mountains themselves being chiefly composed of Triassic rocks.

[207]

RHÆTIC, OR PENARTH SUB-PERIOD.

The attention of geologists has been directed within the last few years, more especially, to a series of deposits which intervene between the New Red Marl of the Trias, and the blue argillaceous limestones and shales of the Lower Lias. The first-mentioned beds, although they attain no great thickness in this country, nevertheless form a well-defined and persistent zone of strata between the unfossiliferous Triassic marls and the lower Liassic limestone with *Ostrea Liassica* and *Ammonites planorbis*, *A. angulatus* and *A. Bucklandi*; being everywhere characterised by the presence of the same groups of organic remains, and the same general lithological character of the beds. These last may be described as consisting of three sub-divisions, the lowermost composed of alternations of marls, clays, and marly limestones in the lower part, forming a gradual passage downwards into the New Red Marls upon which they repose. 2. A middle group of black, thinly laminated or paper-like shales, with thin layers of indurated limestone, and crowded in places with *Pecten Valoniensis*, *Cardium Rhæticum*, *Avicula contorta*, and other characteristic shells, as well as by the presence, nearly always, of a remarkable bed, which is commonly known as the “Bone-bed.” This thin band of stone, which is so well known at Aust, Axmouth, Westbury-on-Severn, and elsewhere, is a brecciated or conglomerated band of variable thickness which, sometimes a sandstone and sometimes a limestone, is always more or less composed of the teeth, scales, and bones of numerous genera of Fishes and Saurians, together with their fossilised excrement, which will be more fully and subsequently described under the name of Coprolites, under the Liassic period.

The molar tooth of a small predaceous fossil mammal of the Microlestes family (μικρος, *little*; ληστης, *beast*), whose nearest living representative appears to be some of the Hypsiprymnidæ or Kangaroo Rats, has been found by Mr. Dawkins in some grey marls underlying the bone-bed on the sea-shore at Watchett, in Somersetshire; affording the earliest known trace of a fossil mammal in the Secondary rocks. Several small teeth belonging to the genus Microlestes have [208] also been discovered by Mr. Charles Moore in a breccia of Rhætic age, filling a fissure traversing Carboniferous Limestone near Frome; and in addition to the discovery of the remains of Microlestes, those of a mammal more closely allied to the Marsupials than any other order, have been met with at Diegerloch, south-east of Stuttgart, in a remarkable bone-breccia, which also yielded coprolites and numerous traces of fishes and reptiles.

The uppermost sub-division includes certain beds of white and cream-coloured limestone, resembling in appearance the smooth fracture and closeness of texture of the lithographic limestone of Solenhofen, and which, known to geologists and quarrymen under the name “white lias,” given to it by Dr. William Smith, was formerly always considered to belong to, and was included in, the Lias proper. The most remarkable bed in this zone is one of only a few inches in thickness, but it has long been known to collectors, and sought after under the name of Cotham Marble or Landscape Stone, the latter name having reference to the curious dendritic markings which make their appearance on breaking the stone at right angles to its bedding, bearing a singular resemblance to a landscape with trees, water, &c.; while the first name is that derived from its occurrence abundantly at Cotham, in the suburbs of Bristol, where the stone was originally found and noticed.

This band of stone is interesting in another respect, because it sometimes shows by its uneven, eroded, and water-worn upper surface, that an interval took place soon after it had been deposited, when the newly-formed stone became partially dissolved, eroded, or worn away by water, before the stratum next in succession was deposited upon it. The same phenomenon is displayed, in a more marked degree, in the uppermost limestone or “white lias” bed of the series, which not only shows an eroded surface, but the holes made by boring Molluscs, exactly as is produced at the present day by the same class of animals, which excavate holes in the rocks between high and low-water marks, to serve for their dwelling-places, and as a protection from the waves to their somewhat delicate shells.

The “White Lias” of Smith is the equivalent of the Koessen beds which immediately underlie the Lower Lias of the Swabian Jura, and have been traced for a hundred miles, from Geneva to the environs of Vienna; and, also, of the Upper St. Cassian beds, which are so called from their occurrence at St. Cassian in the Austrian Alps.

The general character of the series of strata just described, is that of a deposit formed in [209] tolerably shallow water. In the Alps of Lombardy and the Tyrol, in Luxembourg, in France, and, in fact, throughout nearly the whole of Europe, they form a sort of fringe in the margin of the Triassic sea; and, although of comparatively inconsiderable thickness in England, they become highly developed in Lombardy, &c., to an enormous thickness, and constitute the great mass of the Rhætian Alps and a considerable part of the well-known beds of St. Cassian, and Hallstadt in the Austrian Alps. (See page 205.)

The Rhætic beds of Europe were, as a whole, formed under very different conditions in different areas. The thickness of the strata and the large and well-developed fauna (chiefly Mollusca) indicate that the Rhætic strata of Lombardy, and other parts of the south and east of Europe, were deposited in a broad open ocean. On the other hand, the comparatively thin beds of this age in England and north-western Europe, the fauna of which, besides being poor in genera and species, consists of small and dwarfed forms, point to the conclusion that they were in great part deposited in shallow seas and in estuaries, or in lagoons, or in occasional salt lakes, under conditions which lasted for a long period.[56]

In consequence of the importance they assume in Lombardy (the ancient Rhætia), the name “Rhætic Beds” has been given to these strata by Mr. Charles Moore; Dr. Thomas Wright has proposed the designation “Avicula Contorta Zone,” from the plentiful occurrence of that shell in the black shales forming the well-marked middle zone, and which is everywhere present where this group of beds is found; Jules Martin and others have proposed the term “Infra-lias,” or “Infra-liassic strata;” while the name “Penarth Beds” has been assigned to these deposits in this country by Mr. H. W. Bristow, at the suggestion of Sir Roderick Murchison, in consequence of their conspicuous appearance and well-exposed sections in the bold headlands and cliffs of that locality, in the British Channel, west of Cardiff.

A fuller description of these beds will be found in the Reports of the Bath Meeting of the British Association (1864), by Mr. Bristow; also in communications to the *Geological Magazine*, for 1864, by MM. Bristow and Dawkins;[57] in papers read before the Geological Society by Dr. Thomas Wright,[58] Mr. Charles Moore,[59] and Mr. Ralph Tate,[60] as printed in their *Quarterly Journal*; and by Mr. Etheridge, in the Transactions of the Cotteswold Natural History Club for 1865-66. [210] The limits of the Penarth Beds have also been lately accurately laid down by Mr. Bristow in the map of the Geological Survey over the district comprised between Bath, Bristol, and the Severn; and elaborately detailed typical sections of most of the localities in England, where these beds occur, have been constructed by MM. Bristow, Etheridge, and Woodward, of the Geological Survey of Great Britain, which, when published, will greatly add to our knowledge of this remarkable and interesting series of deposits.

JURASSIC PERIOD. [211]

This period, one of the most important in the physical history of the globe, has received its name from the Jura mountains in France, the Jura range being composed of the rocks deposited in the seas of the period. In the term Jurassic, the formations designated as the “Oolite” and “Lias” are included, both being found in the Jura mountains. The Jurassic period presents a very striking assemblage of characteristics, both in its vegetation and in the animal remains which belong to it; many genera of animals existing in the preceding age have disappeared, new genera have replaced them, comprising a very specially organised group, containing not less than 4,000 species.

The Jurassic period is sub-divided into two sub-periods: those of the *Lias* and the *Oolite*.

The Lias

is an English provincial name given to an argillaceous limestone, which, with marl and clay, forms the base of the Jurassic formation, and passes almost imperceptibly into the Lower Oolite in some places, where the Marlstone of the Lias partakes of the mineral character, as well as the fossil remains of the Lower Oolite; and it is sometimes treated of as belonging to that formation. “Nevertheless, the Lias may be traced throughout a great part of Europe as a separate and independent group, of considerable thickness, varying from 500 to 1,000 feet, containing many peculiar fossils, and having a very uniform lithological aspect.”[61] The rocks which represent the Liassic period form the base of the Jurassic system, and have a mean thickness of about 1,200 feet. In the inferior part we find argillaceous sandstones, which are called the sandstones of the Lias, and comprehend the greater part of the *Quadersandstein*, or building-stone of the Germans, above which comes compact limestone, argillaceous, bluish, and yellowish; finally, the formation terminates in the marlstones which are sometimes sandy, and occasionally bituminous.

The Lias, in England, is generally in three groups: 1, the upper, clays and shales, underlying sands; 2, the middle, lias or marlstone; and 3, the lower, clays and limestone; but these have been again sub-divided—the last into six zones, each marked by its own peculiar species of Ammonites; the second into three zones; the third consists of clay, shale, and argillaceous limestone. For the purposes of description we shall, therefore, divide the Lias into these three groups:— [212]

1. *Upper Lias Clay*, consists of blue clay, or shale, containing nodular bands of claystones at the base, crowded with *Ammonites serpentinus*, *A. bifrons*, *Belemnites*, &c.

2. The *Middle Lias*, commonly known as the Marlstone, is surmounted by a bed of oolitic ironstone, largely worked in Leicestershire and in the north of England as a valuable ore of iron. The underlying marls and sands, the latter of which become somewhat argillaceous below, form beds from 200 to 300 feet thick in Dorsetshire and Gloucestershire; the fossils are *Ammonites margaritaceus*, *A. spinatus*, *Belemnites tripartitus*. The upper rock-beds, especially the bed of ironstone on the top, is generally remarkably rich in fossils.

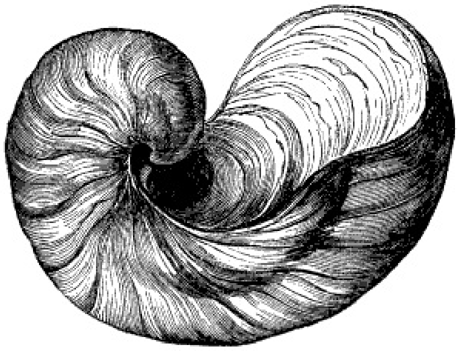


Fig. 88.—Gryphæa incurva.

3. *Lower Lias* (averaging from 600 to 900 feet in thickness) consists, in the lower part, of thin layers of bluish argillaceous limestone, alternating with shales and clays; the whole overlaid by the blue clay of which the lower member of the Liassic group usually consists. This member of the series is well developed in Yorkshire, at Lyme Regis and Charmouth in Dorsetshire, and generally over the South-West and Midland Counties of England. *Gryphæa incurva* (Fig. 88), with sandy bands, occurs at the base, in addition to which we find *Ammonites planorbis Bucklandi*, *A. Ostrea liassica*, *Lima gigantea*, *Ammonites Bucklandi*, &c., in the lower limestones and shales.

Above the clay are yellow sands from 100 to 200 feet thick, underlying the limestone of the Inferior Oolite. These sands were, until lately, considered to belong to the latter formation—as [213] they undoubtedly do physically—until they were shown, by Dr. Thomas Wright, of Cheltenham, to be more nearly allied, by their fossils, to the Lias below than to the Inferior Oolite above, into which they form the passage-beds.

In France the Lias abounds in the Calvados, in Burgundy, Lorraine, Normandy, and the Lyonnais. In the Vosges and Luxembourg, M. Elie de Beaumont states that the Lias containing *Gryphæa incurva* and *Lima gigantea*, and some other marine fossils, becomes arenaceous; and around the Harz mountains, in Westphalia and Bavaria, in its lower parts the formation is sandy, and is sometimes a good building-stone.

“In England the Lias constitutes,” says Professor Ramsay, “a well-defined belt of strata, running continuously from Lyme Regis, on the south-west, through the whole of England, to Yorkshire on the north-east, and is an extensive series of alternating beds of clay, shale, and limestone, with occasional layers of jet in the upper part. The unequal hardness of the clays and limestones of the Liassic strata causes some of its members to stand out in the distinct minor escarpments, often facing the west and north-west. The Marlstone forms the most prominent of these, and overlooks the broad meadows of the lower Lias-clay, that form much of the centre of England.” In Scotland there are few traces of the Lias. Zoophytes, Mollusca, and Fishes of a peculiar organisation, but, above all, Reptiles of extraordinary size and structure gave to the sea of the Liassic period an interest and features quite peculiar. Well might Cuvier exclaim, when the drawings of the Plesiosaurus were sent to him: “Truly this is altogether the most monstrous animal that has yet been dug out of the ruins of a former world!” In the whole of the English Lias there are about 243 genera, and 467 species of fossils. The whole series has been divided into zones characterised by particular Ammonites, which are found to be limited to them, at least locally.

Fig. 89.—Pentacrinites Briareus. Half natural size.

Among the Echinodermata belonging to the Lias we may cite *Asterias lumbricalis* and *Palæocoma Furstembergii*, which constitutes a genus not dissimilar to the star-fishes, of which its radiated form reminds us. The Pentacrinites, of which *Pentacrinites Briareus* is a type, ornaments many collections by its elegant form, and is represented in Figs. 79 and 89. It belongs to the order of Crinoidea, which is represented at the present time by a single living species, *Pentacrinus caput-Medusæ*, one of the rare and delicate Zoophytes of the Caribbean sea.

Oysters (*Ostrea*) made their appearance in the Muschelkalk of the last period, but only in a small number of species; they increased greatly in importance in the Liassic seas.

The *Ammonites*, a curious genus of Cephalopoda, which made their first appearance in small [214]
numbers towards the close of the preceding Triassic period, become quite special in the
Secondary epoch, with the close of which they disappear altogether. They were very abundant in [215]
the Jurassic period, and, as we have already said, each zone is characterised by its peculiar species. The name is taken from the resemblance of the shell to the ram's-horn ornaments which decorated the front of the temple of Jupiter Ammon and the bas-reliefs and statues of that pagan deity. They were Cephalopodous Mollusca with circular shells, rolled upon themselves symmetrically in the same plane, and divided into a series of chambers. The animal only occupied the outer chamber of the shell; all the others were empty. A siphon or tube issuing from the first chamber traversed all the others in succession, as is seen in all the Ammonites and Nautili. This tube enabled the animal to rise to the surface, or to sink to the bottom, for the Ammonite could fill the chambers with water at pleasure, or empty them, thus rendering itself lighter or heavier as occasion required. The Nautilus of our seas is provided with the same curious organisation, and reminds us forcibly of the Ammonites of geological times.

Shells are the only traces which remain of the Ammonites. We have no exact knowledge of the animal which occupied and built them. The attempt at restoration, as exhibited in Fig. 91, will probably convey a fair idea of the Ammonite when living. We assume that it resembled the Nautilus of modern times. What a curious aspect these early seas must have presented, covered by myriads of these Molluscs of all sizes, swimming about in eager pursuit of their prey!

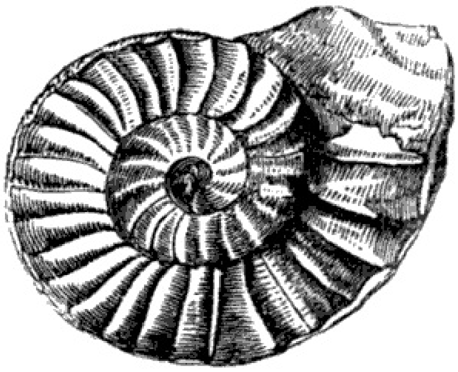


Fig. 90.—Ammonites Turneri, from the Lower Lias.

The Ammonites of the Jurassic age present themselves in a great variety of forms and sizes; some of them of great beauty. *Ammonites bifrons*, *A. Noditianus*, *A. bisulcatus*, *A. Turneri* (Fig. 90), and *A. margaritatus*, are forms characteristic of the Lias.

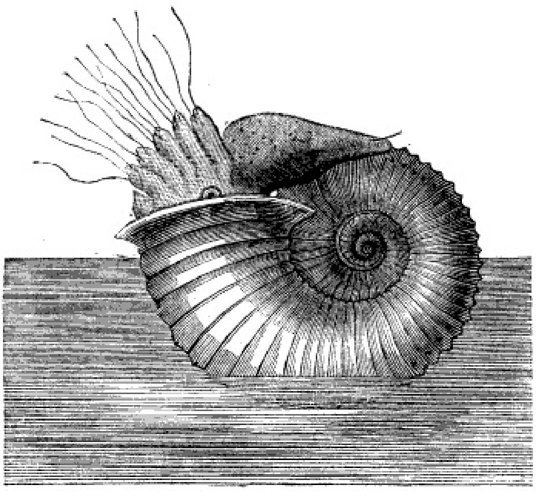


Fig. 91.—Ammonite restored.

The *Belemnites*, molluscous Cephalopods of a very curious organisation, appeared in great numbers, and for the first time, in the Jurassic seas. Of this Mollusc we only possess the fossilised internal "bone," analogous to that of the modern cuttle-fish and the calamary of the present seas. This simple relic is very far from giving us an exact idea of what the animal was to which the name of Belemnite has been given (from Βελεμνον, *a dart*) from their supposed resemblance to the head of a javelin. The slender cylindrical bone, the only vestige remaining to us, was merely the internal skeleton of the animal. When first discovered they were called, by the vulgar, [216] "Thunder-stones" and "Ladies' fingers." They were, at last, inferred to be the shelly processes of some sort of ancient cuttle-fish. Unlike the Ammonite, which floated on the surface and sunk to the bottom at pleasure, the Belemnite, it has been thought, swam nearer the bottom of the sea, and seized its prey from below.

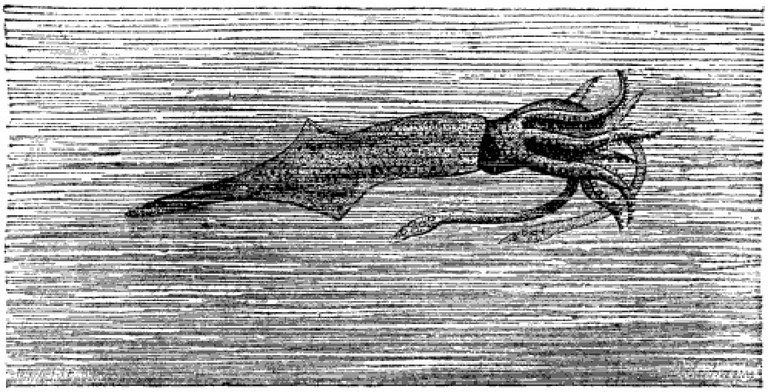


Fig. 92.—Belemnite restored.

In Fig. 92 is given a restoration of the living Belemnite, by Dr. Buckland and Professor Owen, in [217] which the terminal part of the animal is marked in a slightly darker tint, to indicate the place of the bone which alone represents in our days this fossilised being. A sufficiently exact idea of this Mollusc may be arrived at from the existing cuttle-fish. Like the cuttle-fish, the Belemnite secreted a black liquid, a sort of ink or sepia; and the bag containing the ink has frequently been found in a fossilised state, with the ink dried up, and elaborate drawings have been made with this fossil pigment.

The beaks, or horny mandibles of the mouth, which the Belemnite possessed in common with the other naked Cephalopoda, are represented in Fig. 78, p. 181.

As Sir H. De la Beche has pointed out, the destruction of the animals whose remains are known to us by the name of Belemnites was exceedingly great when the upper part of the Lias of Lyme Regis was deposited. Multitudes seem to have perished almost simultaneously, and millions are entombed in a bed beneath Golden Cap, a lofty cliff between Lyme Regis and Bridport Harbour, as well as in the upper Lias generally.[62]

Among the Belemnites characteristic of the Liassic period may be cited *B. acutus* (Fig. 93), *B. pistiliformis*, and *B. sulcatus*.

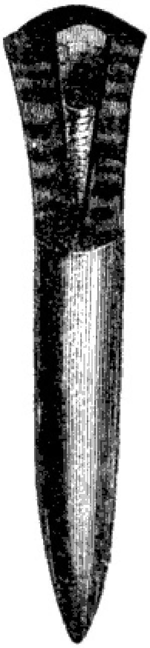


Fig. 93.—Belemnites acutus.

The seas of the period contained a great number of the fishes called *Ganoids*; which are so called from the splendour of the hard and enamelled scales, which formed a sort of defensive armour to protect their bodies. *Lepidotus gigas* was a fish of great size belonging to this age. A smaller fish was the *Tetragonolepis*, or *Æchmodus Buchii*. The *Acrodus nobilis*, of which the teeth are still preserved, and popularly known by the name of *fossil leeches*, was a fish of which an entire skeleton has never been met with. Neither are we better informed as to the *Hybodus reticulatus*. The bony spines, which form the anterior part of the dorsal fin of this fish, had long been an object of curiosity to geologists, under the general name of *Ichthyodorulites*, before they were known to be fragments of the fin of the *Hybodus*. The Ichthyodorulites were supposed by some naturalists to be the jaw of some animal—by others, weapons like those of the living *Balistes* or [218] *Silurus*; but Agassiz has shown them to be neither the one nor the other, but bony spines on the fin, like those of the living genera of *Cestracions* and *Chimæras*, in both of which the concave face is armed with small spines like those of the *Hybodus*. The spines were simply imbedded in the flesh, and attached to it by strong muscles. "They served," says Dr. Buckland, "as in the *Chimæra*, to raise and depress the fin, their action resembling that of a movable mast lowering backward."

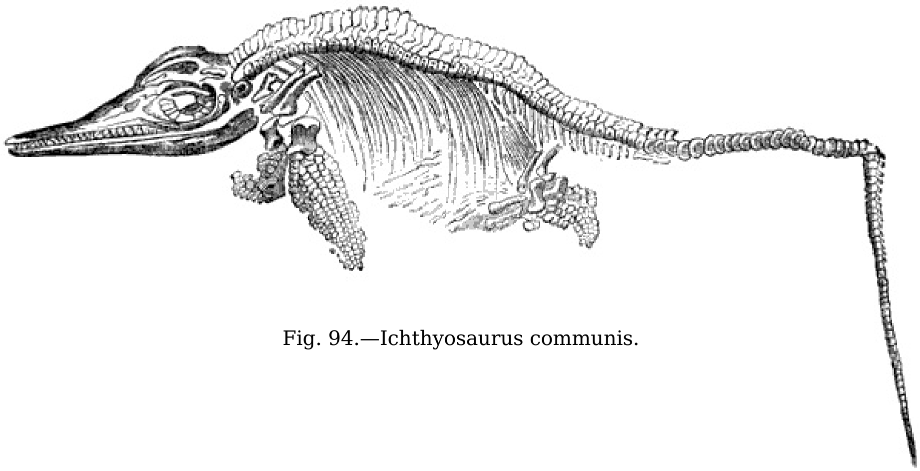


Fig. 94.—Ichthyosaurus communis.

Let us hasten to say, however, that these are not the beings that characterised the age, and were the salient features of the generation of animals which existed during the Jurassic period. These distinguishing features are found in the enormous reptiles with lizard's head, crocodile's conical teeth, the trunk and tail of a quadruped, whale-like paddles, and the double-concave vertebræ of fishes; and this strange form, on such a gigantic scale that even their inanimate remains are examined with a curiosity not unmixed with awe. The country round Lyme Regis, in Dorsetshire, has long been celebrated for the curious fossils discovered in its quarries, and preserved in the muddy accumulations of the sea of the Liassic period. The country is hilly—"up one hill and down another," is a pretty correct provincial description of the walk from Bridport to Lyme Regis—where some of the most frightful creatures the living world has probably ever beheld, sleep the [219] sleep of stones. The quarries of Lyme Regis form the cemetery of the Ichthyosauri; the sepulchre where lie interred these dragons of the ancient seas.

In 1811 a country girl, who made her precarious living by picking up fossils for which the neighbourhood was famous, was pursuing her avocation, hammer in hand, when she perceived some bones projecting a little out of the cliff. Finding, on examination, that it was part of a large skeleton, she cleared away the rubbish, and laid bare the whole creature imbedded in the block of stone. She hired workmen to dig out the block of Lias in which it was buried. In this manner was the first of these monsters brought to light: "a monster some thirty feet long, with jaws nearly a fathom in length, and huge saucer-eyes; which have since been found so perfect, that the petrified lenses have been split off and used as magnifiers," as a writer in *All the Year Round* assures us.

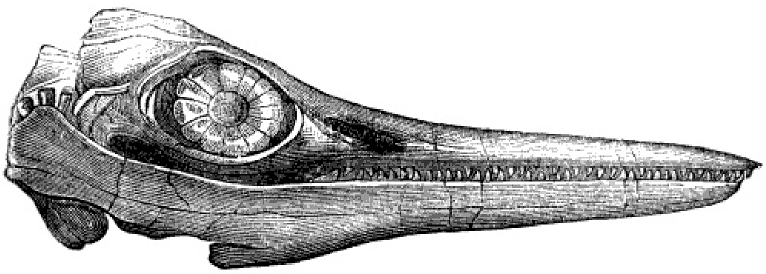


Fig. 95.—Head of Ichthyosaurus platydon.

In Fig. 95 the head of *I. platydon* is represented. As in the Saurians, the openings of the nostrils are situated near the anterior angle of the orbits of the eyes, while those of the Crocodile are near the snout; but, on the other hand, in its osteology and its mode of dentition it nearly resembles the Crocodile; the teeth are pointed and conical—not, however, set in deep or separate sockets, but only implanted in a long and deep continuous groove hollowed in the bones of the jaw. These strong jaws have an enormous opening; for, in some instances, they have been found eight feet in length and armed with 160 teeth. Let us add that teeth lost through the voracity of the animal, or in contests with other animals, could be renewed many times; for, at the inner side [220] of the base of every old tooth, there is always the bony germ of a new one.

The eyes of this marine monster were much larger than those of any animal now living; in volume they frequently exceed the human head, and their structure was one of their most remarkable peculiarities. In front of the sclerotic coat or capsule of the eye there is an annular series of thin bony plates, surrounding the pupil. This structure, which is now only met with in the eyes of certain turtles, tortoises, and lizards, and in those of many birds, could be used so as to increase or diminish the curvature of the transparent cornea, and thus increase or diminish the magnifying power, according to the requirements of the animal—performing the office, in short, of a telescope or microscope at pleasure. The eyes of the Ichthyosaurus were, then, an optical apparatus of wonderful power and of singular perfection, enabling the animal, by their power of adaptation and intensity of vision, to see its prey far and near, and to pursue it in the darkness and in the depths of the sea. The curious arrangement of bony plates we have described furnished, besides, to its globular eye, the power necessary to bear the pressure of a considerable weight of water, as well as the violence of the waves, when the animal came to the surface to breathe, and raised its head above the waves. This magnificent specimen of the fish-lizard, or Ichthyosaurus, as it was named by Dr. Ure, now forms part of the treasures of the British Museum.

At no period in the earth's history have Reptiles occupied so important a place as they did in the Jurassic period. Nature seems to have wished to bring this class of animals to the highest state of development. The great Reptiles of the Lias are as complicated in their structure as the Mammals which appeared at a later period. They probably lived, for the most part, by fishing in shallow creeks and bays defended from heavy breakers, or in the open sea; but they seem to have sought the shore from time to time; they crawled along the beach, covered with a soft skin, perhaps not unlike some of our Cetaceæ. The Ichthyosaurus, from its form and strength, may have braved the waves of the sea as the porpoise does now. Its destructiveness and voracity must have been prodigious, for Dr. Buckland describes a specimen which had between its ribs, in the place where the stomach might be supposed to have been placed, the skeleton of a smaller one—a proof that this monster, not content with preying on its weaker neighbours, was in the habit of devouring its own kind. In the same waters lived the Plesiosaurus, with long neck and form more strange than that of the Ichthyosaurus; and these potentates of the seas were warmed by the same sun and [221]
tenanted the same banks, in the midst of a vegetation not unlike that which the climate of Africa now produces.

The great Saurians in the Lias of Lyme Regis seem to have suffered a somewhat sudden death, partly in consequence of a series of small catastrophes suddenly destroying the animals then existing in particular spots. "In general the bones are not scattered about, and in a detached state, as would happen if the dead animal had descended to the bottom of the sea, to be decomposed, or devoured piecemeal, as, indeed, might also happen if the creature floated for a time on the surface, one animal devouring one part, and another carrying off a different portion; on the contrary, the bones of the skeleton, though frequently compressed, as must arise from the enormous pressure to which they have so long been subjected, are tolerably connected, frequently in perfect, or nearly perfect, order, as if prepared by the anatomist. The skin, moreover, may sometimes be traced, and the compressed contents of the intestines may at times be also observed—all tending to show that the animals were suddenly destroyed, and as suddenly preserved."[63]

These strange and gigantic Saurians seem almost to disappear during the succeeding geological periods; for, although they have been discovered as low down as the Trias in Germany, and as high up as the Chalk in England, they only appear as stragglers in these epochs; so, too, the Reptiles, the existing Saurians are, as it were, only the shadowy, feeble representatives of these powerful races of the ancient world.

Confining ourselves to well-established facts, we shall consider in some detail the best known of these fossil reptiles—the *Ichthyosaurus*, *Plesiosaurus*, and *Pterodactyle*.

The extraordinary creature which bears the name of *Ichthyosaurus* (from the Greek words Ιχθυς σαυρος, signifying fish-lizard), presents certain dispositions and organic arrangements which are met with dispersed in certain classes of animals now living, but they never seem to be again reunited in any single individual. It possesses, as Cuvier says, the snout of a dolphin, the head of a lizard, the jaws and teeth of a crocodile, the vertebræ of a fish, the head and sternum of a lizard, the paddles like those of a whale, and the trunk and tail of a quadruped.

Bayle appears to have furnished the best idea of the Ichthyosaurus by describing it as the Whale of the Saurians—the Cetacean of the primitive seas. It was, in fact, an animal exclusively marine; [222]
which, on shore, would rest motionless like an inert mass. Its whale-like paddles, and fish-like vertebræ, the length of the tail and other parts of its structure, prove that its habits were aquatic; as the remains of fishes and reptiles, and the form of its teeth, show that it was carnivorous. Like the Whale, also, the Ichthyosaurus breathed atmospheric air; so that it was under the necessity of coming frequently to the surface of the water, like that inhabitant of the deep. We can even believe, with Bayle, that it was provided, like the Whale, with vents or blowers, through which it ejected, in columns into the air, the water it had swallowed.

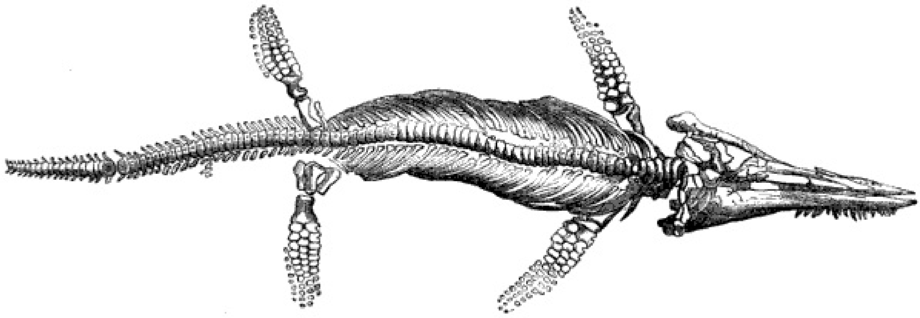


Fig. 96.—Ichthyosaurus platydon.

The dimensions of the Ichthyosaurus varied with the species, of which five are known and described. These are *Ichthyosaurus communis*, *I. platydon*, *I. intermedius*, *I. tenuirostris*, and *I. Cuvierii*, the largest being more than thirty feet in length.

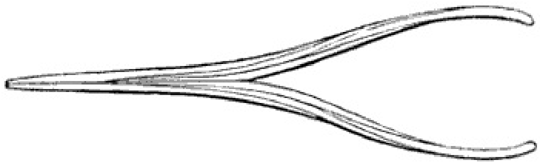


Fig. 97.—Lower jaw of Ichthyosaurus. (Dr. Buckland.)

The short, thick neck of the Ichthyosaurus supported a capacious head, and was continued backwards, from behind the eyes, in a column composed of more than a hundred vertebræ. The animal being adapted, like the whale, for rapid movement through the water, its vertebræ had none of the invariable solidity of those of the Lizard or Crocodile, but rather the structure and [223]
lightness of those of Fishes. The section of these vertebræ presents two hollow cones, connected only by their summits to the centre of the vertebræ, which would permit of the utmost flexibility of movement. The ribs extended along the entire length of the vertebral column, from the head to the pelvis. The bones of the sternum, or that part of the frame which supported the paddles, present the same combinations with those of the sternum in the Ornithorhynchus, or Duck-billed Platypus, of New Holland, an animal which presents the singular combination of a mammalian furred quadruped having the bill of a duck and webbed feet; which dived to the bottom of the water in search of its food, and returned to the surface to breathe the air. In this phenomenon of [224]
living Nature the Creator seems to have repeated, in our days, the organic arrangements which he had originally provided for the Ichthyosaurus.

In order that the animal should be able to move with rapidity in the water, both its anterior and posterior members were converted into fins or paddles. The anterior fins were half as large again as the posterior. In some species each paddle was made up of nearly a hundred bones, of polygonal form, and disposed in series representing the phalanges of the fingers. This hand, jointed at the arm, bears resemblance, in osteological construction, to the paddles, without distinct fingers, of the Porpoise and the Whale. A specimen of the posterior fin of *I. communis*, discovered at Barrow-on-Soar, in Leicestershire, in 1840, by Sir Philip Egerton, exhibited on its posterior margin the remains of cartilaginous rays, which bifurcated as they approached the edge, like those in the fins of a fish. "It had previously been supposed," says Professor Owen, "that the locomotive organs were enveloped, while living, in a smooth integument, like that of the turtle and porpoise, which has no other support than is afforded by the bones and ligaments within; but it now appears that the fin was much larger, expanding far beyond the osseous framework, and deviating widely in its fish-like rays from the ordinary reptilian type." The Professor believes that, besides the fore-paddles, these stiff-necked Saurians were furnished at the end of the tail with a fin to assist them in turning, not placed horizontally, as in the whale, but vertically, forming a powerful instrument of progression and motion. It is obvious that the Ichthyosaurus was an animal powerfully armed for offence and defence. We cannot say, with certainty, whether the skin was smooth, like that of the whale or lizard, or covered with scales, like the great reptiles of our own age. Nevertheless, as the scales of the Fishes and the cuirass and horny armour of other Reptiles of the Lias are preserved, and as no such defensive scales have been found belonging to the Ichthyosaurus, it is probable that the skin was naked and smooth. The tail, composed of from eighty to eighty-five vertebræ, was provided with large and long paddles, arranged vertically as in the Whale.

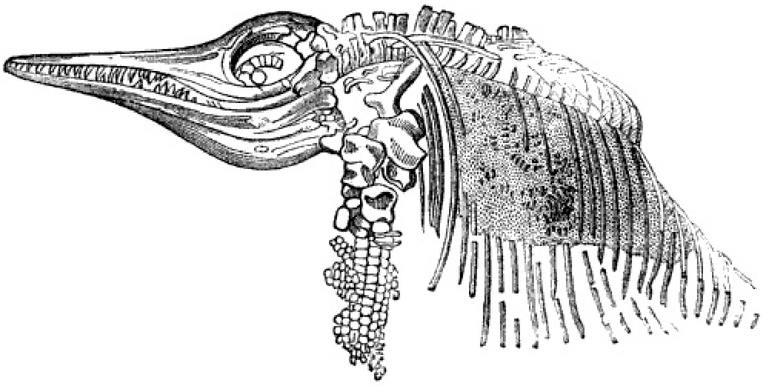


Fig. 98.—Skeleton of Ichthyosaurus.
Containing teeth and bones of Fishes in a coprolitic form. One-fifteenth natural size.

It is curious to see to what a degree of perfection has been carried, in our days, the knowledge of the antediluvian animals, their habits, and their economy. Fig. 98 represents the skeleton of an Ichthyosaurus found in the Lias of Lyme Regis, which still retains in its abdominal cavity coprolites, that is to say, the residue of digestion. The soft parts of the intestinal canal have disappeared, but the *fæces* themselves are preserved, and their examination informs us as to the [225] alimentary regimen of this animal which has perished from the earth many thousands, perhaps millions, of years. Mary Anning, to whom we owe many of the discoveries made in the neighbourhood of Lyme Regis, her native place, had in her collection an enormous coprolite of the Ichthyosaurus. This coprolite (Fig. 99) contained some bones and scales of Fishes, and of divers Reptiles, well enough preserved to have their species identified. It only remains to be added that, among the bones, those of the Ichthyosaurus were often found, especially those of young individuals. The presence of the undigested remains of vertebræ and other bones of animals of its own species in the coprolites of the Ichthyosaurus proves, as we have already had occasion to remark, that this great Saurian must have been a most voracious monster, since it habitually devoured not only fish, but individuals of its own race—the smaller becoming the prey of the larger. The structure of the jaw of the Ichthyosaurus leads us to believe that the animal swallowed its prey without dividing it. Its stomach and intestines must, then, have formed a sort of pouch of great volume, filling entirely the abdominal cavity, and corresponding in extent to the great development of the teeth and jaws.

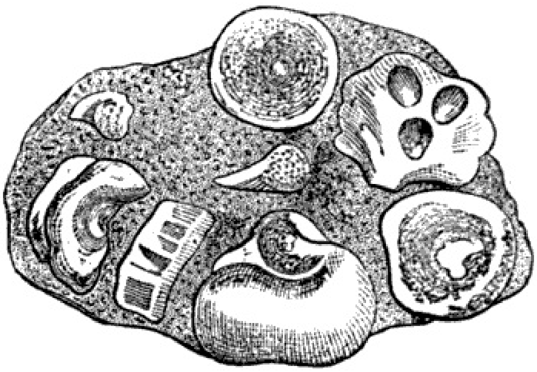


Fig. 99.—Coprolite, enclosing bones of small Ichthyosaurus.

The perfection with which its contents have been preserved in the fossilised coprolites, furnishes indirect proofs that the intestinal canal of the Ichthyosaurus resembled closely that of the shark and the dog-fish—fishes essentially voracious and destructive, which have the intestinal canal spirally convoluted, an arrangement which is exactly that indicated in some of the coprolites of [226] the Ichthyosaurus, as is evident from the impressions which the folds of the intestine have left on the coprolite, of which Fig. 100 is a representation. In the cliffs near Lyme Regis coprolites are abundant in the Liassic formation, and have been found disseminated through the shales and limestones along many miles of that coast.

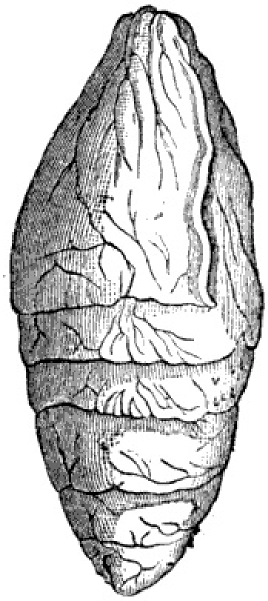


Fig. 100.—Coprolite of
Ichthyosaurus.

What an admirable privilege of science, which is able, by an examination of the simplest parts in the organisation of beings which lived ages ago, to give to our minds such solid teachings and such true enjoyments! “When we discover,” says Dr. Buckland, “in the body of an Ichthyosaurus the food which it has engulfed an instant before its death, when the intervals between its sides present themselves still filled with the remains of fishes which it had swallowed some ten thousand years ago, or a time even twice as great, all these immense intervals vanish, time disappears, and we find ourselves, so to speak, thrown into immediate contact with events which took place in epochs immeasurably distant, as if we occupied ourselves with the affairs of the previous day.”

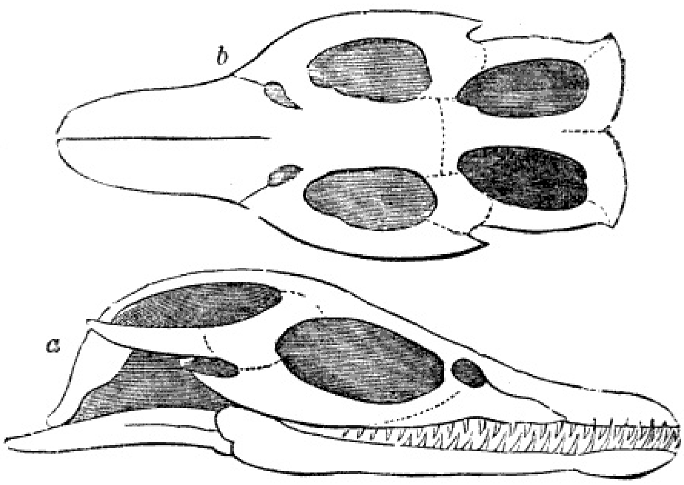


Fig. 101.—Skull of Plesiosaurus restored. (Conybeare.)
a, profile; *b*, seen from above.

The name of *Plesiosaurus* (from the Greek words πλησιος, *near*, and σαυρος, *lizard*) reminds us that this animal, though presenting many peculiarities of general structure, is allied by its organisation to the Saurian or Lizard family, and, consequently, to the Ichthyosaurus.

The Plesiosaurus presents, in its organic structure, the most curious assemblage we have met with among the organic vestiges of the ancient world. The Plesiosaurus was a marine, air-breathing, carnivorous reptile, combining the characters of the head of a Lizard, the teeth of a Crocodile, a neck of excessive length resembling that of a Swan, the ribs of a Chameleon, a body of moderate size, and a very short tail, and, finally, four paddles resembling those of a Whale. Let us bestow a glance upon the remains of this strange animal which the earth has revealed, and which science has restored to us. [227]

The head of the Plesiosaurus presents a combination of the characters belonging to the Ichthyosaurus, the Crocodile, and the Lizard. Its enormously long neck comprises a greater number of vertebræ than the neck of either the Camel, the Giraffe, or even the Swan, which of all the feathered race has the longest neck in comparison to the rest of the body. And it is to be remarked, that, contrary to what obtains in the Mammals, where the vertebræ of the neck are always seven, the vertebræ in birds increase in number with the length of the neck.

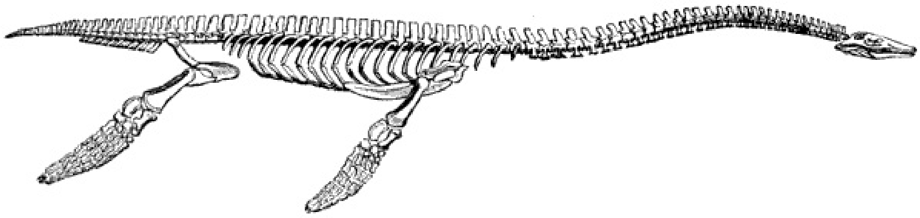


Fig. 102.—Skeleton of Plesiosaurus dolichodeirus restored. (Conybeare principally.)

The body is cylindrical and rounded, like that of the great marine Turtles. It was, doubtless, naked, *i.e.*, not protected with the scales or carapace with which some authors have invested it; for no traces of such coverings have been found near any of the skeletons which have been hitherto discovered. The dorsal vertebræ are attached to each other by nearly plane surfaces like those of terrestrial quadrupeds, a mode of arrangement which must have deprived the whole of its vertebral column of much of its flexibility. Each pair of ribs surrounded the body with a [228] complete girdle, formed of five pieces, as in the Chameleon and Iguana; whence, no doubt, as with the Chameleon, great facilities existed for the contraction and dilatation of the lungs.

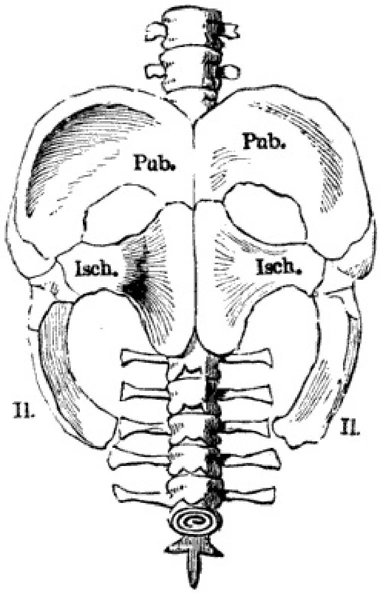


Fig. 103.—Sternum and pelvis of Plesiosaurus. Pub., pubis; Isch., ischium; Il., ilium.

The breast, the pelvis, and the bones of the anterior and posterior extremities furnished an apparatus which permitted the Plesiosaurus, like the Ichthyosaurus and existing Cetaceans, to sink in the water and return to the surface at pleasure (Fig. 103). Prof. Owen, in his “Report on British Reptiles,” characterises them as air-breathing and cold-blooded animals; the proof that they respired atmospheric air immediately, being found in the position and structure of the nasal passages, and the bony mechanism of the thoracic duct and abdominal cavity. In the first, the size and position of the external nostrils (Fig. 102), combined with the structure of the paddles, indicate a striking analogy between the extinct Saurians and the Cetaceans, offering, as the Professor observes, “a beautiful example of the adaptation of structure to the peculiar exigencies of species.” While the evidence that they were cold-blooded animals is found in the flexible or unanchylosed condition of the osseous pieces of the occiput and other cranial bones of the lower jaw, and of the vertebral column; from which the Professor draws the conclusion that the heart was adapted for transmitting a part only of the blood through the respiratory organs; the absence of the ball-and-socket articulations of the bones of the vertebræ, the position of the nostrils near the summit of the head, the numerous short and flat digital bones, which must have been enveloped in a simple undivided integumentary sheath, forming in both fore and hind extremities a paddle closely resembling that of the living Cetacea. The paddles are larger and more powerful than those of the Ichthyosaurus, to compensate for the slight assistance the animal derived from the tail. The latter—shorter, as compared with the length of the rest of the body, than in the Ichthyosaurus—was more calculated to act the part of a rudder, in directing the course of the [229] animal through the water, than as a powerful organ of propulsion.

Such were the strange combinations of form and structure in the Plesiosaurus and Ichthyosaurus—genera of animals whose remains have, after an interment extending to unknown thousands of years, been revealed to light and submitted to examination; nay, rebuilt, bone by bone, until we have the complete skeletons before us, and the habits of the animals described, as if they had been observed in life. Conybeare thus speaks of the supposed habits of these extinct forms, which he had built up from scanty materials: “That the Plesiosaurus was aquatic is evident from the form of its paddles; that it was marine is equally so, from the remains with which it is universally [230] associated; that it may have occasionally visited the shore, the resemblance of its extremities to the turtle may lead us to conjecture; its motion, however, must have been very awkward on land; its long neck must have impeded its progress through the water, presenting a striking contrast to the organisation which so admirably fits the Ichthyosaurus for cutting through the waves. May it not, therefore, be concluded that it swam on or near the surface, arching back its long neck like the swan, and occasionally darting it down at the fish which happened to float within its reach? It may, perhaps, have lurked in shallow water along the coasts, concealed among the sea-weeds, and, raising its nostrils to the surface from a considerable depth, may have found a secure retreat from the assaults of dangerous enemies, while the length and flexibility of its neck may have compensated for the want of strength in its jaws, and incapacity for swift motion through the water, by the suddenness and agility of the attack they enabled it to make on every animal fitted to become its prey."

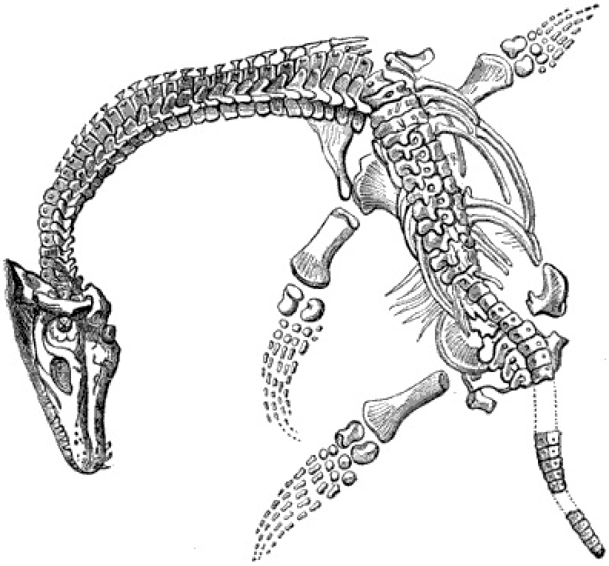
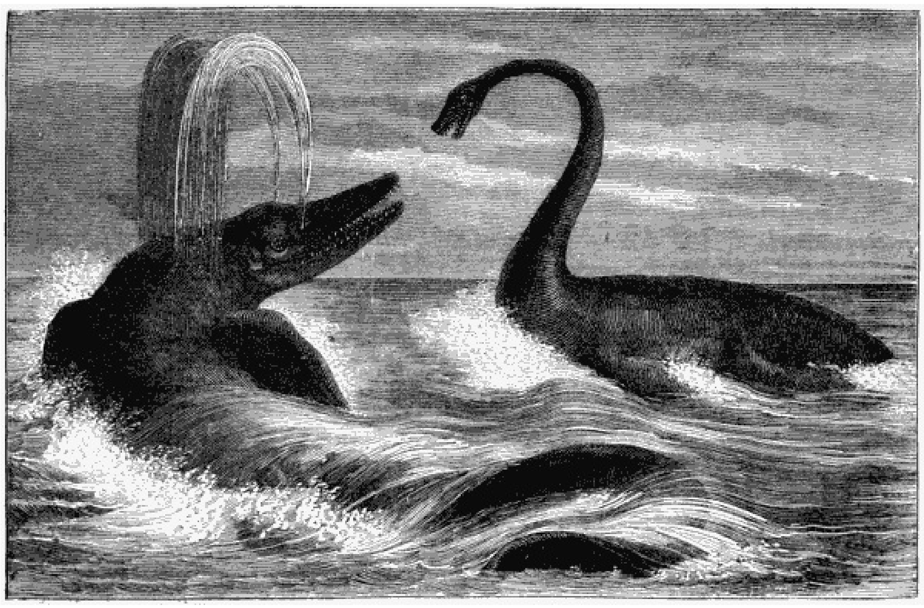


Fig. 104.—Remains of Plesiosaurus macrocephalus. One-twelfth natural size.

The Plesiosaurus was first described by the Rev. W. D. Conybeare and Sir Henry De la Beche, in the "Geological Society's Transactions" for 1821, and a restoration of *P. dolichodeirus*, the most common of these fossils, appeared in the same work for 1824. The first specimen was discovered, as the Ichthyosaurus had been previously, in the Lias of Lyme Regis; since then other individuals and species have been found in the same geological formation in various parts of England, Ireland, France, and Germany, and with such variations of structure that Professor Owen has felt himself justified in recording sixteen distinct species, of which we have represented *P. dolichodeirus* (Fig. 102), as restored by Conybeare, and *P. macrocephalus* (Fig. 104), with its skeleton, as moulded from the limestone of Lyme Regis, which has been placed in the Palæontological Gallery of the British Museum.

[231]



XV.—Ideal scene of the Lias with Ichthyosaurus and Plesiosaurus.

The Plesiosaurus was scarcely so large as the Ichthyosaurus. The specimen of *I. platydon* in the British Museum probably belonged to an animal four-and-twenty feet long, and some are said to indicate thirty feet, while there are species of Plesiosauri measuring eighteen and twenty, the largest known specimen of *Plesiosaurus Cramptoni* found in the lias of Yorkshire, and now in the

Museum of the Royal Society of Dublin, being twenty-two feet four inches in length. On the opposite page (Plate XV.) an attempt is made to represent these grand reptiles of the Lias in their native element, and as they lived.

Cuvier says of the Plesiosaurus, "that it presents the most monstrous assemblage of characteristics that has been met with among the races of the ancient world." This expression should not be understood in a literal sense; there are no monsters in Nature; in no living creature are the laws of organisation ever positively infringed; and it is more in accordance with the general perfection of creation to see in an organisation so special, in a structure which differs so notably from that of the animals of our own days, the simple development of a type, and sometimes also the introduction of beings, and successive changes in their structure. We shall see, in examining the curious series of animals of the ancient world, that the organisation and physiological functions go on improving unceasingly, and that each of the extinct genera which preceded the appearance of man, present, for each organ, modifications which always tend towards greater perfection. The fins of the fishes of Devonian seas become the paddles of the Ichthyosauri and of the Plesiosauri; these, in their turn, become the membranous foot of the Pterodactyle, and, finally, the wing of the bird. Afterwards comes the articulated fore-foot of the terrestrial mammalia, which, after attaining remarkable perfection in the hand of the ape, becomes, finally, the arm and hand of man, an instrument of wonderful delicacy and power, belonging to an enlightened being gifted with the divine attribute of reason! Let us, then, dismiss any idea of monstrosity with regard to these antediluvian animals; let us learn, on the contrary, to recognise, with admiration, the divine proofs of design which they display, and in their organisation to see only the handiwork of the Creator. [233]

Another strange inhabitant of the ancient world, the *Pterodactylus* (from πτερον, *a wing*, and δακτυλος, *a finger*), discovered in 1828, made Cuvier pronounce it to be incontestably the most extraordinary of all the extinct animals which had come under his consideration; and such as, if we saw them restored to life, would appear most strange and dissimilar to anything that now exists. In size and general form, and in the disposition and character of its wings, this fossil genus, according to Cuvier, somewhat resembled our modern bats and vampyres, but had its beak elongated like the bill of a woodcock, and armed with teeth like the snout of a crocodile; its vertebræ, ribs, pelvis, legs, and feet resembled those of a lizard; its three anterior fingers terminated in long hooked claws like that on the fore-finger of the bat; and over its body was a covering, neither composed of feathers as in the bird, nor of hair as in the bat, but probably a naked skin; in short, it was a monster resembling nothing that has ever been heard of upon earth, except the dragons of romance and heraldry. Moreover, it was probably noctivagous and [234] insectivorous, and in both these points resembled the bat; but differed from it in having the most important bones in its body constructed after the manner of those of reptiles.

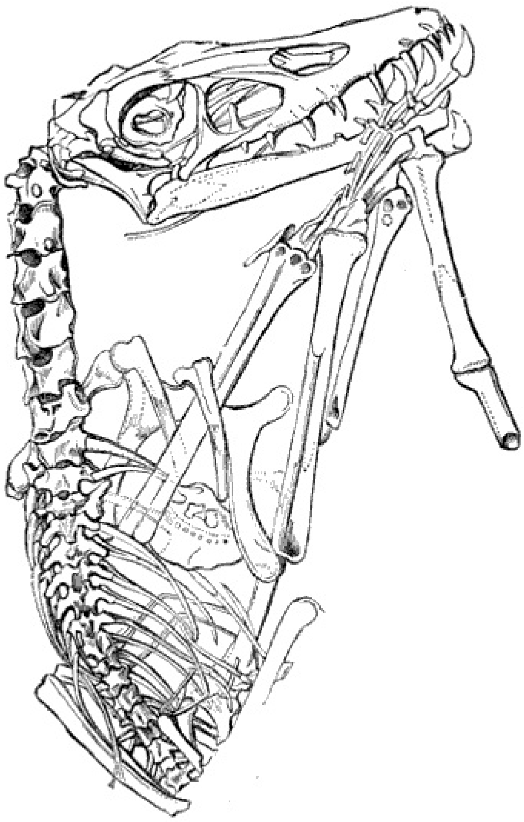


Fig. 105.—Pterodactylus crassirostris.

"Thus, like Milton's fiend, all-qualified for all services and all elements, the creature was a fit [235] companion for the kindred reptiles that swarmed in the seas, or crawled on the shores, of a turbulent planet:

"The Fiend,

O’er bog, or steep, through strait, rough, dense, or rare,
With head, hands, wings, or feet, pursues his way,
And sinks, or swims, or wades, or creeps, or flies.

Paradise Lost, Book II., line 947.

“With flocks of such-like creatures flying in the air, and shoals of Ichthyosauri and Plesiosauri swarming in the ocean, and gigantic Crocodiles and Tortoises crawling on the shores of primæval lakes and rivers—air, sea, and land must have been strangely tenanted in these early periods of our infant world.”[64]

The strange structure of this animal gave rise to most contradictory opinions from the earlier naturalists. One supposed it to be a bird, another a bat, and others a flying reptile. Cuvier was the first to detect the truth, and to prove, from its organisation, that the animal was a Saurian. “Behold,” he says, “an animal which in its osteology, from its teeth to the end of its claws, presents all the characters of the Saurians; nor can we doubt that their characteristics existed in its integuments and softer parts, in its scales, its circulation, its generative organs: it was at the same time provided with the means of flight; but when stationary it could not have made much use of its anterior extremities, even if it did not keep them always folded as birds fold their wings. [236]
It might, it is true, use its small anterior fingers to suspend itself from the branches of trees; but when at rest it must have been generally on its hind feet, like the birds again, and like them it must have carried its neck half-erect and curved backwards, so that its enormous head should not disturb its equilibrium.” This diversity of opinion need not very much surprise us after all, for, with the body and tail of an ordinary mammal, it had the form of a bird in its head and the length of its neck, of the bat in the structure and proportion of its wings, and of a reptile in the smallness of its head and in its beak, armed with at least sixty equal sharp-pointed teeth, differing little in form and size.

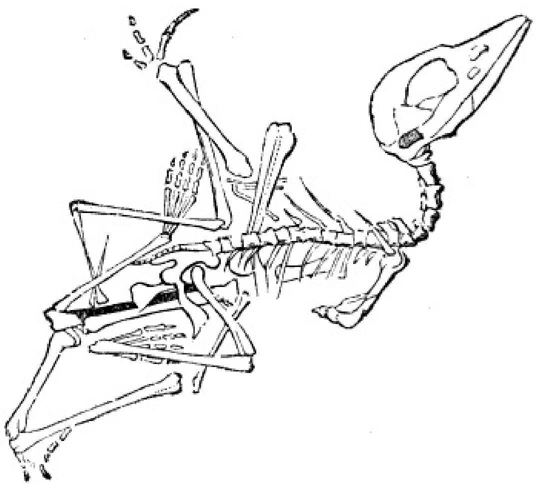


Fig. 106.—Pterodactylus brevirostris.

Dr. Buckland describes eight distinct species, varying in size from a snipe to a cormorant. Of these, *P. crassirostris* (Fig. 105) and *P. brevirostris* (Fig. 106), were both discovered in the Lias of Solenhofen. *P. macronyx* belongs to the Lias of Lyme Regis.

The Pterodactyle was, then, a reptile provided with wings somewhat resembling those of Bats, and formed, as in that Mammal, of a membrane which connected the body with the excessively elongated phalanges of the fourth finger, which served to expand the membrane that answered the purposes of a wing. The Pterodactyle of the Liassic period was, as we have seen, an animal of small size; the largest species in the older Lias beds did not exceed ten or twelve inches in length, or the size of a raven, while the later forms found fossil in the Greensand and Wealden beds must have measured more than sixteen feet between the tips of the expanded wings. On the other hand, its head was of enormous dimensions compared with the rest of the body. We cannot admit, therefore, that this animal could really fly, and, like a bird, beat the air. The membranous appendage which connected its long finger with its body was rather a parachute than a wing. It served to moderate the velocity of its descent when it dropped on its prey from a height. Essentially a climber, it could only raise itself by climbing up tall trees or rocks, after the manner of lizards, and throw itself thence to the ground, or upon the lower branches, by making use of its natural parachute.

The ordinary position of the Pterodactyle was probably upon its two hind feet, the lower extremities being adapted for standing and moving on the ground, after the manner of birds. Habitually, perhaps, it perched on trees; it could creep, or climb along rocks and cliffs, or suspend itself from trees, with the assistance of its claws and feet, after the manner of existing Bats. It is even probable, Dr. Buckland thought, that it had the power of swimming and diving, so [237]
common to reptiles, and possessed by the Vampyre Bat of the island of Bonin. It is believed that the smaller species lived upon insects, and the larger preyed upon fishes, upon which it could throw itself like the sea-gull.

The most startling feature in the organisation of this animal is the strange combination of two powerful wings attached to the body of a reptile. The imagination of the poets long dwelt on such a combination; the *Dragon* was a creation of their fancy, and it played a great part in fable and in pagan mythology. The Dragon, or flying reptile, breathing fire and poisoning the air with his fiery breath, had, according to the fable, disputed with man the possession of the earth. Gods and demigods claimed, among their most famous exploits, the glory of having vanquished this powerful and redoubtable monster.

Among the animals of our epoch, only a single reptile is found provided with wings, or digital appendages analogous to the membranous wings of the bats, and which can be compared to the Pterodactyle. This is called the *Dragon*, one of the Draconidæ, a family of Saurians, which has been described by Daudin, as distinguished by the first six ribs, instead of hooping round the abdomen, extending in nearly a straight line, and sustaining a prolongation of skin which forms a sort of wing analogous to that of the Pterodactyle. Independent of the four feet, this wing sustains the animal, like a parachute, as it leaps from branch to branch; but the creature has no power to beat the air with it as birds do when flying. This reptile lives in the forests of the hottest parts of Africa, and in some isles of the Indian Ocean, especially in Sumatra and Java. The only known species is that figured at page 238 (Fig. 107), which comes from the East Indies.

What a strange population was that which occupied the earth at this stage of its history, when the waters were filled with creatures so extraordinary as those whose history we have traced! Plesiosauri and Ichthyosauri filled the seas, upon the surface of which floated innumerable Ammonites in light skiffs, some of them as large as a good-sized cart-wheel, while gigantic Turtles and Crocodiles crawled on the banks of the rivers and lakes. Only one genus of Mammals had yet appeared, but no birds; nothing broke the silence of the air, if we except the breathing of the terrestrial reptiles and the flight of winged insects.

The earth cooled progressively up to the Jurassic period, the rains lost their continuity and abundance, and the pressure of the atmosphere sensibly diminished. All these circumstances favoured the appearance and the multiplication of innumerable species of animals, whose [238] singular forms then showed themselves on the earth. We can scarcely imagine the prodigious quantity of Molluscs and Zoophytes whose remains lie buried in the Jurassic rocks, forming entire strata of immense thickness and extent.

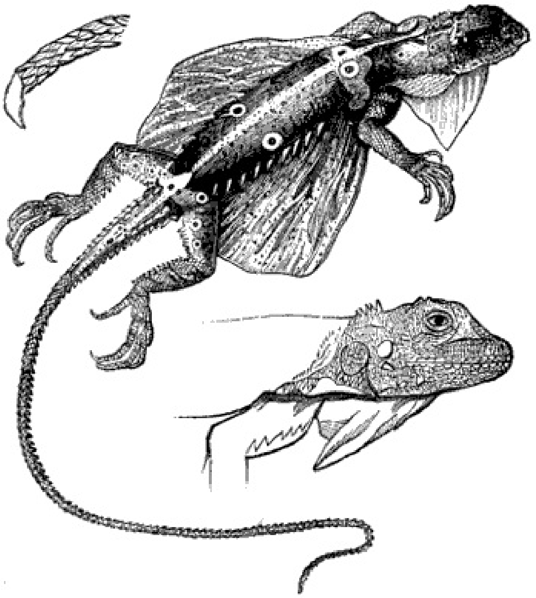


Fig. 107.—Draco volans.

The same circumstances concurred to favour the production of plants. If the shores and seas of the period received such a terrible aspect from the formidable animals we have described, the vegetation which covered the land had also its peculiar character and appearance. Nothing that we know of in the existing scenery of the globe surpasses the rich vegetation which decorated the continents of the Jurassic period. A temperature still of great elevation, a humid atmosphere, [239] and, we have no reason to doubt, a brilliant sun, promoted the growth of a luxuriant vegetation, such as some of the tropical islands, with their burning temperature and maritime climate, can only give us an idea of, while it recalls some of the Jurassic types of vegetation. The elegant Voltzias of the Trias had disappeared, but the Horse-tails (*Equiseta*) remained, whose slender and delicate stems rose erect in the air with their graceful panicles; the gigantic rushes also remained; and though the tree-ferns had lost their enormous dimensions of the Carboniferous age, they still preserved their fine and delicately-cut leaves.

Alongside these vegetable families, which passed upwards from the preceding age, an entire family—the Cycads (Fig. 72, p. 168)—appear for the first time. They soon became numerous in genera, such as Zamites, Pterophyllum (Williamsonia), and Nilssonia. Among the species which characterise this age, we may cite the following, arranging them in families:—

FERNS.	CYCADS.	CONIFERS.
Odontopteris cycadea.	Zamites distans.	Taxodites.

Taumopteris Munsteri.	Zamites heterophyllus.	Pinites.
Camptopteris crenata.	Zamites gracilis.	
	Pterophyllum dubium.	
	Nilssonia contigua.	
	Nilssonia elegantissima.	
	Nilssonia Sternbergii.	

The *Zamites* seem to be forerunners of the Palms, which make their appearance in the following epoch; they were trees of elegant appearance, closely resembling the existing Zamias, which are trees of tropical America, and especially of the West India Islands; they were so numerous in species and in individuals that they seem to have formed, of themselves alone, one half of the forests during the period which engages our attention. The number of their fossilised species exceeds that of the living species. The trunk of the Zamites, simple and covered with scars left by the old leaves, supports a thick crown of leaves more than six feet in length, disposed in fan-like shape, arising from a common centre.

The *Pterophyllum* (Williamsonia), formed great trees, of considerable elevation, and covered with large pinnated leaves from top to bottom. Their leaves, thin and membranous, were furnished with leaflets truncated at the summit and traversed by fine nervures, not convergent, but abutting on the terminal truncated edge.

The *Nilssonia*, finally, were Cycadeaceæ resembling the Pterophyllum, but with thick and coriaceous leaves, and short leaflets contiguous to, and in part attached to the base; they were obtuse or nearly truncated at the summit, and would present nervures arched or confluent towards that summit. [240]

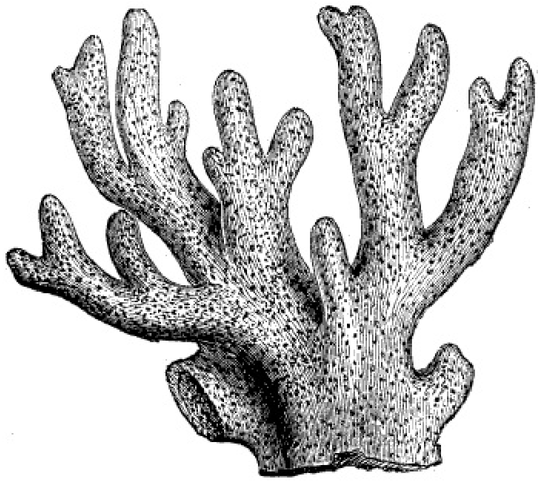
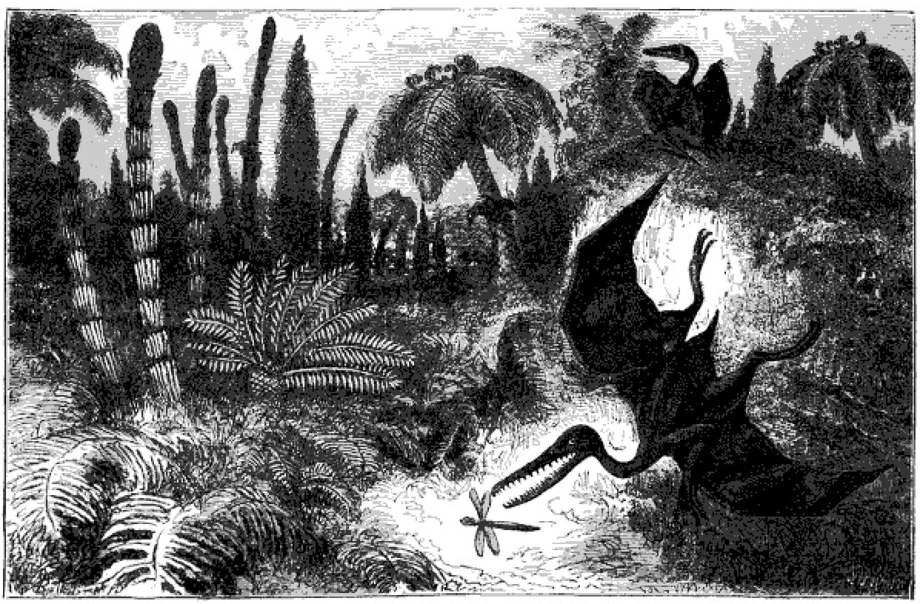


Fig. 108.—Millepora alcicornis.
(Recent Coral.)

The essential characters of the vegetation during the Liassic sub-period were:—1. The great predominance of the Cycadeaceæ, thus continuing the development which commenced in the previous period, expanding into numerous genera belonging both to this family and that of the *Zamites* and *Nilssonia*; 2. The existence among the Ferns of many genera with reticulated veins or nervures, and under forms of little variation, which scarcely show themselves in the more ancient formations.

[241]



On the opposite page (Plate XVI.) is an ideal landscape of the Liassic period; the trees and shrubs characteristic of the age are the elegant Pterophyllum, which appears in the extreme left of the picture, and the Zamites, which are recognisable by their thick and low trunk and fan-like tuft of foliage. The large horsetail, or Equisetum of this epoch, mingles with the great Tree-ferns and the Cypress, a Conifer allied to those of our own age. Among animals, we see the Pterodactyle specially represented. One of these reptiles is seen in a state of repose, resting on its hind feet. [243] The other is represented, not flying, after the manner of a bird, but throwing itself from a rock in order to seize upon a winged insect, the dragon-fly (*Libellula*), the remains of which have been discovered, associated with the bones of the Pterodactyle, in the lithographic limestone of Pappenheim and Solenhofen.

Oolitic Sub-period.

This period is so named because many of the limestones entering into the composition of the formations it comprises, consist almost entirely of an aggregation of rounded concretionary grains resembling, in outward appearance, the roe or eggs of fishes, and each of which contains a nucleus of sand, around which concentric layers of calcareous matter have accumulated; whence the name, from ωον, *egg*, and λιθος, *stone*.

The Oolite series is usually subdivided into three sections, the *Lower*, *Middle*, and *Upper Oolite*. These rocks form in England a band some thirty miles broad, ranging across the country from Yorkshire, in the north-east, to Dorset, in the south-west, but with a great diversity of mineral character, which has led to a further subdivision of the series, founded on the existence of particular strata in the central and south-western counties:—

Upper.	Middle.	Lower.
1. Purbeck Beds.	1. Coral Rag.	1. Cornbrash.
2. Portland Stone and Sand.	2. Oxford Clay.	2. Great Oolite & Forest Marble.
3. Kimeridge Clay.		3. Stonesfield Slate.
		4. Fuller’s Earth.
		5. Inferior Oolite.

The alternations of clay and masses of limestone in the Liassic and Oolite formations impart some marked features to the outline of the scenery both of France and England: forming broad valleys, separated from each other by ranges of limestone hills of more or less elevation. In France, the Jura mountains are composed of the latter; in England, the slopes of this formation are more gentle—the valleys are intersected by brooks, and clothed with a rich vegetation; it forms what is called a tame landscape, as compared with the wilder grandeur of the Primary rocks—it pleases more than it surprises. It yields materials also, more useful than some of the older formations, numerous quarries being met with which furnish excellent building-materials, especially around Bath, where the stone, when first quarried, is soft and easily worked, but becomes harder on [244] exposure to the air.

The annexed section (Fig. 109) will give some idea of the configuration which the stratification assumes, such as may be observed in proceeding from the north-west to the south-east, from Caermarthenshire to the banks of the Ouse.

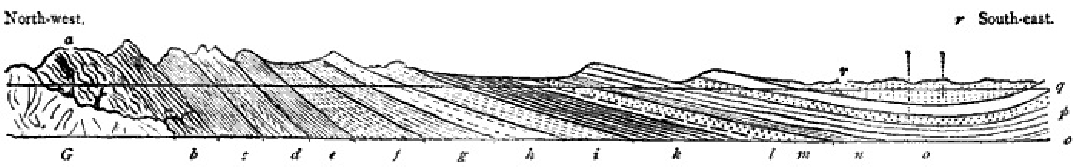


Fig. 109.—General view of the succession of British strata, with the elevations they reach above the level of the sea.
G, Granitic rocks; *a*, Gneiss; *b*, Mica-schist; *c*, Skiddaw or Cumbrian Slates; *d*, Snowdon rocks; *e*, Plynlymmon rocks; *f*, Silurian rocks; *g*, Old Red Sandstone; *h*, Carboniferous Limestone; *i*, Millstone Grit; *k*, Coal-measures; *l*, Magnesian Limestone; *m*, New Red Sandstone; *n*, Lias; *o*, Lower, Middle, and Upper Oolites; *p*, Greensand; *q*, Chalk; *r*, Tertiary strata.

Lower Oolite Fauna.

The most salient and characteristic feature of this age is, undoubtedly, the appearance of animals belonging to the class of Mammals. But the organisation, quite special, of the first of the Mammalia will certainly be a matter of astonishment to the reader, and must satisfy him that Nature proceeded in the creation of animals by successive steps, by transitions which, in an almost imperceptible manner, connect the beings of one age with others more complicated in their organisation. The first Mammals which appeared upon the earth, for example, did not enjoy all the organic attributes belonging to the more recent creations of the class. In the latter the young are brought forth living, and not from eggs, like Birds, Reptiles, and Fishes. But the former belonged to that order of animals quite special, and never numerous, the young of which are transferred in a half-developed state, from the body of the mother to an external pouch in which they remain until they become perfected; in short, to marsupial animals. The mother nurses her young during a certain time in a sort of pouch external to the body, in the neighbourhood of the abdomen, and provided with teats to which the young adhere. After a more or less prolonged sojourn in this pouch, the young animal, when sufficiently matured and strong enough to battle [245] with the world, emerges from its warm retreat, and enters fully into life and light; the process being a sort of middle course between oviparous generation, in which the animals are hatched from eggs after exclusion from the mother's body, like Birds; and viviparous, in which the animals are brought forth alive, as in the ordinary Mammals.

In standard works on natural history the animals under consideration are classed as *mammiferous Didelphæ*. They are brought forth in an imperfect state, and during their transitional condition are suckled in a pouch supported by bones called *marsupial*, which are attached by their extremities to the pelvis, and serve to support the marsupium, whence the animals provided with these provisions for bringing up their progeny are called *Marsupial Mammals*. The Opossum, Kangaroo, and Ornithorhynchus are existing representatives of this group.

Fig. 110.—Jaw of Thylacotherium Prevostii.

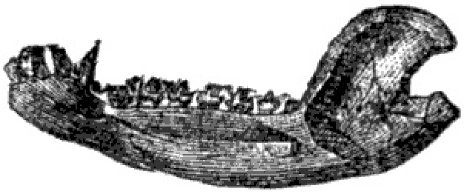


Fig. 111.—Jaw of Phascolotherium.

The name of *Thylacotherium*, or *Amphitherium*, or *Phascolotherium*, is given to the first of these marsupial Mammals which made their appearance, whose remains have been discovered in the Lower Oolite, and in one of its higher stages, namely, that called the *Great Oolite*. Fig. 110 represents the jaw of the first of these animals, and Fig. 111 the other—both of the natural size. These jaw-bones represent all that has been found belonging to these early marsupial animals; and Baron Cuvier and Professor Owen have both decided as to their origin. The first was found in the Stonesfield quarries. The Phascolotherium, also a Stonesfield fossil, was the ornament of Mr. Broderip's collection. The animals which lived on the land during the Lower Oolitic period would be nearly the same with those of the Liassic. The insects were, perhaps, more numerous.

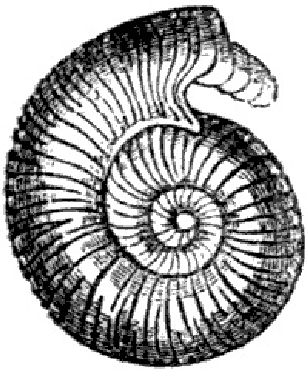


Fig. 112.—Ammonites Herveyii.

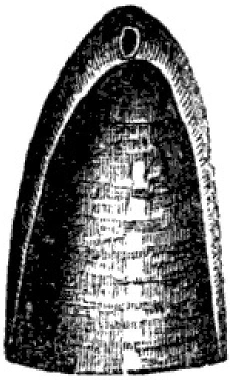


Fig. 113.—Terebratula digona.

The marine fauna included Reptiles, Fishes, Molluscs, and Zoophytes. Among the first were the Pterodactyle, and a great Saurian, the Teleosaurus, belonging to a family which made its appearance in this age, and which reappears in the following epoch. Among the Fishes, the [246] Ganoids and Ophiopsis predominate. Among the Ammonites, *Ammonites Humphriesianus*, *A. Herveyii* (Fig. 112), *A. Brongniarti*, *Nautilus lineatus*, and many other representatives of the cephalopodous Mollusca. Among the Brachiopods are *Terebratula digona* (Fig. 113) and *T. spinosa*. Among the Gasteropoda the *Pleurotomaria conoidea* is remarkable from its elegant shape and markings, and very unlike any of the living *Pleurotoma* as represented by *P. Babylonia* (Fig. 114). *Ostrea Marshii* and *Lima proboscidea*, which belong to the Acephala, are fossil Mollusca of this epoch, to which also belong *Entalophora cellarioides*, *Eschara Ranviliana*, *Bidiastopora cervicornis*; elegant and characteristic molluscous Polyzoa. We give a representation of two living species, as exhibiting the form of these curious beings. (Figs. 115 and 116.)

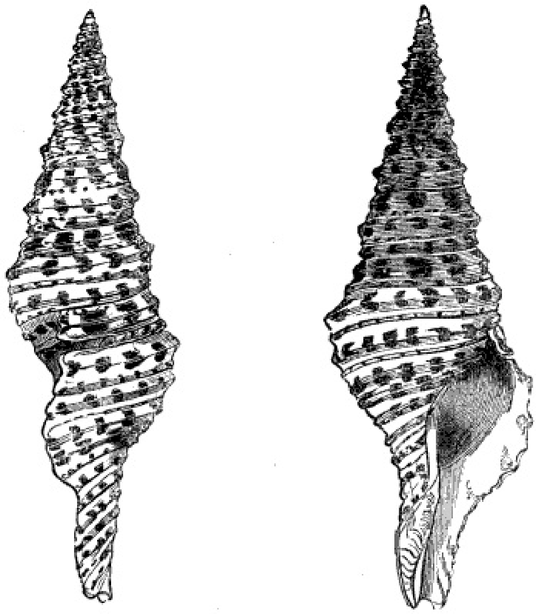


Fig. 114.—Pleurotoma Babylonia. (Recent.)

The Echinoderms and Polyps appear in great numbers in the deposits of the Lower Oolite: [247] *Apiocrinus elegans*, *Hyboclypus gibberulus*, *Dysaster Endesii* represent the first; *Montlivaltia caryophyllata*, *Anabacia orbulites*, *Cryptocœnia bacciformis*, and *Eunomia radiata* represent the second.

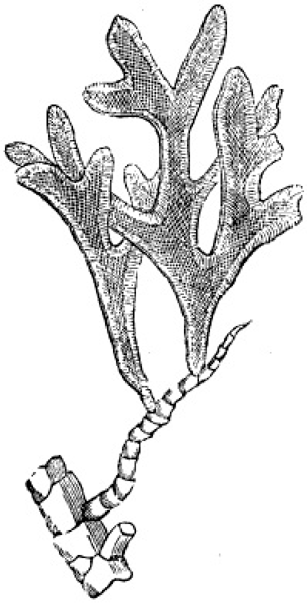


Fig. 115.—Adeona folifera.
(Recent Polyzoa.)

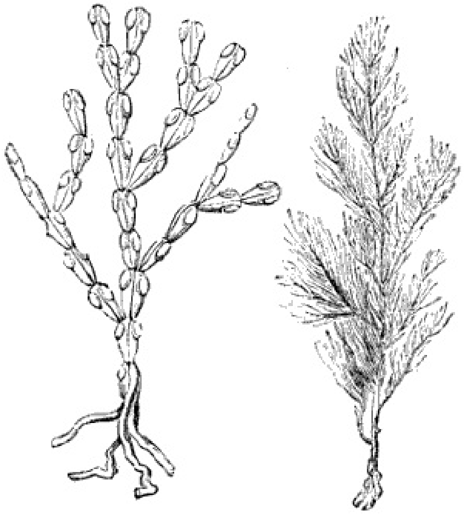


Fig. 116.—Cellaria loriculata.
(Recent Polyzoa.)

This last and most remarkable species of Zoophyte presents itself in great masses many yards in circumference, and necessitates a long period of time for its production. This assemblage of little creatures living under the waters but only at a small depth beneath the surface, as Mr. Darwin has demonstrated, has nevertheless produced banks, or rather islets, of considerable extent, which at one time constituted veritable reefs rising out of the ocean. These reefs were principally constructed in the Jurassic period, and their extreme abundance is one of the characteristics of this geological age. The same phenomenon continues in our day, but by the agency of a new race of zoophytes, which carry on their operations, preparing a new continent, probably, in the *atolls* [248] of the Pacific Ocean. (See Fig. 108, p. 240.)

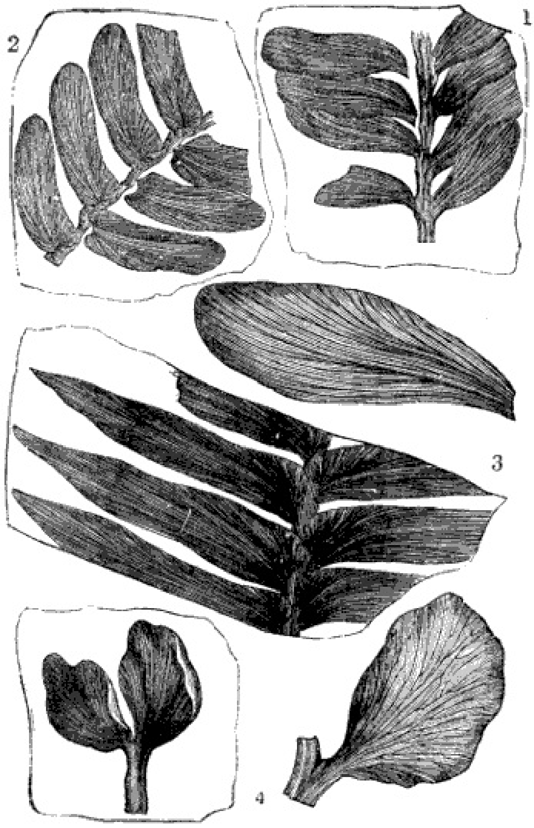


Fig. 117.
1, Otopteris dubia; 2, Otopteris obtusa; 3, Otopteris acuminata; 4, Otopteris cuneata.

The flora of the epoch was very rich. The Ferns continue to exist, but their size and bearing were sensibly inferior to what they had been in the preceding period. Among them Otopteris, distinguished for its simply pinnated leaves, whose leaflets are auriculate at the base: of the five [249]
species, 1, *O. dubia*; and 2, *O. obtusa*; and 3, *O. acuminata*; and 4, *O. cuneata* (Fig. 117), are from the Oolite. In addition to these we may name *Coniopteris Murrayana*, *Pecopteris Desnoyersii, Pachypteris lanceolata*, and *Phlebopteris Phillipsii*; and among the Lycopods, *Lycopodus falcatus*.

The vegetation of this epoch has a peculiar facies, from the presence of the family of the Pandanaceæ, or screw-pines, so remarkable for their aërial roots, and for the magnificent tuft of leaves which terminates their branches. Neither the leaves nor the roots of these plants have, however, been found in the fossil state, but we possess specimens of their large and spherical fruit, which leave no room for doubt as to the nature of the entire plant.

The Cycads were still represented by the *Zamias*, and by many species of Pterophyllum. The Conifers, that grand family of recent times, to which the pines, firs, and other trees of our northern forests belong, began to occupy an important part in the world's vegetation from this epoch. The earliest Conifers belonged to the genera *Thuites*, *Taxites*, and *Brachyphyllum*. The *Thuites* were true *Thuyas*, evergreen trees of the present epoch, with compressed branches, small imbricated and serrated leaves, somewhat resembling those of the Cypress, but distinguished by many points of special organisation. The *Taxites* have been referred, with some doubts, to the Yews. Finally, the *Brachyphyllum* were trees which, according to the characteristics of their vegetation, seem to have approached nearly to two existing genera, the *Arthotaxis* of Tasmania, and the *Weddringtonias* of South Africa. The leaves of the Brachyphyllum are short and fleshy, with a large and rhomboidal base.

Lower Oolite Rocks.

The formation which represents the Lower Oolite, and which in England attains an average thickness of from 500 to 600 feet, forms a very complex system of stratification, which includes the two formations, *Bajocien* and *Bathonian*, adopted by M. D'Orbigny and his followers. The lowest beds of the *Inferior Oolite* occur in Normandy, in the Lower Alps (Basses-Alpes), in the neighbourhoods of Lyons and Neuchatel. They are remarkable near Bayeux for the variety and beauty of their fossils: the rocks are composed principally of limestones—yellowish-brown, or red, charged with hydrated oxide of iron, often oolitic, and reposing on calcareous sands. These [250]
deposits are surmounted by alternate layers of clay and marl, blue or yellow—the well-known *Fuller's Earth*, which is so called from its use in the manufacture of woollen fabrics to extract the grease from the wool. The second series of the Lower Oolite, which attains a thickness of from 150 to 200 feet on the coast of Normandy, and is well developed in the neighbourhood of Caen and in the Jura, has been divided, in Britain, into four formations, in an ascending scale:—

1. The *Great* or *Bath Oolite*, which consists principally of a very characteristic, fine-grained, white, soft, and well-developed oolitic limestone, at Bath, and also at Caen in Normandy. At the

base of the Great Oolite the Stonesfield beds occur, in which were found the bones of the marsupial Mammals, to which we have already alluded; and along with them bones of Reptiles, principally Pterodactyles, together with some finely-preserved fossil plants, fruits, and insects.

2. *Bradford Clay*, which is a bluish marl, containing many fine Encrinites (commonly called stone-lilies), but which had only a local existence, appearing to be almost entirely confined to this formation. "In this case, however," says Lyell, "it appears that the solid upper surface of the 'Great Oolite' had supported, for a time, a thick submarine forest of these beautiful Zoophytes, until the clear and still water was invaded with a current charged with mud, which threw down the stone-lilies, and broke most of their stems short off near the point of attachment. The stumps still remain in their original position."[65] See Fig. 1, Plate XIX., p. 261. (Bradford, or Pear, Encrinite.)

3. *Forest Marble*, which consists of an argillaceous shelly limestone, abounding in marine fossils, and sandy and quartzose marls, is quarried in the forest of Wichwood, in Wiltshire, and in the counties of Dorset, Wilts, and Somerset.

4. The *Cornbrash* (wheat-lands) consists of beds of rubbly cream-coloured limestone, which forms a soil particularly favourable to the cultivation of cereals; hence its name.[66]

The Lower Oolite ranges across the greater part of England, but "attains its maximum development near Cheltenham, where it can be subdivided, at least, into three parts. Passing north, the two lower divisions, each more or less characterised by its own fossils, disappear, and the Ragstone north-east of Cheltenham lies directly upon the Lias; apparently as conformably as [251] if it formed its true and immediate successor, while at Dundry the equivalents of the upper freestones and ragstones (the lower beds being absent) lie directly on the exceedingly thin sands, which there overlie the Lower Lias. In Dorsetshire, on the coast, the series is again perfect, though thin. Near Chipping Norton, in Oxfordshire, the Inferior Oolite disappears altogether, and the Great Oolite, having first overlapped the Fullers' Earth, passes across the Inferior Oolite, and in its turn seems to lie on the Upper Lias with a regularity as perfect as if no formation in the neighbourhood came between them. In Yorkshire the changed type of the Inferior Oolite, the prevalence of sands, land-plants, and beds of coal, occur in such a manner as to leave no doubt of the presence of terrestrial surfaces on which the plants grew, and all these phenomena lead to the conclusion that various and considerable oscillations of level took place in the British area during the deposition of the strata, both of the Inferior Oolite and of the formations which [252] immediately succeed it."[67]

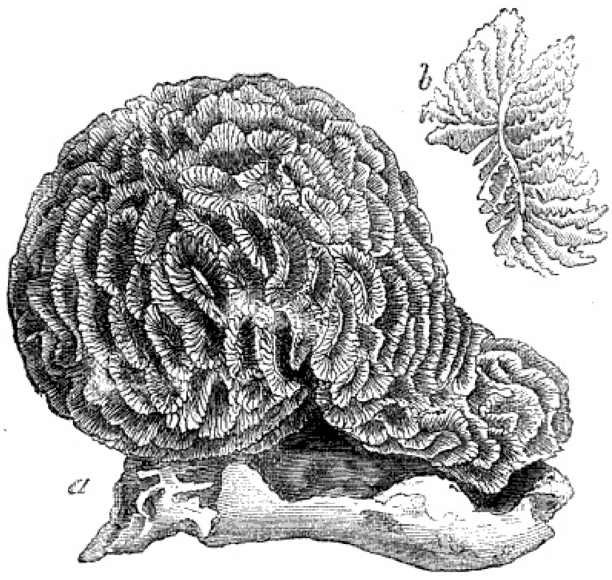
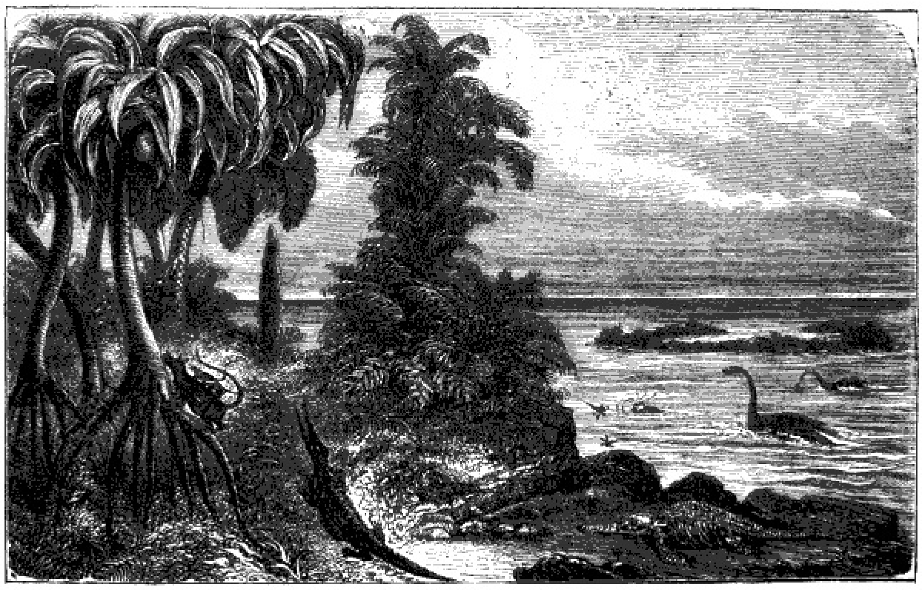


Fig. 118.—Meandrina Dædalæa.
a, entire figure, reduced; *b*, portion, natural size.
(Recent Coral.)

The Inferior Oolite here alluded to is a thin bed of calcareous freestone, resting on, and sometimes replaced by yellow sand, which constitutes the passage-beds from the Liassic series. The Fullers' Earth clay lies between the limestones of the Inferior and Great Oolite, at the base of which last lies the Stonesfield slate—a slightly oolitic, shelly limestone, or flaggy and fissile sandstone, some six feet thick, rich in organic remains, and ranging through Oxfordshire towards the north-east, into Northamptonshire and Yorkshire. At Colley Weston, in Northamptonshire, fossils of *Pecopteris polypodioides* are found. In the Great Oolite formation, near Bath, are many corals, among which the *Eunomia radiata* is very conspicuous. The fossil is not unlike the existing brain-coral of the tropical seas (Fig. 118). The work of this coral seems to have been suddenly stopped by "an invasion," says Lyell, "of argillaceous matter, which probably put a sudden stop to the growth of Bradford Encrinites, and led to their preservation in marine strata."[68] The Cornbrash is, in general, a cream-coloured limestone, about forty feet thick, in the south-west of England, and occupying a considerable area in Dorsetshire and North Wilts, as at Cricklade, Malmesbury, and Chippenham, in the latter county. *Terebratula obovata* is its characteristic shell, and *Nucleolites clunicularis*, *Lima gibbosa*, and *Avicula echinata* occur constantly in great numbers. Wherever it occurs the Cornbrash affords a rich and fertile soil, well adapted for the growth of wheat, while the Forest Marble, as a soil, is generally poor. The Cornbrash passes downwards into the Forest Marble, and sometimes, as at Bradford, near Bath, is replaced by clay. This clay, called the Bradford clay, is almost wholly confined to the county of Wilts. *Terebratula decussata* is one of the most characteristic fossils, but the most common is the Apiocrinites or pear-shaped encrinite, whose remains in this clay are so perfectly preserved that the most minute articulations are often found in their natural positions. Plate XIX., p. 261 (Fig. 1), represents an adult attached by a solid base to the rocky bottom on which it grew, whilst the smaller individuals show the Encrinite in its young state—one with arms expanded, the other with them closed. Ripple-marked slabs of fissile Forest Marble are used as a roofing-slate, and may be traced over a broad band of country in Wiltshire and Gloucestershire, separated from each other by thin seams of clay, in which the undulating ridges of the sand are preserved, and even the footmarks of small [255] Crustaceans are still visible.



XVII.—Ideal Landscape of the Lower Oolite Period.

On the opposite page (Plate XVII.) is represented an ideal landscape of the period of the Lower Oolite. On the shore are types of the vegetation of the period. The *Zamites*, with large trunk covered with fan-like leaves, resembled in form and bearing the existing Zamias of tropical regions; a *Pterophyllum*, with its stem covered from base to summit with its finely-cut feathery leaves; Conifers closely resembling our Cypress, and an arborescent Fern. What distinguishes this sub-period from that of the Lias is a group of magnificent trees, *Pandanus*, remarkable for their aërial roots, their long leaves, and globular fruit.

Upon one of the trees of this group the artist has placed the *Phascolotherium*, not very unlike to our Opossum. It was amongst the first of the Mammalia which appeared in the ancient world. The artist has here enlarged the dimensions of the animal in order to show its form. Let the reader reduce it in imagination one-sixth, for it was not larger than an ordinary-sized cat.

A Crocodile and the fleshless skeleton of the Ichthyosaurus remind us that Reptiles still occupied an important place in the animal creation. A few Insects, especially Dragon-flies, fly about in the air. Ammonites float on the surface of the waves, and the terrible Plesiosaurus, like a gigantic swan, swims about in the sea. The circular reef of coral, the work of ancient Polyps, foreshadows the atolls of the great ocean, for it was during the Jurassic period that the Polyps of the ancient world were most active in the production of coral-reefs and islets.

Middle Oolite.

The terrestrial flora of this age was composed of Ferns, Cycads, and Conifers. The first represented by the *Pachypteris microphylla*, the second by *Zamites Moreana*. *Brachyphyllum Moreanum* and *B. majus* appear to have been the Conifers most characteristic of the period; fruits have also been found in the rocks of the period, which appear to belong to Palms, but this point is still obscure and doubtful.

Numerous vestiges of the fauna which animated the period are also revealed in the rocks of this age. Certain hemipterous insects appear on the earth for the first time, and the Bees among the Hymenoptera, Butterflies among the Lepidoptera, and Dragon-flies among the Neuroptera. In the [256] bosom of the ocean, or upon its banks, roamed the *Ichthyosaurus*, *Ceteosaurus*, *Pterodactylus crassirostris*, and the *Geosaurus*; the latter being very imperfectly known.

The Ceteosaurus whose bones have been discovered in the upper beds of the Great Oolite at Enslow Rocks, at the Kirtlington Railway Station, north of Oxford, and some other places, was a species of Crocodile nearly resembling the modern Gavial or Crocodile of the Ganges. This huge whale-like reptile has been described by Professor John Phillips as unmatched in size and strength by any of the largest inhabitants of the Mesozoic land or sea—perhaps the largest animal that ever walked upon the earth. A full-grown Ceteosaurus must have been *at least* fifty feet long, ten feet high, and of a proportionate bulk. In its habits it was, probably, a marsh-loving or river-side animal, dwelling amidst filicene, cycadaceous, and coniferous shrubs and trees full of insects and small mammalia. The one small and imperfect tooth which has been found resembles that of Iguanodon more than of any other reptile; and it seems probable that the Ceteosaurus was nourished by vegetable food, which abounded in the vicinity of its haunts, and was not obliged to contend with the Megalosaurus for a scanty supply of more stimulating diet. [69]

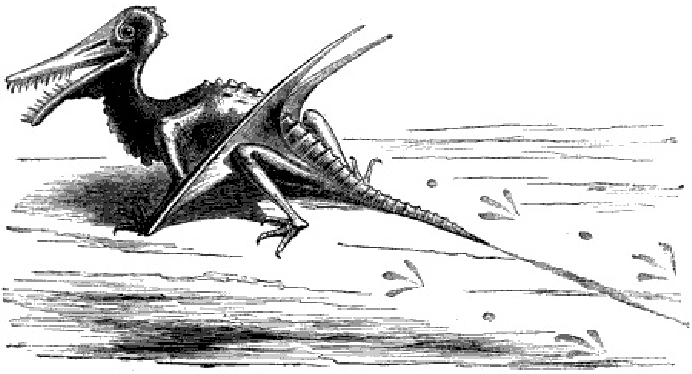
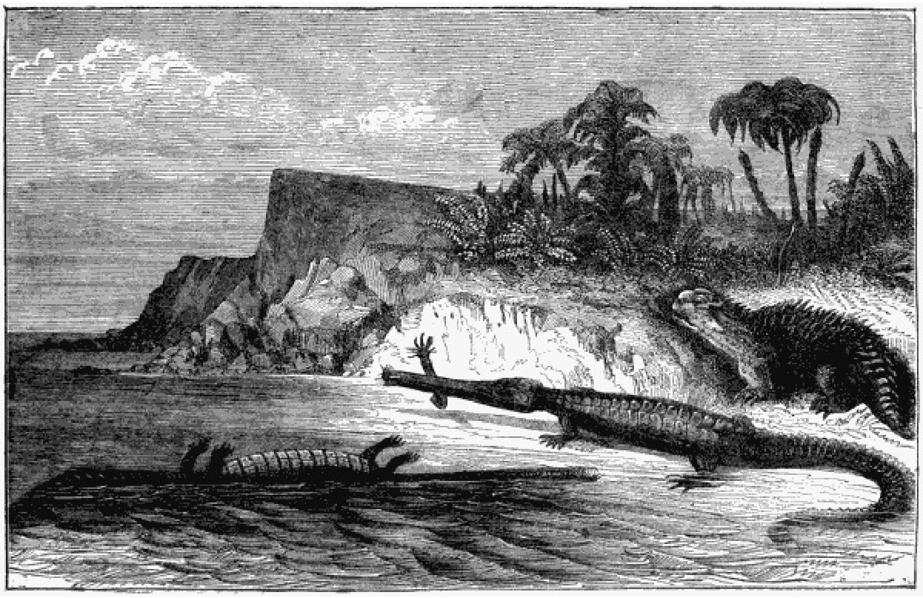


Fig. 119.—Ramphorynchus restored. One-quarter natural size.

Another reptile allied to the Pterodactyle lived in this epoch—the *Ramphorynchus*, distinguished from the Pterodactyle by a long tail. The imprints which this curious animal has left upon the sandstone of the period are impressions of its feet and the linear furrow made by its tail. Like the Pterodactyle, the Ramphorynchus, which was about the size of a crow, could not precisely fly, but, aided by the wing (a sort of natural parachute formed by the membrane connecting the fingers with the body), it could throw itself from a height upon its prey. Fig. 119 represents a restoration of this animal. The footprints in the soil are in imitation of those which accompany the remains of the Ramphorynchus in the Oolitic rocks, and they show the imprints of the anterior and posterior feet and also the marks made by the tail.

This tail was very long, far surpassing in length the rest of the vertebral column, and consisting of more than thirty vertebræ—which were at first short, but rapidly elongate, retain their length for a considerable distance, and then gradually diminish in size.

[258]



XVIII.—Ideal landscape of the Middle Oolitic Period.

Another genus of Reptiles appears in the Middle Oolite, of which we have had a glimpse in the Lias and Great Oolite of the preceding section. This is the *Teleosaurus*, which the recent investigations of M. E. Deslongchamps allow of re-construction. The Teleosaurus enables us to [259]
form a pretty exact idea of these Crocodiles of the ancient seas—these cuirassed Reptiles, which the German geologist Cotta describes as “the great barons of the kingdom of Neptune, armed to the teeth, and clothed in an impenetrable panoply; the true filibusters of the primitive seas.”

The Teleosaurus resembled the Gavials of India. The former inhabited the banks of rivers, perhaps the sea itself; they were longer, more slender, and more active than the living species; they were about thirty feet in length, of which the head may be from three to four feet, with their enormous jaws sometimes with an opening of six feet, through which they could engulf, in the depths of their enormous throat, animals of considerable size.

The *Teleosaurus cadomensis* is represented on the opposite page (Plate XVIII.), after the sketch of M. E. Deslongchamps, carrying from the sea in its mouth a *Geoteuthis*, a species of Calamary of the Oolitic epoch. This creature was coated with a cuirass both on the back and belly. In order to show this peculiarity, a living individual is represented on the shore, and a dead one is floating on its back in shallow water, leaving the ventral cuirass exposed.

Behind the *Teleosaurus cadomensis* in the engraving, another Saurian, the *Hylæosaurus*, is represented, which makes its appearance in the Cretaceous epoch. We have here adopted the restoration which has been so ably executed by Mr. Waterhouse Hawkins, at the Crystal Palace, Sydenham. [260]

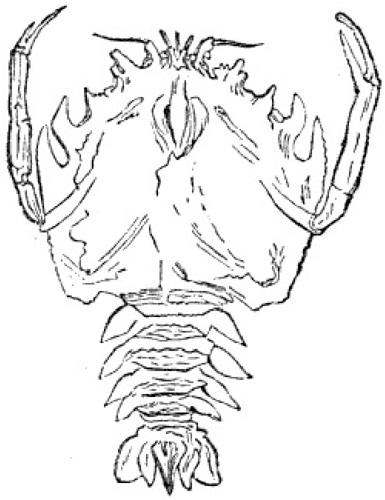


Fig. 120.—Eryon arctiformis.

Besides the numerous Fishes with which the Oolitic seas swarmed, they contained some Crustaceans, Cirripedes, and various genera of Mollusca and Zoophytes. *Eryon arctiformis*, represented in Fig. 119, belongs to the class of Crustaceans, of which the spiny lobster is the type. Among the Mollusca were some Ammonites, Belemnites, and Oysters, of which many hundred species have been described. Of these we may mention *Ammonites refractus, A. Jason and A. cordatus, Ostrea dilatata, Terebratula diphya, Diceras arietena, Belemnites hastatus*, and *B. Puzosianus*. In some of the finely-laminated clays the Ammonites are very perfect, but somewhat compressed, with the outer lip or margin of the aperture entire (Fig. 120). Similar prolongations have been noticed in Belemnites found by Dr. Mantell in the Oxford Clay, near Chippenham.

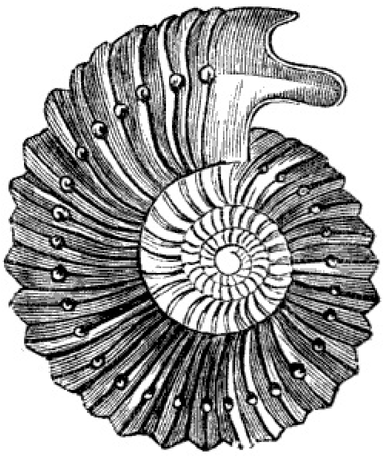
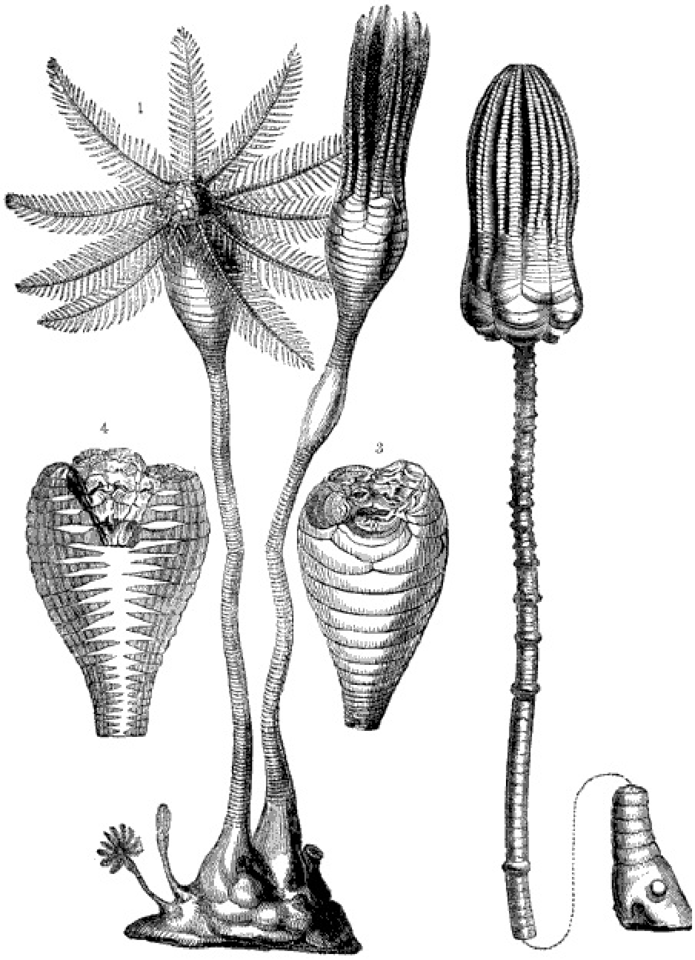


Fig. 121.—Perfect Ammonite.

[261]



XIX.—Fig. 1.—Apiocrinites rotundus. Fig. 2.—Encrinus liliiformis.

Among the Echinoderms, *Cidaris glandiferus*, *Apiocrinus Roissyanus*, and *A. rotundus*, the graceful *Saccocoma pectinata*, *Millericrinus nodotianus*, *Comatula costata*, and *Hemicidaris crenularis* may be mentioned; *Apiocrinites rotundus*, figured in Plate XIX., is a reduced restoration: 1, being expanded; *a*, closed; 3, a cross section of the upper extremity of the pear- [263]
shaped head; 4, a vertical section showing the enlargement of the alimentary canal, with the hollow lenticular spaces which descend through the axis of the column, forming the joints, and giving elasticity and flexure to the whole stem, without risk of dislocation. *A. rotundus* is found at Bradford in Wiltshire, Abbotsbury in Dorset, at Soissons, and Rochelle. This species—known as the Bradford Pear-Encrinite—is only found in the strata mentioned.

The Corals of this epoch occur in great abundance. We have already remarked that these aggregations of Polyps are often met with at a great depth in the strata. These small calcareous structures have been formed in the ancient seas, and the same phenomenon is extending the terrestrial surface in our days in the seas of Oceania, where reefs and atolls of coral are rising by slow and imperceptible steps, but with no less certainty. Although their mode of production must always remain to some extent a mystery, the investigations of M. Lamaroux, Mr. Charles Darwin, and M. D'Orbigny have gone a long way towards explaining their operations; for the Zoophyte in action is an aggregation of these minute Polyps. Describing what he believes to be a sea-pen, a Zoophyte allied to *Virgularia Patagonia*, Mr. Darwin says: "It consists of a thin, straight, fleshy stem, with alternate rows of polypi on each side, and surrounding an elastic stony axis. The stem at one extremity is truncate, but at the other is terminated by a vermiform fleshy appendage. The stony axis which gives strength to the stem, may be traced at this extremity into a mere vessel filled with granular matter. At low water hundreds of these zoophytes might be seen, projecting like stubble, with the truncate end upwards, a few inches above the surface of the muddy sand. When touched or pulled, they drew themselves in suddenly, with force, so as nearly or quite to disappear. By this action, the highly-elastic axis must be bent at the lower extremity, where it is naturally slightly curved; and I imagine it is by this elasticity alone that the zoophyte is enabled to rise again through the mud. Each polypus, though closely united to its brethren, has a distinct mouth, body, and tentacula. Of these polypi, in a large specimen there must be many thousands. Yet we see that they act by one movement; that they have one central axis, connected with a system of obscure circulation." Such is the brief account given by a very acute observer of these singular beings. They secrete the calcareous matter held in solution in the oceanic waters, and produce the wonderful structures we have now under consideration; and these calcareous banks have been in course of formation during many geological ages. They just reach the level of the [264]
waters, for the polyps perish as soon as they are so far above the surface that neither the waves nor the flow of the tides can reach them. In the Oolitic rocks these banks are frequently found from twelve to fifteen feet thick, and many leagues in length, and preserving, for the most part, the relative positions which they occupied in the sea while in course of formation.

The rocks which now represent the Middle Oolitic Period are usually divided into the *Oxford Clay*, the lower member of which is an arenaceous limestone, known as the *Kellaways Rock*, which in Wiltshire and other parts of the south-west of England attains a thickness of eight or ten feet, with the impressions of numerous Ammonites, and other shells. In Yorkshire, around Scarborough, it reaches the thickness of thirty feet; and forms well-developed beds of bluish-black marl in the department of Calvados, in France. It is the base of this clay which forms the soil (*Argile de Dives*) of the valley of the Auge, renowned for its rich pasturages and magnificent cattle. The same beds form the base of the oddly-shaped but fine rocks of La Manche, which are popularly known as the *Vaches Noires* (or black cows)—a locality celebrated, also, for its fine Ammonites transformed into pyrites.

The *Oxford Clay* constitutes the base of the hills in the neighbourhood of Oxford, forming a bed of clay sometimes more than 600 feet thick. It is found well-developed in France, at Trouville, in the department of the Calvados; and at Neuvisy, in the department of the Ardennes, where it attains a thickness of about 300 feet. It is a bluish, sometimes whitish limestone (often argillaceous), and bluish marl. The *Gryphæa dilatata* is the most common fossil in the Oxford Clay. The *Coral Rag* is so called from the fact that the limestone of which it is chiefly composed consists, in part, of an aggregation of considerable masses of petrified Corals; not unlike those now existing in the Pacific Ocean, supposing them to be covered up for ages and fossilised. This coral stratum extends through the hills of Berkshire and North Wilts, and it occurs again near Scarborough. In the counties of Dorset, Bedford, Buckingham, and Cambridge, and some other parts of England, the limestone of the Coral Rag disappears and is replaced by clay—in which case the Oxford Clay is overlaid directly by the Kimeridge Clay. In France it is found in the departments of the Meuse, of the Yonne, of the Ain, of the Charente Inférieure. In the Alps the *Diceras limestone* is regarded, by most geologists, as coeval with the English Coral Rag.

Upper Oolite. [265]

Some marsupial Mammals have left their remains in the Upper Oolite as in the Lower. They belong to the genus *Sphalacotherium*. Besides the Plesiosauri and Teleosauri, there still lived in the maritime regions a Crocodile, the *Macrorhynchus*; and the monstrous *Pœcilopleuron*, with sharp cutting teeth, one of the most formidable animals of this epoch; the *Hylæosaurus*, *Cetiosaurus*, *Stenosaurus*, and *Streptospondylus*, and among the Turtles, the *Emys* and *Platemys*. [266]
As in the Lower Oolite, so also in the Upper, Insects similar to those by which we are surrounded, pursued their flight in the meadows and hovered over the surface of the water. Of these, however, too little is known for us to give any very precise indication on the subject of their special organisation.

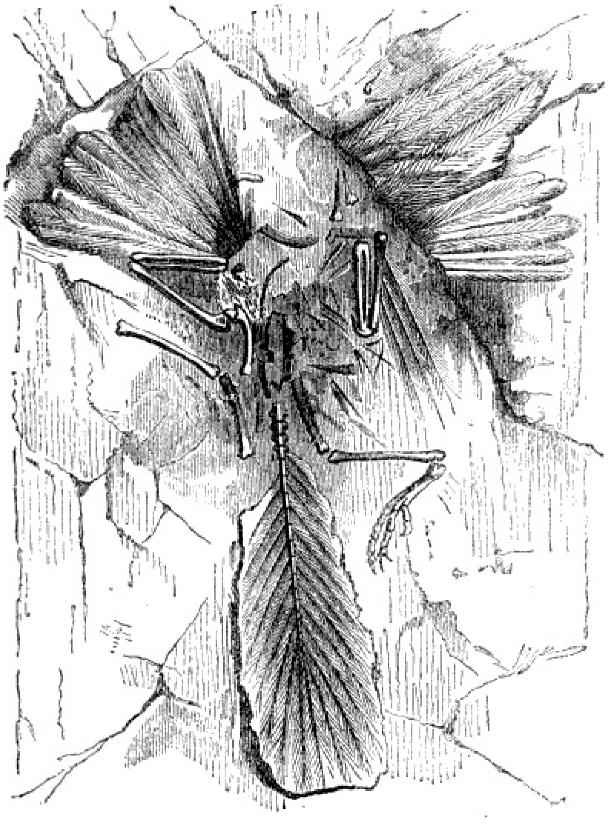


Fig. 122.—Bird of Solenhofen (Archæopteryx).

The most remarkable fact relating to this period is the appearance of the first bird. Hitherto the Mammals, and of these only imperfectly-organised species, namely, the Marsupials, have alone appeared. It is interesting to witness birds appearing immediately after. In the quarries of lithographic stone at Solenhofen, the remains of a bird, with feet and feathers, have been found, but without the head. These curious remains are represented in Fig. 122, in the position in which they were discovered. The bird is usually designated the Bird of Solenhofen.

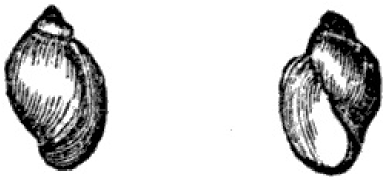
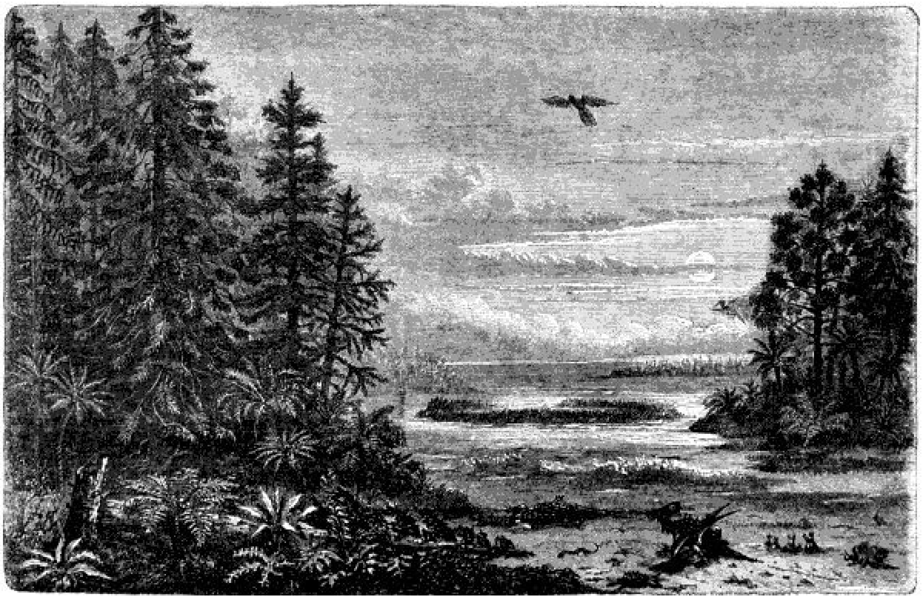


Fig. 123.
Shell of Physa fontinalis.

The Oolitic seas of this series contained Fishes belonging to the genera *Asteracanthus*, *Strephodes*, *Lepidotus*, and *Microdon*. The Cephalopodous Mollusca were not numerous, the predominating genera belonging to the Lamellibranchs and to the Gasteropods, which lived on the shore. The reef-making Madrepores or Corals were more numerous. A few Zoophytes in the fossil state testify to the existence of these extraordinary animals. The fossils characteristic of the fauna of the period include *Ammonites decipiens* and *A. giganteus*, *Natica elegans* and *hemispherica*, *Ostrea deltoidea* and *O. virgula*, *Trigonia gibbosa*, *Pholadomya multicostata* and *P. acuticostata*, *Terebratula subsella*, and *Hemicidaris Purbeckensis*. Some *Fishes*, *Turtles*, *Paludina*, *Physa* (Fig. 123), *Unio*, *Planorbis* (Fig. 201), and the little crustacean bivalves, the Cypris, constituted the fresh-water fauna of the period.

The terrestrial flora of the period consisted of Ferns, Cycadeaceæ, and Conifers; in the ponds and swamps some Zosteræ. The *Zosteræ* are monocotyledonous plants of the family of the Naïdaceæ, which grow in the sandy mud of maritime regions, forming there, with their long, narrow, and ribbon-like leaves, vast prairies of the most beautiful green. At low tides these masses of verdure appear somewhat exposed. They would form a retreat for a great number of marine animals, and afford nourishment to others.

[267]



XX.—Ideal Landscape of the Upper Oolitic Period.

On the opposite page an ideal landscape of the period (Plate XX.) represents some of the features of the Upper Oolite, especially the vegetation of the Jurassic period. The *Sphenophyllum*, among the Tree-ferns, is predominant in this vegetation; some *Pandanas*, a few *Zamites*, and many *Conifers*, but we perceive no Palms. A coral islet rises out of the sea, having somewhat of the form of the *atolls* of Oceania, indicating the importance these formations assumed in the Jurassic period. The animals represented are the *Crocodileimus* of Jourdan, the *Ramphorynchus*, with the imprints which characterise its footsteps, and some of the invertebrated animals of the period, as the *Asteria*, *Comatula*, *Hemicidaris*, *Pteroceras*. Aloft in the air floats the bird of Solenhofen, the *Archæopteryx*, which has been re-constructed from the skeleton, with the exception of the head, which remains undiscovered. [269]

The rocks which represent the Upper Oolite are usually divided into two series: 1. The *Purbeck Beds*; 2. The *Portland Stone and Sand*; and 3. The *Kimeridge Clay*.

The *Kimeridge Clay*, which in many respects bears a remarkable resemblance to the Oxford Clay, is composed of blue or yellowish argillaceous beds, which occur in the state of clay and shale (containing locally beds of bituminous schist, sometimes forming a sort of earthy impure coal), and several hundred feet in thickness. These beds are well developed at Kimeridge, in Dorsetshire, whence the clay takes its name. In some parts of Wiltshire the beds of bituminous matter have a shaly appearance, but there is an absence of the impressions of plants which usually accompany the bitumen, derived from the decomposition of plants. These rocks, with their characteristic fossils, *Cardium striatulum* and *Ostrea deltoidea*, are found throughout England: in France, at Tonnerre, Dept. Yonne; at Havre; at Honfleur; at Mauvage; in the department of the Meuse it is so rich in shells of *Ostrea deltoidea* and *O. virgula*, that, "near Clermont in Argonne, a few leagues from St. Menehould," says Lyell,[70] "where these indurated marls crop out from beneath the Gault, I have seen them (*Gryphæa virgula*) on decomposing leave the surface of every ploughed field literally strewed over with this fossil oyster."

The second section of this series consists of the oolitic limestone of Portland, which is quarried in the Isle of Portland and in the cliffs of the Isle of Purbeck in Dorsetshire, and also at Chilmark in the Vale of Wardour, in Wiltshire. In France, the Portland beds are found near Boulogne, at Cirey-le-Château, Auxerre, and Gray (Haute Saône).

The Isle, or rather peninsula of Portland,[71] off the Dorsetshire coast, rises considerably above [270]
the sea-level, presenting on the side of the port a bold line of cliffs, connected with the mainland by the Chesil bank,[72] an extraordinary formation, consisting of a beach of shingle and pebbles loosely piled on the blue Kimeridge clay, and stretching ten miles westward along the coast. The quarries are chiefly situated in the northerly part of the island. The story told of this remarkable island is an epitome of the revolutions the surface of the earth has undergone. The slaty Purbeck beds which overlie the Portland stone are of a dark-yellowish colour; they are burnt in the neighbourhood for lime. The next bed is of a whiter and more lively colour. It is the stone of which the portico of St. Paul's and many of the houses of London, built in Queen Anne's time, were constructed. The building-stone contains fossils exclusively marine. Upon this stratum rests a bed of limestone formed in lacustrine waters. Finally, upon this bed rests another deposit of a substance which consists of very well-preserved vegetable earth or *humus*, quite analogous to our vegetable soil, of the thickness of from fifteen to eighteen inches, and of a blackish colour; it contains a strong proportion of carbonaceous earth; it abounds in the silicified remains of Conifers and other plants, analogous to the *Zamia* and *Cycas*—this soil is known as the "dirt-bed." The trunks of great numbers of silicified trees and tropical plants are found here erect, their roots fixed in the soil, and of species differing from any of our forest trees. "The ruins of a forest upon the ruins of a sea," says Esquiros, "the trunks of these trees were petrified while still growing. The region now occupied by the narrow channel and its environs had been at first a sea, in whose bed the Oolitic deposits which now form the Portland stone accumulated: the bed of the sea gradually rose and emerged from the waves. Upon the land thus rescued from the deep, plants began to grow; they now constitute with their ruins the soil of the dirt-bed. This soil, with its forest of trees, was afterwards plunged again into the waters—not the bitter waters of the ocean, but in the fresh waters of a lake formed at the mouth of some great river."

Time passed on, however; a calcareous sediment brought from the interior by the waters, formed a layer of mud over the dirt-bed; finally, the whole region was covered by a succession of calcareous deposits, until the day when the Isle of Portland was again revealed to light. "From the facts observed," says Lyell, "we may infer:—1. That those beds of the Upper Oolite, called the [271]
Portland, which are full of marine shells, were overspread with fluviatile mud, which became dry land, and covered with a forest, throughout a portion of space now occupied by the south of England, the climate being such as to admit of the growth of the *Zamia* and *Cycas*. 2. This land at length sank down and was submerged with its forest beneath a body of fresh water from which sediment was thrown down enveloping fluviatile shells. 3. The regular and uniform preservation of this thin bed of black earth over a distance of many miles, shows that the change from dry land to the state of a fresh-water lake, or estuary, was not accompanied by any violent denudation or rush of water, since the loose black earth, together with the trees which lay prostrate on its surface, must inevitably have been swept away had any such violent catastrophe taken place."[73]

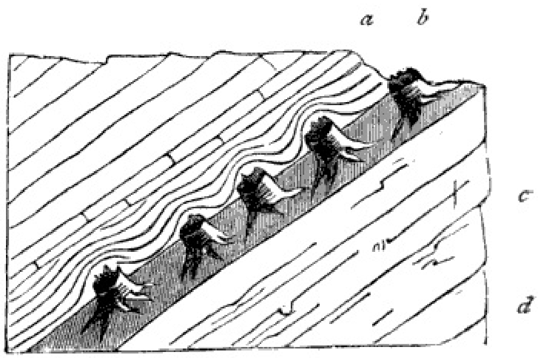


Fig. 124.—Geological humus. *a*, Fresh-water calcareous slate (Purbeck); *b*, Dirt-bed, with roots and stems of trees; *c*, Fresh-water beds; *d*, Portland Stone.

The soil known as the *dirt-bed* is nearly horizontal in the Isle of Portland; but we discover it again not far from there in the sea-cliffs of the Isle of Purbeck, having an inclination of 45°, where the trunks continue perfectly parallel among themselves, affording a fine example of a change in the position of beds originally horizontal. Fig. 124 represents this species of geological *humus*. "Each *dirt-bed*" says Sir Charles Lyell, "may, no doubt, be the memorial of many thousand years or centuries, because we find that two or three feet of vegetable soil is the only monument which many a tropical forest has left of its existence ever since the ground on which it now stands was first covered with its shade."[74]

This bed of vegetable soil is, then, near the summit of that long and complicated series of beds which constitute the Jurassic period; these ruins, still vegetable, remind us forcibly of the coal-beds, for they are nothing else than a less advanced state of that kind of vegetable fossilisation which was perfected on such an immense scale, and during an infinite length of time in the coal period.

The Purbeck beds, which are sometimes subdivided into Lower, Middle, and Upper, are mostly fresh-water formations, intimately connected with the Upper Portland beds. But there they begin and end, being scarcely recognisable except in Dorsetshire, in the sea-cliffs of which they were first studied. They are finely exposed in Durdlestone Bay, near Swanage, and at Lulworth Cove, on the same coast. The *lower beds* consist of a purely fresh-water marl, eighty feet thick, containing shells of *Cypris*, *Limnæa*, and some *Serpulæ* in a bed of marl of brackish-water origin, and some *Cypris*-bearing shales, strangely broken up at the west end of the Isle of Purbeck. [272]

The *Middle series* consists of twelve feet of marine strata known as the "cinder-beds," formed of a vast accumulation of *Ostrea distorta*, resting on fresh-water strata full of *Cypris fasciculata*, *Planorbis*, and *Limnæa*, by which this strata has been identified as far inland as the vale of Wardour in Wiltshire. Above the cinder-beds are shales and limestones, partly of fresh-water and partly of brackish-water origin, in which are Fishes, many species of Lepidotus, and the crocodilian reptile, *Macrorhynchus*. On this rests a purely marine deposit, with *Pecten*, *Avicula*, &c. Above, again, are brackish beds with *Cyrena*, overlying which is thirty feet of fresh-water limestone, with *Fishes*, *Turtles*, and *Cyprides*.

The *upper beds* are purely fresh-water strata, about fifty feet thick, containing *Paludina*, *Physa*, *Limnæa*, all very abundant. In these beds the Purbeck marble, formerly much used in the ornamental architecture of the old English cathedrals, was formerly quarried. (See Note, page 274.)

A few words may be added, in explanation of the term *oolite*, applied to this sub-period of the Jurassic formation. In a great number of rocks of this series the elements are neither crystalline nor amorphous—they are, as we have already said, oolitic; that is to say, the mass has the form of the roe of certain fishes. The question naturally enough arises, Whence this singular oolitic structure assumed by the components of certain rocks? It is asserted that the grinding action of the sea acting upon the precipitated limestone produces rounded forms analogous to grains of sand. This hypothesis may be well founded in some cases. The marine sediments which are deposited in some of the warm bays of Teneriffe are found to take the spheroidal granulated form of the oolite. But these local facts cannot be made to apply to the whole extent of the oolitic formations. We must, therefore, look further for an explanation of the phenomena.

It is admitted that if the cascades of Tivoli, for example, can give birth to the oolitic grains, the same thing happens in the quietest basins, that in stalactite-caverns oolitic grains develop themselves, which afterwards, becoming cemented together from the continued, but very slow, affluence of the calcareous waters, give rise to certain kinds of oolitic rocks. [273]

On the other hand, it is known that nodules, more or less large, develop themselves in marls in consequence of the concentration of the calcareous elements, without the possibility of any wearing action of water. Now, as there exists every gradation of size between the smallest oolitic grains and the largest concretions, it is reasonable to suppose that the oolites are equally the product of concentration.

Finally, from research to research, it is found that perfectly constituted oolites—that is to say, concentric layers, as in the Jurassic limestone—develop themselves in vegetable earth in places where the effects of water in motion is not more admissible than in the preceding instances.

Thus we arrive at the conclusion, that if Nature sometimes forms crystals with perfect terminations in magmas in the course of solidification, she gives rise also to spheroidal forms surrounding various centres, which sometimes originate spontaneously, and in other cases are accumulated round the débris of fossils, or even mere grains of sand. Nevertheless, all mineral substances are not alike calculated to produce oolitic rocks; putting aside some particular cases, this property is confined to limestone and oxide of iron.

With regard to the distribution of the Jurassic formation on the terrestrial globe, it may be stated that the Cotteswold Hills in England, and in France the Jura mountains, are almost entirely composed of these rocks, the several series of beds being all represented in them—this circumstance, in fact, induced Von Humboldt to name the formation after this latter range. The Upper Lias also exists in the Pyrenees and in the Alps; in Spain; in many parts of Northern Italy; in Russia, especially in the government of Moscow, and in the Crimea; but it is in Germany where it occupies the most important place. A thin bed of oolitic limestone presents, at Solenhofen in Bavaria, a geological repository of great celebrity, containing fossil Plants, Fishes, Insects, Crustaceans, with some Pterodactyles, admirably preserved; it yielded also some of the earliest of the feathered race. The fine quarries of lithographic stone at Pappenheim, so celebrated all over Europe, belong to the Jurassic formation.

It has recently been announced that these rocks have been found in India; they contribute largely to the formation of the main mass of the Himalayas, and to the chain of the Andes in South America; finally, from recent investigations, they seem to be present in New Zealand. [274]

In England the Lias constitutes a well-defined belt about thirty miles broad, extending from Dorsetshire, in the south, to Yorkshire, in the north, formed of alternate beds of clay, shales, and limestone (with layers of jet), on the coast near Whitby. It is rich, as we have seen, in ancient life, and that in the strongest forms imaginable. From the unequal hardness of the rocks it comprises, it stands out boldly in some of the minor ranges of hills, adding greatly to the picturesque beauty of the scenery in the centre of the country. In Scotland the formation occupies a very limited space.

A map of the country at the close of the Jurassic period would probably show double the extent of dry land in the British Islands, compared with what it displayed as an island in the primordial ocean; but Devon and Cornwall had long risen from the sea, and it is probable that the Jurassic beds of Dorsetshire and France were connected by a tongue of land running from Cherbourg to the Liassic beds of Dorsetshire, and that Boulogne, still an island, was similarly connected with the Weald.

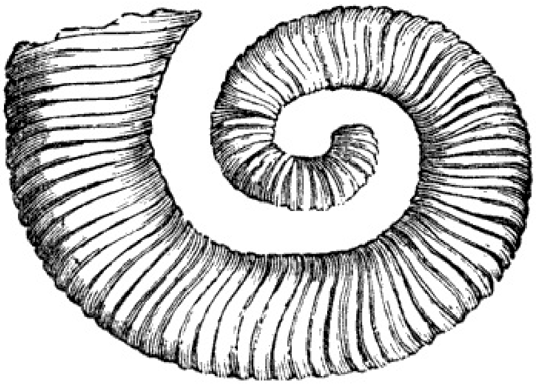


Fig. 125.—Crioceras Duvallii, Sowerby.
A non-involuted Ammonite.
(Neocomian.)

Note.—Sections of the Purbeck strata of Dorsetshire have been constructed by Mr. Bristow, from actual measurement, in the several localities in the Isle of Purbeck, where they are most clearly and instructively displayed.

These sections, published by the Geological Survey, show in detail the beds in their regular and natural order of succession, with the thickness, mineral character, and contents, as well as the fossils, of each separate bed.

[275]

THE CRETACEOUS PERIOD.

The name *Cretaceous* (from *creta*, chalk) is given to this epoch in the history of our globe because the rocks deposited by the sea, towards its close, are almost entirely composed of chalk (carbonate of lime).

Carbonate of lime, however, does not now appear for the first time as a part of the earth’s crust; we have already seen limestone occurring, among the terrestrial materials, from the Silurian period; the Jurassic formation is largely composed of carbonate of lime in many of its beds, which are enormous in number as well as extent; it appears, therefore, that in the period called *Cretaceous* by geologists, carbonate of lime was no new substance in the constitution of the globe. If geologists have been led to give this name to the period, it is because it accords better than any other with the characteristics of the period; with the vast accumulations of chalky or earthy limestone in the Paris basin, and the beds of so-called Greensand, and Chalk of the same age, so largely developed in England.

We have already endeavoured to establish the origin of lime, in speaking of the Silurian and Devonian periods, but it may be useful to recapitulate the explanation here, even at the risk of repeating ourselves.

We have said that lime was, in all probability, introduced to the globe by thermal waters flowing abundantly through the fissures, dislocations, and fractures in the ground, which were themselves caused by the gradual cooling of the globe; the central nucleus being the grand reservoir and source of the materials which form the solid crust. In the same manner, therefore, as the several eruptive substances—such as granites, porphyries, trachytes, basalts, and lava—have been ejected, so have thermal waters charged with carbonate of lime, and often accompanied by silica, found their way to the surface in great abundance, through the fissures, fractures, and dislocations in the crust of the earth. We need only mention here the Iceland geysers, the springs of Plombières, and the well-known thermal springs of Bath and elsewhere in this country.

But how comes lime in a state of bicarbonate, dissolved in these thermal waters, to form rocks? That is what we propose to explain. [276]

During the primary geological periods, thermal waters, as they reached the surface, were discharged into the sea and united themselves with the waves of the vast primordial ocean, and the waters of the sea became sensibly calcareous—they contained, it is believed, from one to two per cent. of lime. The innumerable animals, especially Zoophytes, and Mollusca with solid shells, with which the ancient seas swarmed, secreted this lime, out of which they built up their mineral dwelling—or shell. In this liquid and chemically calcareous medium, the Foraminifera and Polyps of all forms swarmed, forming an innumerable population. Now what became of the bodies of these creatures after death? They were of all sizes, but chiefly microscopic; that is, so small as to be individually all but invisible to the naked eye. The perishable animal matter disappeared in the bosom of the waters by decomposition, but there still remained behind the indestructible inorganic matter, that is to say, the carbonate of lime forming their testaceous covering; these calcareous deposits accumulating in thick beds at the bottom of the sea, became compacted into a solid mass, and formed a series of continuous beds superimposed on each other. These, increasing imperceptibly in the course of ages, ultimately formed the rocks of the *Cretaceous* period, which we have now under consideration.

These statements are not, as the reader might conceive from their nature, a romantic conception invented to please the imagination of those in search of a system—the time is past when geology should be regarded as the romance of Nature—nor has what we advance at all the character of an arbitrary conception. One is no doubt struck with surprise on learning, for the first time, that all the limestone rocks, all the calcareous stones employed in the construction of our dwellings, our cities, our castles and cathedrals, were deposited in the seas of an earlier world, and are only composed of an aggregation of shells of Mollusca, or fragments of the testaceous coverings of Foraminifera and other Zoophytes—nay, that they were secreted from the water itself, and then assimilated by these minute creatures, and that this would appear to have been the great object of their creation in such myriads. Whoever will take the trouble to observe, and reflect on what he observes, will find all his doubts vanish. If chalk be examined with a microscope, it will be found to be composed of the remains of numerous Zoophytes, of minute and divers kinds of shells, and, above all, of Foraminifera, so small that their very minuteness seems to have rendered them indestructible. A hundred and fifty of these small beings placed end to end, in a line, will only occupy the space of about one-twelfth part of an inch. [277]

Chalk under the Microscope.

Fig. 126.—Chalk of Meudon (magnified).

Much of this curious information was unknown, or at least only suspected, when Ehrenberg began his microscopical investigations. From small samples of chalk reduced to powder, placed upon the object-glass, and examined under the microscope, Ehrenberg prepared the designs which we reproduce from his learned micrographical work, in which some of the elegant forms discovered in the Chalk are illustrated, greatly magnified. Fig. 126 represents the chalk of Meudon, in France, in which ammonite-like forms of Foraminifera and others, equally beautiful, appear. Fig. 127, from the chalk of Gravesend, contains similar objects. Fig. 128 is an example of [278] chalk from the island of Moën, in Denmark; and Fig. 129, that which is found in the Tertiary rocks of Cattolica, in Sicily. In all these the shells of Ammonites appear, with clusters of round Foraminifera and other Zoophytes. In two of these engravings (Figs. 126 and 128), the chalk is represented in two modes—in the upper half, by transparency or transmitted light; in the lower half, the mass is exhibited by superficial or reflected light.

Chalk under the Microscope.

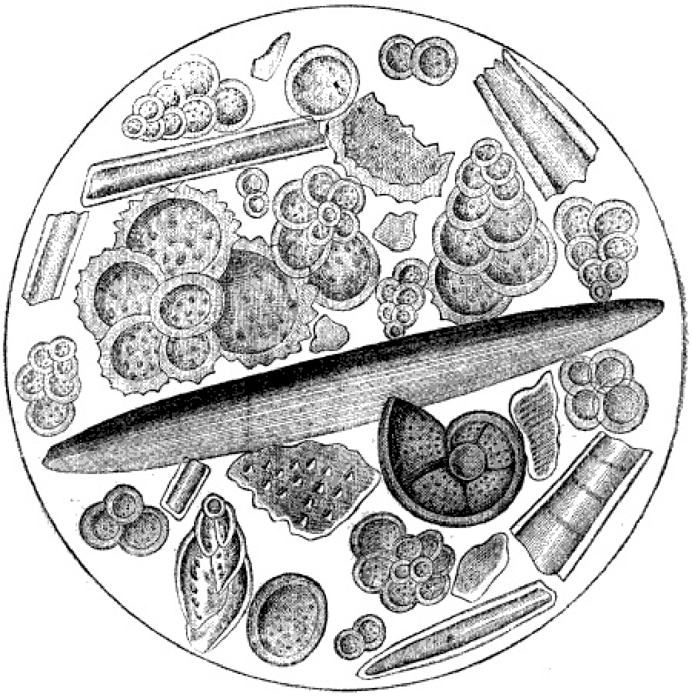


Fig. 127.—Chalk of Gravesend. (After Ehrenberg).—Magnified.

Observation, then, establishes the truth of the explanation we have given concerning the formation of the chalky or Cretaceous rocks; but the question still remains—How did these rocks, originally deposited in the sea, become elevated into hills of great height, with bold escarpments, like those known in England as the North and South Downs? The answer to this involves the consideration of other questions which have, at present, scarcely got beyond hypothesis.

Chalk under the Microscope.

Fig. 128.—Chalk of the Isle of Moën, Denmark.

During and after the deposition of the Portland and Purbeck beds, the entire Oolite Series, in the south and centre of England and other regions, was raised above the sea-level and became dry land. Above these Purbeck beds, as Professor Ramsay tells us [in the district known as the Weald], "we have a series of beds of clays, sandstones, and shelly limestones, indicating by their fossils that they were deposited in an estuary where fresh water and occasionally brackish water and marine conditions prevailed. The Wealden and Purbeck beds indeed represent the delta of an [279] immense river which in size may have rivalled the Ganges, Mississippi, Amazon, &c., and whose waters carried down to its mouth the remains of land-plants, small Mammals, and great terrestrial Reptiles, and mingled them with the remains of Fishes, Molluscs, and other forms native to its waters. I do not say that this immense river was formed or supplied by the drainage [280] of what we now call Great Britain—I do not indeed know where this continent lay, but I do know that England formed a part of it, and that in size it must have been larger than Europe, and was probably as large as Asia, or the great continent of America." Speaking of the geographical extent of the Wealden, Sir Charles Lyell says: "It cannot be accurately laid down, because so much of it is concealed beneath the newer marine formations. It has been traced about 200 miles from west to east; from the coast of Dorsetshire to near Boulogne, in France; and nearly 200 [281] miles from north-west to south-east, from Surrey and Hampshire to Beauvais, in France;"[75] but he expresses doubt, supposing the formation to have been continuous, if the two areas were contemporaneous, the region having undergone frequent changes, the great estuary having altered its form, and even shifted its place. Speaking of a hypothetical continent, Sir Charles Lyell says: "If it be asked where the continent was placed from the ruins of which the Wealden strata were derived, and by the drainage of which a great river was fed, we are half tempted to speculate on the former existence of the Atlantis of Plato. The story of the submergence of an ancient continent, however fabulous in history, must have been true again and again as a geological event."[76]

Chalk under the Microscope.

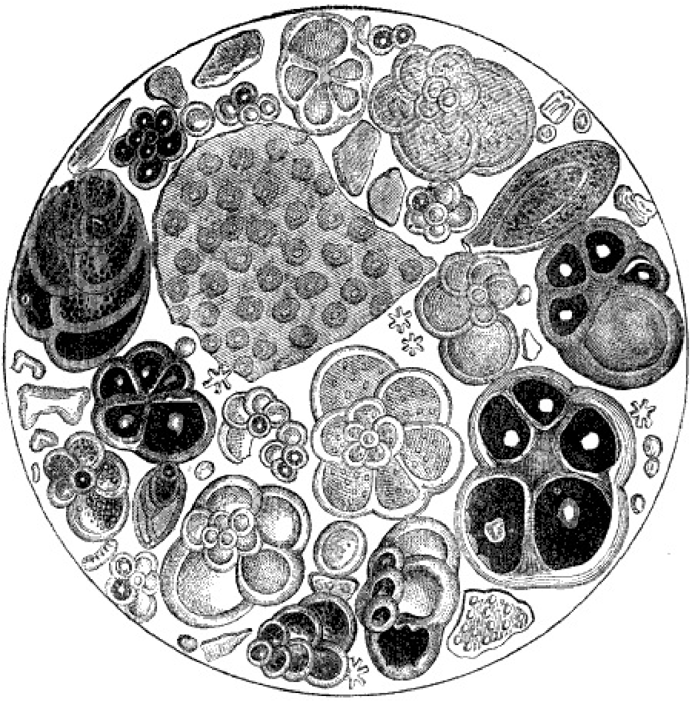


Fig. 129.—Chalk of Cattolica, Sicily (magnified).

The proof that the Wealden series were accumulated under fresh-water conditions and as a river deposit[77] lies partly in the nature of the strata, but chiefly in the nature of the organic remains. The fish give no positive proof, but a number of Crocodilian reptiles give more conclusive evidence, together with the shells, most of them being of fresh-water origin, such as Paludina, Planorbis, Lymnæa, Physa, and such like, which are found living in many ponds and rivers of the present day. Now and then we find bands of marine remains, not mixed with fresh-water deposits, but interstratified with them; showing that at times the mouth and delta of the river had sunk a little, and that it had been invaded by the sea; then by gradual change it was lifted up, and became an extensive fresh-water area. This episode at last comes to an end by the complete submergence of the Wealden area; and upon these fresh-water strata a set of marine sands and clays, and upon these again thick beds of pure white earthy limestone of the Cretaceous period were deposited. The lowest of these formations is known as the Lower Greensand; then followed the clays of the Gault, which were succeeded by the Upper Greensand. Then, resting upon the Upper Greensand, comes the vast mass of Chalk which in England consists of soft white earthy limestone, containing, in the upper part, numerous bands of interstratified flints, which were mostly sponges originally, that have since become silicified and converted into flint. The strata of chalk where thickest are from 1,000 to 1,200 feet in thickness. Their upheaval into dry land brought this epoch to an end; the conditions which had contributed to its formation ceased in our area, and as the uppermost member of the Secondary rocks, it closes the record of Mesozoic times in England.

Let us add, to remove any remaining doubts, that in the basin of a modern European sea—the [282] Baltic—a curious assemblage of phenomena, bearing on the question, is now in operation. The bed and coast-line of the Baltic continue slowly but unceasingly to rise, and have done so for several centuries, in consequence of the constant deposit which takes place of calcareous shells, added to the natural accumulations of sand and mud. The Baltic Sea will certainly be filled up in time by these deposits, and this modern phenomenon, which we find in progress, so to speak, brings directly under our observation an explanation of the manner in which the cretaceous rocks were produced in the ancient world, more especially when taken in connection with another branch of the same subject to which Sir Charles Lyell called attention, in an address to the Geological Society. It appears that just as the northern part of the Scandinavian continent is now rising, and while the middle part south of Stockholm remains unmoved, the southern extremity in Scania is sinking, or at least has sunk, within the historic period; from which he argues that there may have been a slow upheaval in one region, while the adjoining one was stationary, or in course of submergence.

After these explanations as to the manner in which the cretaceous rocks were formed, let us examine into the state of animal and vegetable life during this important period in the earth's history.

The vegetable kingdom of this period forms an introduction to the vegetation of the present time. Placed at the close of the Secondary epoch, this vegetation prepares us for transition, as it were, to the vegetation of the Tertiary epoch, which, as we shall see, has a great affinity with that of our own times.

The landscapes of the ancient world have hitherto shown us some species of plants of forms strange and little known, which are now extinct. But during the period whose history we are tracing, the vegetable kingdom begins to fashion itself in a less mysterious manner; Palms appear, and among the regular species we recognise some which differ little from those of the tropics of our days. The dicotyledons increase slightly in number amid Ferns and Cycads, which have lost much of their importance in numbers and size; we observe an obvious increase in the dicotyledons of our own temperate climate, such as the alder, the wych-elm, the maple, and the walnut, &c.

"As we retire from the times of the primitive creation," says Lecoq, "and slowly approach those of our own epoch, the sediments seem to withdraw themselves from the polar regions and restrict themselves to the temperate or equatorial zones. The great beds of sand and limestone, which [283] constitute the Cretaceous formation, announce a state of things very different from that of the preceding ages. The seasons are no longer marked by indications of central heat; zones of latitude already show signs of their existence.

"Hitherto two classes of vegetation predominated: the cellular *Cryptogams* at first, the dicotyledonous *Gymnosperms* afterwards; and in the epoch which we have reached—the transition epoch of vegetation—the two classes which have reigned heretofore become enfeebled, and a third, the dicotyledonous *Angiosperms*, timidly take possession of the earth—they consist at first of a small number of species, and occupy only a small part of the soil, of which they afterwards take their full share; and in the succeeding periods, as in our own times, we shall see that their reign is firmly established; during the Cretaceous period, in short, we witness the appearance of the first dicotyledonous *Angiosperms*. Some arborescent Ferns still maintain their position, and the elegant *Protopteris Singeri*, Preissl., and P. *Buvigneri*, Brongn., still unfold their light fronds to the winds of this period. Some *Pecopteri*, differing from the Wealden species, live along with them. Some *Zamites*, *Cycads*, and *Zamiostrobi* announce that in the Cretaceous period the temperature was still high. New Palms show themselves, and, among others, *Flabellaria chamæropifolia* is especially remarkable for the majestic crown at its summit.

"The *Conifers* have endured better than the *Cycadeæ*; they formed then, as now, great forests, where *Damarites*, *Cunninghamias*, *Araucarias*, *Eleoxylons*, *Abietites*, and *Pinites* remind us of numerous forms still existing, but dispersed all over the earth.

"From this epoch date the *Comptonias*, attributed to the Myricaceæ; *Almites Friesii*, Nils., which we consider as one of the Betulaceæ; *Carpinites arenaceus*, Gœp., which is one of the Cupuliferæ; the *Salicites*, which are represented to us by the arborescent willows; the Acerinæ would have their *Acerites cretaceæ*, Nils., and the Juglanditæ, the *Juglandites elegans*, Gœp. But the most interesting botanical event of this period is the appearance of the *Credneria*, with its triple-veined leaves, of which no less than eight species have been found and described, but whose place in the systems of classification still remains uncertain. The *Crednerias*, like the *Salicites*, were certainly trees, as were most of the species of this remote epoch."

In the following illustration are represented two of the Palms belonging to the Cretaceous period, restored from the imprints and fragments of the fossil remains left by the trunk and branches in the rocks of the period (Fig. 130.)

[284]

Fig. 130.—Fossil Palms restored.

But if the vegetation of the Cretaceous period exhibits sensible signs of approximation to that of our present era, we cannot say the same of the animal creation. The time has not yet come when Mammals analogous to those of our epoch gave animation to the forests, plains, and shores of the ancient world; even the Marsupial Mammals, which made their appearance in the Liassic and Oolitic formations, no longer exist, so far as is known, and no others of the class have taken their place. No climbing Opossum, with its young ones, appears among the leaves of the Zamites. The earth appears to be still tenanted by Reptiles, which alone break the solitudes of the woods and the silence of the valleys. The Reptiles, which seem to have swarmed in the seas of the Jurassic period, partook of the crocodilian organisation, and those of this period seem to bear more resemblance to the Lizards of our day. In this period the remains of certain forms indicate that they stood on higher legs; they no longer creep on the earth, and this is apparently the only approximation which seems to connect them more closely with higher forms. [285]

It is not without surprise that we advert to the immense development, the extraordinary dimensions which the Saurian family attained at this epoch. These animals which, in our days, rarely exceed a yard or so in length, attained in the Cretaceous period as much as twenty. The marine lizard, which we notice under the name of *Mosasaurus*, was then the scourge of the seas, playing the part of the Ichthyosauri of the Jurassic period; for, from the age of the Lias to that of the Chalk, the Ichthyosauri, the Plesiosauri, and the Teleosauri were, judging from their organisation, the tyrants of the waters. They appear to have become extinct at the close of the Cretaceous period, and to give place to the *Mosasaurus*, to whom fell the formidable task of keeping within proper limits the exuberant production of the various tribes of Fishes and Crustaceans which inhabited the seas. This creature was first discovered in the celebrated rocks of St. Peter’s Mount at Maestricht, on the banks of the Meuse. The skull alone was about four feet in length, while the entire skeleton of *Iguanodon Mantelli*, discovered by Dr. Mantell in the Wealden strata, has since been met with in the Hastings beds of Tilgate Forest, measuring, as Professor Owen estimates, between fifty and sixty feet in length. These enormous Saurians disappear in their turn, to be replaced in the seas of the Tertiary epoch by the Cetaceans; and henceforth animal life begins to assume, more and more, the appearance it presents in the actually existing creation.

Seeing the great extent of the seas of the Cretaceous period, Fishes were necessarily numerous. The pike, salmon, and dory tribes, analogous to those of our days, lived in the seas of this period; [286] they fled before the sharks and voracious dog-fishes, which now appeared in great numbers, after just showing themselves in the Oolitic period.

The sea was still full of Polyps, Sea-urchins, Crustaceans of various kinds, and many genera of Mollusca different from those of the Jurassic period; alongside of gigantic Lizards are whole piles of animalculæ—those Foraminifera whose remains are scattered in infinite profusion in the Chalk, over an enormous area and of immense thickness. The calcareous remains of these little beings, incalculable in number, have indeed covered, in all probability, a great part of the terrestrial surface. It will give a sufficient idea of the importance of the Cretaceous period in connection with these organisms to state that, in the rocks of the period, 268 genera of animals, hitherto unknown, and more than 5,000 species of special living beings have been found; the thickness of the rocks formed during the period being enormous. Where is the geologist who will venture to estimate the time occupied in creating and destroying the animated masses of which this formation is at once both the cemetery and the monument? For the purposes of description it will be convenient to divide the Cretaceous series into lower and upper, according to their relative ages and their peculiar fossils.

The Lower Cretaceous Period.

English equivalents.	French classification.
Lower Greensand, upper part.	Étage Aptien st.
Lower Greensand, lower part.	„ Néocomien supérieur.
Weald clay and Hastings sands.	„ Néocomien inférieur.

The Lower Wealden or Hastings Sand consists of sand, sandstone, and calciferous grit, clay, and shale, the argillaceous strata predominating. This part of the Wealden consists, in descending order, of:—

	Feet.
Tunbridge Wells sand—Sandstone and loam	150
Wadhurst clay—Blue and brown shale and clay, with a little calc grit	100
Ashdown sands—Hard sand, with beds of calc grit	160
Ashburnham sands—Mottled, white, and red clay and sandstone	330

The Hastings sand has a hard bed of white sand in its upper part, whose steep natural cliffs produce the picturesque scenery of the "High rocks" of Hastings in Sussex.

Calcareous sandstone and grit, in which Dr. Mantell found the remains of the *Iguanodon* and *Hylæosaurus*, form an upper member of the Tunbridge Wells Sand. The formation extends over [287] Hanover and Westphalia; the Wealden of these countries, according to Dr. Dunker and Von Meyer, corresponding in their fossils and mineral characters with those of the English series. So that "we can scarcely hesitate," says Lyell, "to refer the whole to one great delta."[78]

The overlying Weald clay crops out from beneath the Lower Greensand in various parts of Kent and Sussex, and again in the Isle of Wight, and in the Isle of Purbeck, where it reappears at the base of the chalk.

The upper division (or the Weald clay) is, as we have said, of purely fresh-water origin, and is supposed to have been the estuary of some vast river which, like the African Quorra, may have formed a delta some hundreds of miles broad, as suggested by Dr. Dunker and Von Meyer.

The Lower Greensand is known, also, as the *Néocomien*, after Neocomium, the Latin name of the city of Neufchatel, in Switzerland, where this formation is largely developed, and where, also, it was first recognised and established as a distinct formation. Dr. Fitton, in his excellent monograph of the Lower Cretaceous formations, gives the following descending succession of rocks as observable in many parts of Kent:—

		Feet.
1.	Sand, white, yellowish, or brown, with concretions of limestone and chert	70
2.	Sand, with green matter	70 to 100
3.	Calcareous stone, called Kentish rag	60 to 80

These divisions, which are traceable more or less from the southern part of the Isle of Wight to Hythe in Kent, present considerable variations. At Atherfield, where sixty-three distinct strata, measuring 843 feet, have been noticed, the limestone is wholly wanting, and some fossils range through the whole series, while others are confined to particular divisions; but Prof. E. Forbes states, that when the same conditions are repeated in overlying strata the same species reappear; but that changes of depth, or of the mineral nature of the sea-bottom, the presence or absence of lime or of peroxide of iron, the occurrence of a muddy, sandy, or gravelly bottom, are marked by the absence of certain species, and the predominance of others.[79]

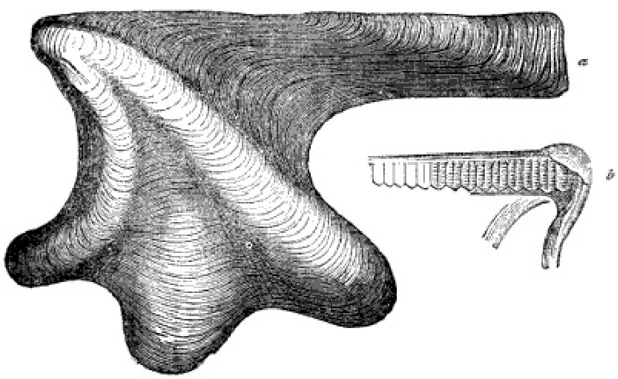


Fig. 131.—Perna Mulleti. One-quarter natural size.
a, exterior; *b*, part of the upper hinge.

Among the marine fauna of the Néocomian series the following are the principal. Among the [288]

Acephala, one of the largest and most abundant shells of the lower Néocomian, as displayed in the Atherfield section, is the large *Perna Mulleti* (Fig. 131).

The *Scaphites* have a singular boat-shaped form, wound with contiguous whorls in one part, which is detached at the last chamber, and projects in a more or less elongated condition.

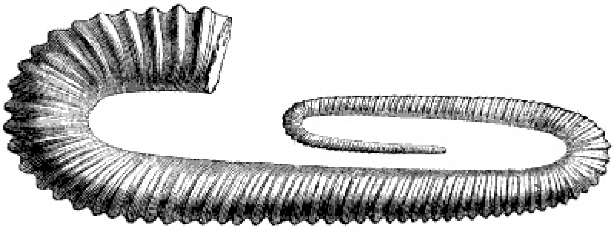


Fig. 132.—Hamites. One-third natural size.

Hamites, *Crioceras*, and *Ancyloceras* have club-like terminations at both extremities; they may almost be considered as non-involuted Ammonites with the spiral evolutions disconnected or partially unrolled, as in the engraving (Figs. 125 and 132). *Ancyloceras Matheronianus* seems to have had spines projecting from the ridge of each of the convolutions. [289]

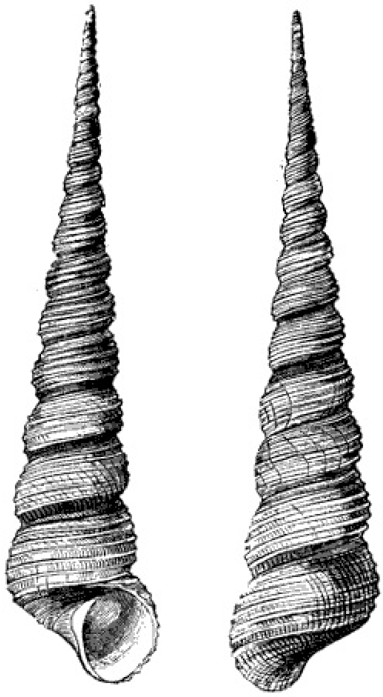


Fig. 133.—Shell of Turritella terebra.
(Living form.)

The *Toxoceras* had the shell also curved, and not spiral.

The *Baculites* had the shell differing from all Cephalopods, inasmuch as it was elongated, conical, perfectly straight, sometimes very slender, and tapering to a point. [290]

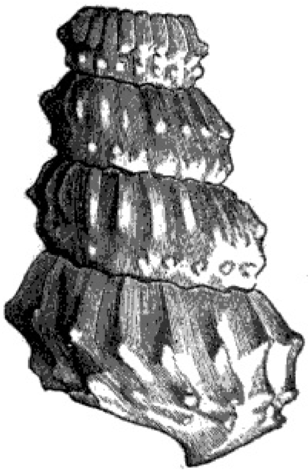


Fig. 134.—Turrillites
costatus.
(Chalk.)

The *Turrilites* have the shell regular, spiral, and *sinistral*; that is, turning to the left in an oblique spiral of contiguous whorls. The engraving will convey the idea of their form (Fig. 134).

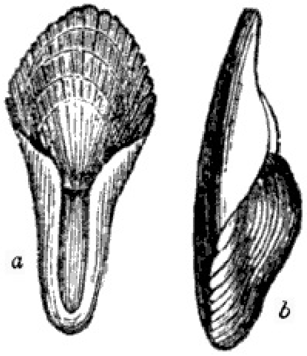


Fig. 135—Terebrirostra lyra.
a, back view; *b*, side view.

Among others, as examples of form, we append Figs. 133, 135, 136.

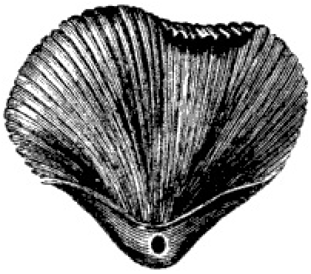


Fig. 136.—Terebratula deformis.

This analysis of the marine fauna belonging to the Néocomian formation might be carried much further, did space permit, or did it promise to be useful; but, without illustration, any further merely verbal description would be almost valueless.

Numerous Reptiles, a few Birds, among which are some "Waders," belong to the genera of *Palæornis* or *Cimoliornis*; new Molluscs in considerable quantities, and some extremely varied Zoophytes, constitute the rich fauna of the Lower Chalk. A glance at the more important of these animals, which we only know in a few mutilated fragments, is all our space allows; they are true medals of the history of our globe, medals, it is true, half effaced by time, but which consecrate the memory of departed ages.

In the year 1832 Dr. Mantell added to the wonderful discoveries he had made in the Weald of Sussex, that of the great Lizard-of-the-woods, the *hylæosaurus* (ὑλη, *wood*, σαυρος, *lizard*). This discovery was made in Tilgate forest, near Cuckfield, and the animal appears to have been from twenty to thirty feet in length. The osteological characters presented by the remains of the Hylæosaurus are described by Dr. Mantell as affording another example of the blending of the Crocodilian with the Lacertian type of structure; for we have, in the pectoral arch, the scapula or omoplate of a crocodile associated with the coracoid of a lizard. Another remarkable feature in these fossils is the presence of the large angular bones or spines, which, there is reason to infer, constituted a serrated crest along the middle of the back; and the numerous small oval dermal [291]
bones which appear to have been arranged in longitudinal series along each side of the dorsal fringe.

The *Megalosaurus*, the earliest appearance of which is among the more ancient beds of the Liassic and Oolitic series, is again found at the base of the Cretaceous rocks. It was, as we have seen, an enormous lizard, borne upon slightly raised feet; its length exceeded forty feet, and in bulk it was equal to an elephant seven feet high.

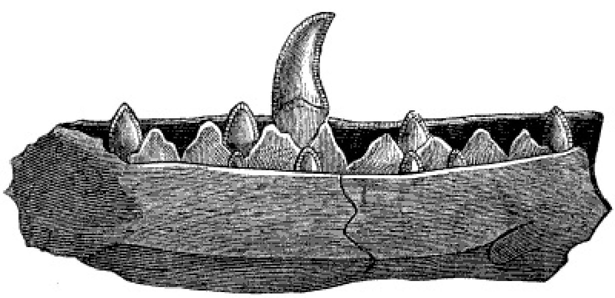


Fig. 137.—Lower Jaw of the Megalosaurus.

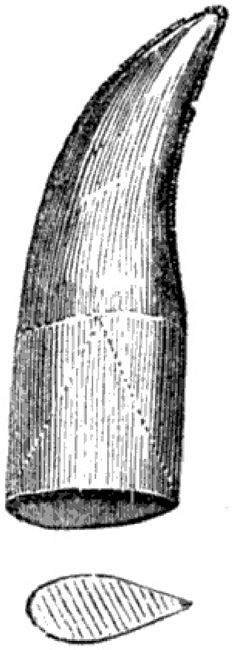


Fig. 138.—Tooth of Megalosaurus.

The Megalosaurus found in the ferruginous sands of Cuckfield, in Sussex, in the upper beds of the Hastings Sands, must have been at least sixty or seventy feet long. Cuvier considered that it partook both of the structure of the Iguana and the Monitors, the latter of which belong to the Lacertian Reptiles which haunt the banks of the Nile and tropical India. The Megalosaurus was probably an amphibious Saurian. The complicated structure and marvellous arrangement of the teeth prove that it was essentially carnivorous. It fed probably on other Reptiles of moderate size, such as the Crocodiles and Turtles which are found in a fossil state in the same beds. The jaw represented in Fig. 137 is the most important fragment of the animal we possess. It is the lower jaw, and supports many teeth: it shows that the head terminated in a straight muzzle, thin and flat on the sides, like that of the *Gavial*, the Crocodile of India. The teeth of the Megalosaurus were in perfect accord with the destructive functions with which this formidable creature was [292] endowed. They partake at once of the nature of a knife, sabre, and saw. Vertical at their junction with the jaw, they assume, with the increased age of the animal, a backward curve, giving them the form of a gardener's pruning-knife (Fig. 138; also *c.* Fig. 179). After mentioning some other particulars, respecting the teeth, Buckland says: "With teeth constructed so as to cut with the whole of their concave edge, each movement of the jaws produced the combined effect of a knife and a saw, at the same time that the point made a first incision like that made by a point of a double-cutting sword. The backward curvature taken by the teeth at their full growth renders the escape of the prey when once seized impossible. We find here, then, the same arrangements which enable mankind to put in operation many of the instruments which they employ."

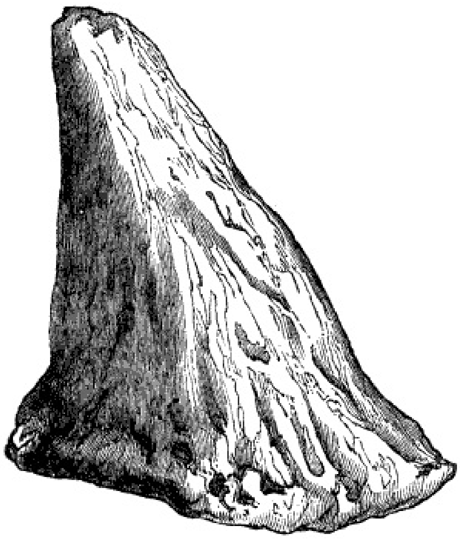


Fig. 139.—Nasal Horn of Iguanodon.
Two-thirds natural size.

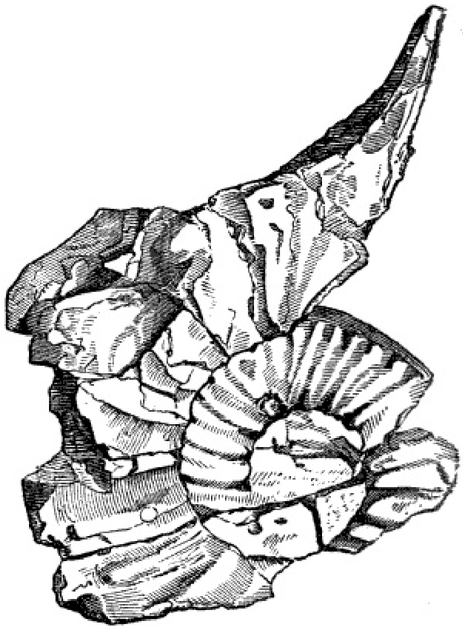


Fig. 140.—Ammonites rostratus.
(Upper Greensand.)

The *Iguanodon*, signifying *Iguana-toothed* (from the Greek word, οδους, *tooth*), was more gigantic still than the Megalosaurus; one of the most colossal, indeed, of all the Saurians of the ancient world which research has yet exposed to the light of day. Professor Owen and Dr. Mantell [293] were not agreed as to the form of the tail; the former gentleman assigning it a short tail, which would affect Dr. Mantell's estimate of its probable length of fifty or sixty feet; the largest thigh-bone yet found measures four feet eight inches in length. The form and disposition of the feet, added to the existence of a bony horn (Fig. 139), on the upper part of the muzzle or snout, almost identifies it as a species with the existing Iguanas, the only Reptile which is known to be provided with such a horn upon the nose; there is, therefore, no doubt as to the resemblance between these two animals; but while the largest of living Iguanas scarcely exceeds a yard in length, its fossil congener was probably fifteen or sixteen times that length. It is difficult to resist the feeling of astonishment, not to say incredulity, which creeps over one while contemplating so striking a disproportion as that which subsists between this being of the ancient world and its ally of the new.

The Iguanodon carried, as we have said, a horn on its muzzle; the bone of its thigh, as we have seen, surpassed that of the Elephant in size; the form of the bone and feet demonstrates that it was formed for terrestrial locomotion; and its dental system shows that it was herbivorous.

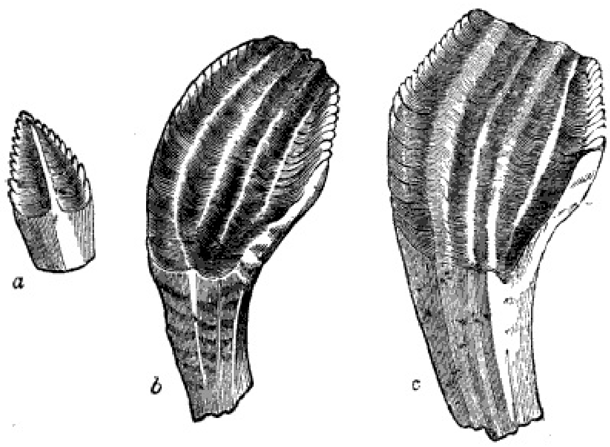


Fig. 141.—Teeth of Iguanodon.
a, young tooth; *b*, *c*, teeth further advanced, and worn.
(Wealden.)

The teeth (Fig. 141), which are the most important and characteristic organs of the whole animal, [294] are imbedded laterally in grooves, or sockets, in the dentary bone; there are three or four sockets of successional teeth on the inner side of the base of the old teeth. The place thus occupied by the edges of the teeth, their trenchant and saw-like form, their mode of curvature, the points where they become broader or narrower which turn them into a species of nippers or scissors—are all suitable for cutting and tearing the tough vegetable substances which are also found among the remains buried with this colossal reptile, a restoration of which is represented in Plate XXI., p. 296.

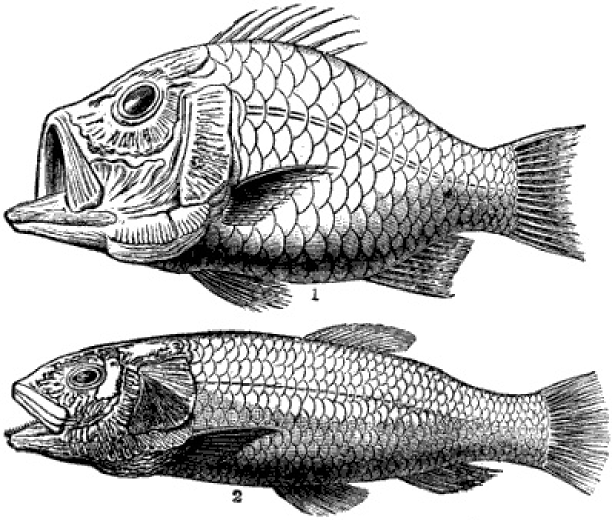
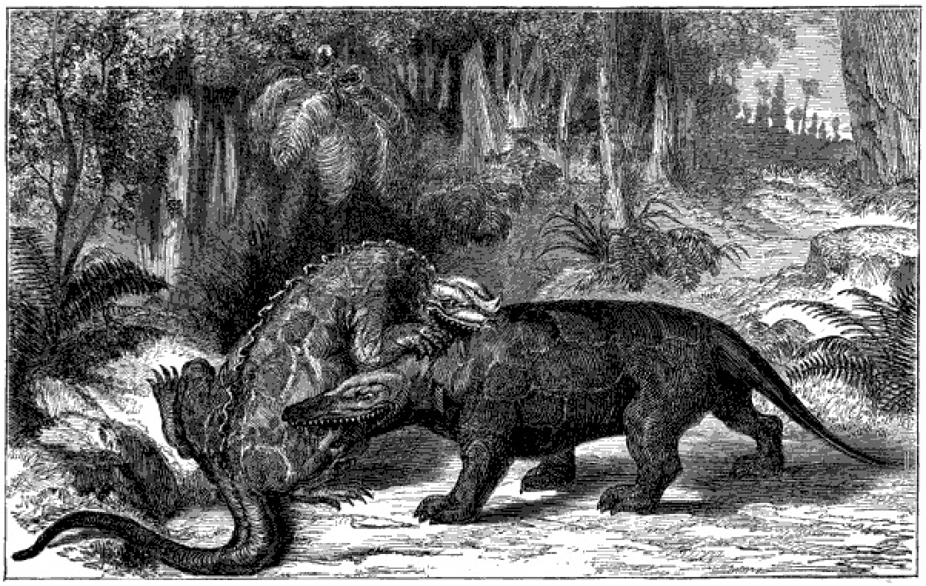


Fig. 142.—Fishes of the Cretaceous period.
1, Beryx Lewesiensis; 2, Osmeroides Mantelli.

The Cretaceous seas contained great numbers of Fishes, among which some were remarkable for their strange forms. The *Beryx Lewesiensis* (1), and the *Osmeroides Mantelli* (2) (Fig. 142), are restorations of these two species as they are supposed to have been in life. The *Odontaspis* is a new genus of Fishes which may be mentioned. *Ammonites rostratus* (Fig. 140), and *Exogyra conica* (Fig. 147), are common shells in the Upper Greensand.

[296]



XXI.—Ideal scene in the Lower Cretaceous Period, with Iguanodon and Megalosaurus.

[297]

The seas of the Lower Cretaceous period were remarkable in a zoological point of view for the great number of species and the multiplicity of generic forms of molluscous Cephalopods. The Ammonites assume quite gigantic dimensions; and we find among them new species distinguished by their furrowed transverse spaces, as in the *Hamites* (Fig. 132). Some of the *Ancyloceras* attained the magnitude of six feet, and other genera, as the *Scaphites*, the *Toxoceras*, the *Crioceras* (Fig. 125), and other Mollusca, unknown till this period, appeared now. Many Echinoderms, or sea-urchins, and Zoophytes, have enriched these rocks with their animal remains, and would give its seas a condition quite peculiar.

On the opposite page an ideal landscape of the period is represented (Plate XXI.), in which the Iguanodon and Megalosaurus struggle for the mastery in the centre of a forest, which enables us also to convey some idea of the vegetation of the period. Here we note a vegetation at once exotic and temperate—a flora like that of the tropics, and also resembling our own. On the left we observe a group of trees, which resemble the dicotyledonous plants of our forests. The elegant *Credneria* is there, whose botanical place is still doubtful, for its fruit has not been found, although it is believed to have belonged to plants with two seed-leaves, or dicotyledonous, and the arborescent Amentaceæ. An entire group of trees, composed of Ferns and Zamites, are in the background; in the extreme distance are some Palms. We also recognise in the picture the alder, the wych-elm, the maple, and the walnut-tree, or at least species analogous to these.

The Néocomian beds in France are found in Champagne, in the departments of the Aube, the Yonne, the Haute-Alps, &c. They are largely developed in Switzerland at Neufchatel, and in

Germany.

1. The Lower Néocomian consists of marls and greyish clay, alternating with thin beds of grey limestone. It is very thick, and occurs at Neufchatel and in the Drôme. The fossils are *Spatangus retusus*, *Crioceras* (Fig. 125), *Ammonites Asterianus*, &c.

2. *Orgonian* (the limestone of Orgon). This group exists, also, at Aix-les-Bains in Savoy, at Grenoble, and generally in the thick, white, calcareous beds which form the precipices of the Drôme. The fossils *Chama ammonia*, *Pigaulus*, &c.

3. The *Aptien* (or Greensand) consists generally of marls and clay. In France it is found in the department of Vaucluse, at Apt (whence the name Aptien), in the department of the Yonne, and in the Haute-Marne. Fossils, *Ancyloceras Matheronianus*, *Ostrea aquila*, and *Plicatula placunea*. [298] These beds consist here of greyish clay, which is used for making tiles; there of bluish argillaceous limestone, in black or brownish flags. In the Isle of Wight it becomes a fine sandstone, greyish and slightly argillaceous, which at Havre, and in some parts of the country of Bray, become well-developed ferruginous sandstones.

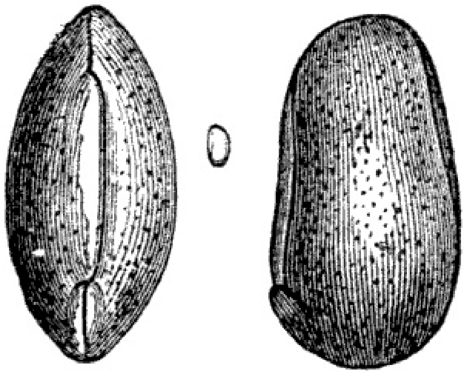


Fig. 143.—Cypris spinigera.

We have noted that the Lower Néocomian formation, although a marine deposit, is in some respects the equivalent of the *Weald Clay*, a fresh-water formation of considerable importance on account of its fossils. We have seen that it was either formed at the mouth of a great river, or the river was sufficiently powerful for the fresh-water current to be carried out to sea, carrying with it some animals, forming a fluviatile, or lacustrine fauna, on a small scale. These were small Crustaceans of the genus *Cypris*, with some molluscous Gasteropoda of the genera *Melania*, *Paludina*, and acephalous Mollusca of the five genera *Cyrena*, *Unio*, *Mytilus*, *Cyclas*, and *Ostrea*. Of these, *Cypris spinigera* (Fig. 143) and *Cypris Valdensis* (Fig. 144) may be considered as among the most characteristic fossils of this local fauna.

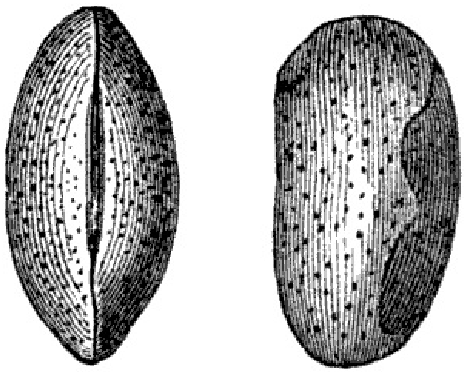


Fig. 144.—Cypris Valdensis.

The Cretaceous series is not interesting for its fossils alone; it presents also an interesting subject for study in a mineralogical point of view. The white Chalk, examined under the microscope by Ehrenberg, shows a curious globiform structure. The green part of its sandstone and limestone constitutes very singular compounds. According to the result of Berthier’s analysis, we must consider them as silicates of iron. The iron shows itself here not in beds, as in the Jurassic rocks, but in masses, in a species of pocket in the Orgonian beds. They are usually hydrates in the state of hematites, accompanied by quantities of ochre so abundant that they are frequently unworkable. In the south of France these veins were mined to a great depth by the [299] ancient monks, who were the metallurgists of their age. But for the artist the important Orgonian beds possess a special interest; their admirable vertical fractures, their erect perpendicular peaks, each surpassing the other in boldness, form his finest studies. In the Var, the defiles of Vésubia, of the Esteron, and Tinéa, are jammed up between walls of peaks, for many hundreds of yards, between which there is scarcely room for a narrow road by the side of the roaring torrent. “In the Drôme,” says Fournet, “the entrance to the beautiful valley of the Vercors is closed during a part of the year, because, in order to enter, it is necessary to cross the two gullies, the *Great* and *Little Goulet*, through which the waters escape from the valley. Even during the dry season, he who would enter the gorge must take a foot-bath.

“This state of things could not last; and in 1848 it was curious to see miners suspended on the sides of one of these lateral precipices, some 450 feet above the torrent, and about an equal distance below the summit of the Chalk. There they began to excavate cavities or niches in the face of the rock, all placed on the same level, and successively enlarged. These were united together in such a manner as to form a road practicable for carriages; now through a gallery, now covered by a corbelling, to look over which affords a succession of surprises to the traveller.

“This is not all,” adds M. Fournet: “he who traverses the high plateaux of the country finds at every step deep diggings in the soil, designated pits or *scialets*, the oldest of which have their sides clothed with a curious vegetation, in which the *Aucolin* predominates; shelter is found in these pits from the cutting winds which rage so furiously in these elevated regions. Others form a kind of cavern, in which a temperature obtains sufficient to freeze water even in the middle of summer. These cavities form natural *glaciers*, which we again find upon some of the table-lands of the Jura.

“The cracks and crevasses of the limestone receive the waters produced by falling rain and melted snow; true to the laws of all fluid bodies, they filter through the rocks until they reach the lower and impervious marly beds, where they form sheets of water, which in course of time find some outlet through which they discharge themselves. In this manner subterranean galleries, sometimes of great extent, are formed, in which are assembled all the marvels which crumbling stalactites, stalagmites, placid lakes, and headlong torrents can produce; finally, these waters, forcing their way through the external orifices, give rise to those fine cascades which, with the first gushing torrent, form an actual river.”

The *Albien* of Alc. D’Orbigny, which Lyell considers to be the equivalent of the *Gault*, French [300]
authors treat as the “*glauconie*” formation, the name being drawn from a rock composed of chalk with greenish grains of *glauconite*, or silicate of iron, which is often mixed with the limestone of this formation. The fossils by which it is identified are very varied. Among its numerous types, we find Crustaceans belonging to the genera *Arcania* and *Corystes*; many new Mollusca, *Buccinum*, *Solen*, *Pterodonta*, *Voluta*, *Chama*, &c.; great numbers of molluscous Brachiopods, forming highly-developed submarine strata; some Echinoderms, unknown up to this period, and especially a great number of Zoophytes; some Foraminifera, and many Polyzoa (Bryozoa). The glauconitic formation consists of two groups of strata: the *Gault* Clay and the *glauconitic* chalk, or Upper Greensand and Chloritic Marl.

Upper Cretaceous Period.

During this phase of the terrestrial evolutions, the continents, to judge from the fossilised wood which we meet with in the rocks which now represent it, would be covered with a very rich vegetation, nearly identical, indeed, with that which we have described in the preceding sub-period; according to Adolphe Brongniart, the “age of angiosperms” had fairly set in; the Cretaceous flora displays, he considers, a transitional character from the Secondary to the Tertiary vegetation; that the line between the gymnosperms, or naked-seeded plants, and the angiosperms, having their seeds enclosed in seed-vessels, runs between the Upper and Lower Cretaceous formations. “We can now affirm,” says Lyell, “that these Aix-la-Chapelle plants, called Credneria, flourished before the rich reptilian fauna of the secondary rocks had ceased to exist. The Ichthyosaurus, Pterodactyle, and Mosasaurus were of coeval date with the oak, the walnut, and the fig.”[80]

The terrestrial fauna, consisting of some new Reptiles haunting the banks of rivers, and Birds of the genus Snipe, have certainly only reached us in small numbers. The remains of the marine fauna are, on the contrary, sufficiently numerous and well preserved to give us a great idea of its riches, and to enable us to assign to it a characteristic facies.

The sea of the Upper Cretaceous period bristled with numerous submarine reefs, occupying a
vast extent of its bed—reefs formed of Rudistes (Lamarck), and of immense quantities of various [301]
kinds of corals which are everywhere associated with them. The Polyps, in short, attain here one of the principal epochs of their existence, and present a remarkable development of forms; the same occurs with the Polyzoa (Bryozoa) and Amorphozoa; while, on the contrary, the reign of the Cephalopods seems to end. Beautiful types of these ancient reefs have been revealed to us, and we discover that they have been formed under the influence of submarine currents, which accumulated masses of these animals at certain points. Nothing is more curious than this assemblage of *Rudistes*—still standing erect, isolated or in groups—as may be seen, for instance, at the summit of the mountains of the *Cornes* in the Corbières, upon the banks of the pond of Berre in Provence, and in the environs of Martigues, at La Cadière, at Figuières, and particularly above Beausset, near Toulon.

“It seems,” says Alcide D’Orbigny, “as if the sea had retired in order to show us, still intact, the submarine fauna of this period, such as it was when in life. There are here enormous groups of *Hippurites* in their places, surrounded by Polyps, Echinoderms, and Molluscs, which lived in union in these animal colonies, analogous to those which still exist in the coral-reefs of the Antilles and Oceania. In order that these groups should have been preserved intact, they must first have been covered suddenly by sediment, which, being removed by the action of the atmosphere, reveals to us, in their most secret details, this Nature of the past.”

In the Jurassic period we have already met with these isles or reefs formed by the accumulation of Coral and other Zoophytes; they even constituted, at that period, an entire formation called the *Coral-rag*. The same phenomenon, reproduced in the Cretaceous seas, gave rise to similar calcareous formations. We need not repeat what we have said already on this subject when describing the Jurassic period. The coral or madrepore isles of the Jurassic epoch and the reefs of Rudistes and Hippurites of the Cretaceous period have the same origin, and the *atolls* of Oceania are reproductions in our own day of precisely similar phenomena.

The invertebrate animals which characterise the Cretaceous age are among

CEPHALOPODA.

Nautilus sublævigatus and *N. Danicus; Ammonites rostratus; Belemnitella mucronata.* [302]

GASTEROPODA.

Voluta elongata; Phorus canaliculatus; Nerinea bisulcata; Pleurotomaria Fleuriausa, and *P. Santonensis; Natica supracretacea.*

ACEPHALA.

Trigonia scabra; Inoceramus problematicus and *I. Lamarckii; Clavigella cretacea; Pholadomya æquivalvis; Spondylus spinosus; Ostrea vesicularis; Ostrea larva; Janira quadricostata; Arca Gravesii; Hippurites Toucasianus* and *H. organisans; Caprina Aguilloni; Radiolites radiosus*, and *R. acuticostus.*

BRACHIOPODA.

Crania Ignabergensis; Terebratula obesa.

POLYZOA (BRYOZOA) AND ESCHINODEMATA.

Reticulipora obliqua; Ananchytes ovatus; Micraster cor-anguinum, Hemiaster bucardium and *H. Fourneli; Galerites albogalerus; Cidaris Forchammeri; Palæocoma Furstembergii.*

1. POLYPI; 2. FORAMINIFERA; 3. AMORPHOZOA.

1. *Cycollites elliptica; Thecosmilia rudis; Enallocœnia ramosa; Meandrina Pyrenaica; Synhelia Sharpeana*. 2. *Orbitoides media; Lituola nautiloidea; Flabellina rugosa*. 3. *Coscinopora cupuliformis; Camerospongia fungiformis*.

Among the numerous beings which inhabited the Upper Cretaceous seas there is one which, by its organisation, its proportions, and the despotic empire which it would exercise in the bosom of the waters, is certainly most worthy of our attention. We speak of the *Mosasaurus*, which was long known as the great animal of *Maestricht*, because its remains were found near that city in the most modern of the Cretaceous deposits.

In 1780 a discovery was made in the quarries of Saint Peter's Rocks, near Maestricht, of the head of a great Saurian, which may now be seen in the Museum of Natural History in Paris. This discovery baffled all the science of the naturalists, at a period when the knowledge of these [303] ancient beings was still in its infancy. One saw in it the head of a Crocodile; another, that of a Whale; memoirs and monographs rained down, without throwing much light on the subject. It required all the efforts of Adrian Camper, joined to those of the immortal Cuvier, to assign its true zoological place to the Maestricht animal. The controversy over this fine fossil engaged the attention of the learned for the remainder of the last century and far into the present.

Maestricht is a city of the Netherlands, built on the banks of the Meuse. At the gates of this city, in the hills which skirt the left or western bank of the river, there rises a solid mass of cretaceous formation known as Saint Peter's Rocks. In composition these beds correspond with the Meudon chalk beds, and they contain similar fossils. The quarries are about 100 feet deep, consisting in the upper part of twenty feet abounding in corals and Polyzoa, succeeded by fifty feet of soft yellowish limestone, furnishing a fine building stone, which has been quarried from time immemorial, and extends up to the environs of Liège; this is succeeded by a few inches of greenish soil with Encrinites, and then by a very white chalk with layers of flints. The quarry is filled with marine fossils, often of great size.

These fossil remains, naturally enough, attracted the attention of the curious, and led many to visit the quarries; but of all the discoveries which attracted attention the greatest interest attached to the gigantic animal under consideration. Among those interested by the discovery of these strange vestiges was an officer of the garrison of Maestricht, named Drouin. He purchased the bones of the workmen as the pick disengaged them from the rock, and concluded by forming a collection in Maestricht, which was spoken of with admiration. In 1766, the trustees of the British Museum, hearing of this curiosity, purchased it, and had it removed to London. Incited by the example of Drouin, Hoffmann, the surgeon of the garrison, set about forming a similar collection, and his collection soon exceeded that of Drouin's Museum in riches. It was in 1780 that he purchased of the quarrymen the magnificent fossil head, exceeding six feet in length, which has since so exercised the sagacity of naturalists.

Hoffman did not long enjoy the fruits of his precious prize, however; the chapter of the church of Maestricht claimed, with more or less foundation, certain rights of property; and in spite of all protest, the head of the *Crocodile of Maestricht*, as it was already called, passed into the hands of the Dean of the Chapter, named Goddin, who enjoyed the possession of his antediluvian trophy [304] until an unforeseen incident changed the aspect of things. This incident was nothing less than the bombardment and surrender of Maestricht to the Army of the North under Kleber, in 1794.

The Army of the North did not enter upon a campaign to obtain the crania of Crocodiles, but it had on its staff a savant who was devoted to such pacific conquests. Faujas de Saint-Fond, who was the predecessor of Cordier in the Zoological Chair of the Jardin des Plantes, was attached to the Army of the North as Scientific Commissioner; and it is suspected that, in soliciting this mission, our naturalist had in his eye the already famous head of the Crocodile of the Meuse. However that may be, Maestricht fell into the hands of the French, and Faujas eagerly claimed the famous fossil for the French nation, which was packed with the care due to a relic numbering so many thousands of ages, and dispatched to the Museum of Natural History in Paris. On its arrival, Faujas undertook a labour which, as he thought, was to cover him with glory. He commenced the publication of a work entitled "The Mountain of Saint Peter of Maestricht," describing all the fossil objects found in the Dutch quarry there, especially the *Great Animal* of Maestricht. He endeavoured to prove that this animal was a Crocodile.

Unfortunately for the glory of Faujas, a Dutch savant had devoted himself to the same study. Adrian Camper was the son of a great anatomist of Leyden, Pierre Camper, who had purchased of the heirs of the surgeon Hoffman some parts of the skeleton of the animal found in the quarry of Saint Peter. He had even published in the *Philosophical Transactions* of London, as early as 1786, a memoir, in which the animal is classed as a Whale. At the death of his father, Adrian Camper re-examined the skeleton, and in a work which Cuvier quotes with admiration, he fixed the ideas which were until then floating about. He proved that the bones belonged neither to a Fish, nor a Whale, nor to a Crocodile, but rather to a particular genus of Saurian Reptiles, or marine lizards, closely resembling in many important structural characters, existing Monitors and Iguanas, and peculiar to rocks of the Cretaceous period, both in Europe and America. Long before Faujas had finished the publication of his work on *La Montagne de Saint-Pierre* that of Adrian Camper had appeared, and totally changed the ideas of the world on this subject. It did not, however, hinder Faujas from continuing to call his animal the Crocodile of Maestricht. He even announced, some time after, that Adrian Camper was also of his opinion. "Nevertheless," says Cuvier, "it is as far from the Crocodile as it is from the Iguana; and these two animals differ as much from each other [305] in their teeth, bones, and viscera, as the ape differs from the cat, or the elephant from the horse."

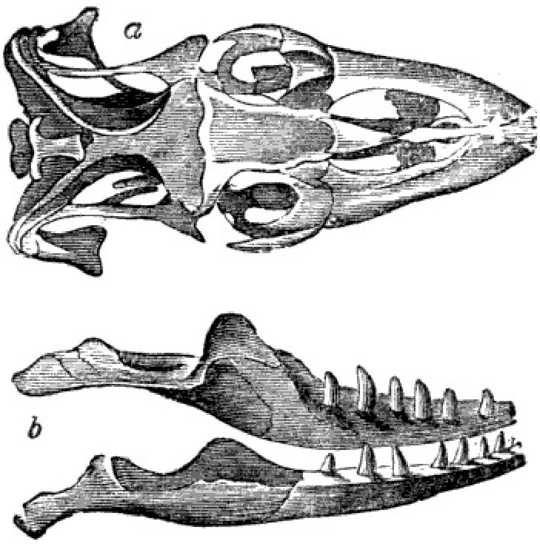


Fig. 145.
a, skull of Monitor Niloticus; *b*, under-jaw of same.

The masterly memoir of Cuvier, while confirming all the views of Camper, has restored the individuality of this surprising being, which has since received the name of Mosasaurus, that is to say, Saurian or Lizard of the Meuse. It appears, from the researches of Camper and Cuvier, that this reptile of the ancient world formed an intermediate genus between the group of the Lacertilia, which comprehends the Monitors (represented in Fig. 145), and the ordinary Lizards; and the Lacertilia, whose palates are armed with teeth, a group which embraces the *Iguana* and the *Anolis*. In respect to the Crocodiles, the Mosasaurus resembles them in so far as they all belong to the same class of Reptiles.

The idea of a lizard, adapted for living and moving with rapidity at the bottom of the water, is not readily conceived; but a careful study of the skeleton of the Mosasaurus reveals to us the secret of this anatomical mechanism. The vertebræ of the animal are concave in front and convex behind; they are attached by means of orbicular or arched articulations, which permitted it to execute easily movements of flexion in any direction. From the middle of the back to the extremity of the tail these vertebræ are deficient in the articular processes which support and strengthen the trunk of terrestrial vertebrated animals: they resemble in this respect the vertebræ of the Dolphins; an organisation necessary to render swimming easy. The tail, compressed laterally at the same time that it was thick in a vertical direction, constituted a straight rudder, short, solid, and of great power. An arched bone was firmly attached to the body of each caudal vertebra in the same manner as in Fishes, for the purpose of giving increased [306] power to the tail; finally, the extremities of the animal could scarcely be called feet, but rather paddles, like those of the Ichthyosaurus, the Plesiosaurus, and the Whale. We see in Fig. 146 that the jaws are armed with numerous teeth, fixed in their sockets by an osseous base, both large and solid. Moreover, an altogether peculiar dental system occupies the vault of the palate, as in the case of certain Serpents and Fishes, where the teeth are directed backwards, like the barb of a hook, thus opposing themselves to the escape of prey. Such a disposition of the teeth sufficiently proves the destructive character of this Saurian.

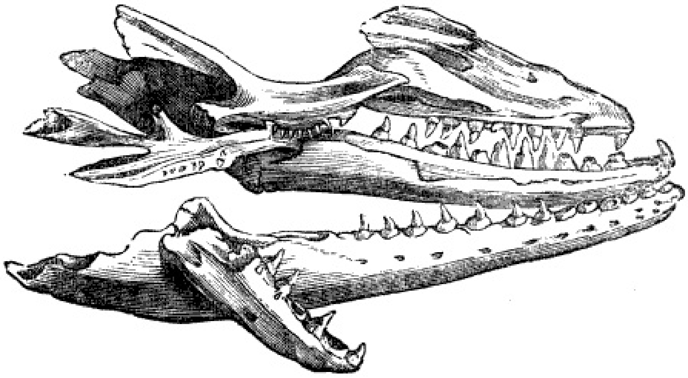
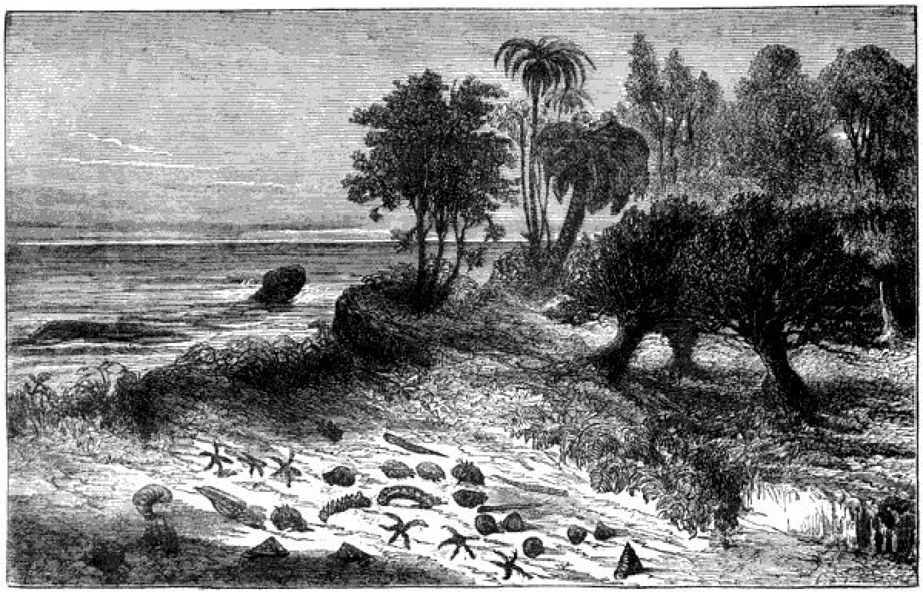


Fig. 146.—Head of Mosasaurus Camperi.

The dimensions of this aquatic lizard, estimated at twenty-four feet, are calculated to excite surprise. But, as we have already seen, the Ichthyosauri and Teleosauri were of great dimensions, as were also the Iguanodon and Megalosaurus, which were ten times the size of living Iguanas. In all these colossal forms we can only see a difference of dimensions, the aggrandisement of a type; the laws which affected the organisation of all these beings remain unchanged, they were not errors of Nature—*monstrosities*, as we are sometimes tempted to call them—but simply types, uniform in their structure, and adapted by their dimensions to the physical conditions with which God had surrounded them.

[307]



XXII.—Ideal Landscape of the Cretaceous Period.

In Plate XXII. is represented an ideal view of the earth during the *Upper Cretaceous* period. In the sea swims the Mosasaurus; Molluscs, Zoophytes, and other animals peculiar to the period are [309] seen on the shore. The vegetation seems to approach that of our days; it consists of Ferns and Cycadeæ (Pterophyllums), mingled with Palms, Willows, and some dicotyledons of species analogous to those of our present epoch. Algæ, then very abundant, composed the vegetation of the sea-shore.

We have said that the terrestrial flora of the Upper Cretaceous period was nearly identical with that of the Lower. The marine flora of these two epochs included some Algæ, Confervæ, and Naïadæ, among which may be noted the following species: *Confervites fasciculatus*, *Chondrites Mantelli*, *Sargassites Hynghianus*. Among the Naïadæ, *Zosterites Orbigniana*, *Z. lineata*, and several others.

The *Confervæ* are fossils which may be referred, but with some doubt, to the filamentous Algæ, which comprehend the great group of the Confervæ. These plants were formed of simple or branching filaments, diversely crossing each other; or subdivided, and presenting traces of transverse partitions.

The *Chondrites* are, perhaps, fossil Algæ, with thick, smooth branching fronds, pinnatifid, or divided into pairs, with smooth cylindrical divisions, and resembling *Chondrus*, *Dumontia*, and *Halymenia* among living genera.

The *Sargassites*, finally, have been vaguely referred to the genus *Sargassum*, so abundant in tropical seas. These Algæ are distinguished by a filiform, branched, or ramose stem, bearing foliaceous appendages, regular, often petiolate, and altogether like leaves, and globular vesicles, supported by a small stalk.

The rocks which actually represent the *Upper Cretaceous period* divide themselves naturally into six series; but British and French geologists make some distinction: the former dividing them into 1, *Maestricht* and *Faxoe* beds, said not to occur in England; 2, *White Chalk*, with *flints*; 3, *White Chalk*, without *flint*s; 4, *Chalk Marl*; 5, *Upper Greensand*; and 6, *Gault*. The latter four are divided by foreign geologists into 1, *Turonian*; 2, *Senonian*; 3, *Danian*.

The *Gault* is the lowest member of the Upper Cretaceous group. It consists of a bluish-black clay mixed with greensand, which underlies the Upper Greensand. Near Cambridge, where the Gault is about 200 feet thick, a layer of shells, bones, and nodules, called the "Coprolite Bed," from nine inches to a foot thick, represents the Upper Greensand, and rests on the top of the Gault Clay. These nodules and fossils are extensively worked on account of the phosphatic matter they contain, and when ground and converted into superphosphate of lime they furnish a very valuable agricultural manure. The Gault attains a thickness of about 100 feet on the south-east [310] coast of England. It extends into Devonshire, Mr. Sharpe considering the Black Down beds of that country as its equivalents. It shows itself in the Departments of the Pas-de-Calais, the Ardennes, the Meuse, the Aube, the Yonne, the Ain, the Calvados, and the Seine-Inférieure. It presents very many distinct mineral forms, among which two predominate: green sandstone and blackish or grey clays. It is important to know this formation, for it is at this level that the Artesian waters flow in the wells of Passy and Grenelle, near Paris.

The *glaucous* chalk, or Upper Greensand, which is represented typically in the departments of the Sarthe, of the Charente-Inférieure, of the Yonne and the Var, is composed of quartzose sand, clay, sandstone, and limestone. In this formation, at the mouth of the Charente, we find a remarkable bed, which has been described as a submarine forest. It consists of large trees with their branches imbedded horizontally in vegetable matter, containing kidney-shaped nodules of amber, or fossilised resin.

The *Turonian* beds are so named because the province of Touraine, between Saumur and Montrichard, possesses the best-developed type of this strata. The mineralogical composition of the beds is a fine and grey marly chalk, as at Vitry-le-François; of a pure white chalk, with a very fine grain, slightly argillaceous, and poor in fossils, in the Departments of the Yonne, the Aube, and the Seine-Inférieure; granular tufaceous chalk, white or yellowish, mixed with spangles of mica, and containing Ammonites, in Touraine and a part of the Department of the Sarthe; white, grey, yellow, or bluish limestone, inclosing Hippurites and Radiolites. In England the Lower Chalk passes also into Chalk Marl, with Ammonites, and then into beds known as the Upper Greensand, containing green particles of glauconite, mixed, in Hampshire and Surrey, with much calcareous matter. In the Isle of Wight this formation attains a thickness of 100 feet. The *Senonian* beds take their name from the ancient *Senones*. The city of Sens is in the centre of the best-characterised portion of this formation; Epernay, Meudon, Sens, Vendôme, Royau, Cognac, Saintes, are the typical regions of the formation in France. In the Paris basin, inclusive of the Tours beds, it attains a thickness of upwards of 1,500 feet, as was proved by the samples brought up, during the sinking of the Artesian well, at Grenelle, by the borings.

In its geographical distribution the Chalk has an immense range; fine Chalk of nearly similar aspect and composition being met with in all directions over hundreds of miles, alternating in its lower beds with layers of flints. In England the higher beds usually consist of a pure-white [311] calcareous mass, generally too soft for building-stone, but sometimes passing into a solid rock.

The *Danian* beds, which occupy the summit of the scale in the Cretaceous formation, are finely developed at Maestricht, on the Meuse; and in the Island of Zeeland, belonging to Denmark; where they are represented by a slightly yellowish, compact limestone, quarried for the construction of the city of Faxoe. It is slightly represented in the Paris basin at Meudon, and Laversines, in the Department of the Oise, by a white and often rubbly limestone known as *pisolitic limestone*. In this formation *Ammonites Danicus* is found. The yellowish sandy limestone of Maestricht is referred to the *Danian* type. Besides Molluscs, Polyps, and Polyzoa (Bryozoa), this limestone contains remains of Fishes, Turtles, and Crocodiles. But what has rendered this rock so celebrated was that it contained the remains of the *great animal of Mæstricht*, the Mæsasaurus.

At the close of the geological period, whose natural physiognomy we have thus traced, Europe was still far from displaying the configuration which it now presents. A map of the period would represent the great basin of Paris (with the exception of a zone of Chalk), the whole of Switzerland, the greater part of Spain and Italy, the whole of Belgium, Holland, Prussia, Hungary, Wallachia, and Northern Russia, as one vast sheet of water. A band of Jurassic rocks still connected France and England at Cherbourg—which disappeared at a later period, and caused the separation of the British Islands from what is now France.

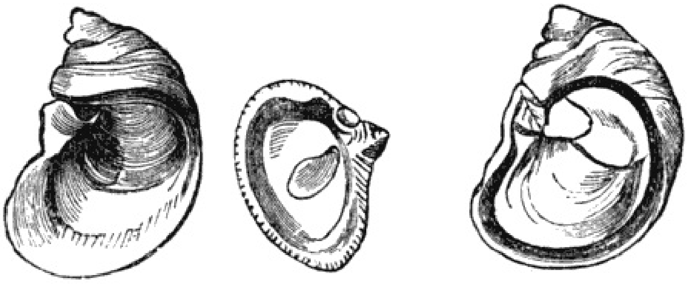


Fig. 147.—Exogym conica. Upper Greensand and Gault, from Blackdown Hill.

[54] "The Physical Geography and Geology of Great Britain," 2nd ed., p. 60.

[55] A. C. Ramsay, *Quart. Jour. Geol. Soc.*, vol. 27, p. 191.

[56] See A. C. Ramsay, "On the Physical Relations of the New Red Marl, Rhætic Beds, and Lower Lias," *Quart. Jour. Geol. Soc.*, vol. 27, p. 189.

[57] *Quart. Jour. Geol. Soc.*, vol. xx., p. 396.

[58] Ibid, vol. xvii., p. 483.

[59] Ibid, vol. xvi., p. 374.

[60] Ibid, vol. xx., p. 103.

[61] Lyell, "Elements of Geology," p. 413.

[62] De la Beche's "Geological Manual," 3rd ed., p. 447.

[63] "Geological Manual," by H. T. De la Beche, 3rd ed., p. 346.

[64] Professor Buckland on the Pterodactylus. "Trans. Geol. Soc.," 2nd series, vol. iii., p. 217.

[65] "Elements of Geology," p. 399.

[66] See Bristow in Descriptive Catalogue of Rocks, in *Mus. Pract. Geol.*, p. 134.

[67] President's Address, by Professor A. C. Ramsay. *Quart. Jour. Geol. Soc.*, 1864, vol. xx., p. 4.

[68] "Elements of Geology," p. 400.

[69] For a full account of the Ceteosaurus, see "The Geology of the Thames Valley," by Prof. John Phillips, F.R.S. 1871.

[70] "Elements of Geology," p. 393.

[71] For details respecting these strata the reader may consult, with advantage, the useful handbook to the geology of Weymouth and Portland, by Robert Damon.

[72] See Bristow and Whitaker "On the Chesil Bank," *Geol. Mag.*, vol. vi., p. 433.

[73] "Elements of Geology," p. 389.

[74] Ibid, p. 391.

[75] "Elements of Geology," p. 349.

[76] Ibid, p. 350.

[77] "The Physical Geology and Geography of Great Britain," by A. C. Ramsay, F.R.S., p. 64.

[78] Lyell's "Elements of Geology," p. 349.

[79] Ibid, p. 340.

[80] Lyell's "Elements of Geology," p. 333.

TERTIARY PERIOD.

A new organic creation makes its appearance in the Tertiary period; nearly all the animal life is changed, and what is most remarkable in this new development is the appearance, in larger numbers, of the great class of Mammifera.

During the Primary period, Crustaceans and Fishes predominated in the animal kingdom; in the Secondary period the earth was assigned to Reptiles; but during the Tertiary period the Mammals were kings of the earth; nor do these animals appear in small number, or at distant intervals of time; great numbers of these beings appear to have lived on the earth, and at the same moment; many of them being, so to say, unknown and undescribed.

If we except the Marsupials, the first created Mammals would appear to have been the Pachyderms, to which the Elephant belongs. This order of animals long held the first rank; it was almost the only representative of the Mammal during the first of the three periods which constitute the Tertiary epoch. In the second and third periods Mammals appear of species which have now become extinct, and which were alike curious from their enormous proportions, and from the singularity of their structure. Of the species which appeared during the latter part of the epoch, the greater number still exist. Among the new Reptiles, some Salamanders, as large as Crocodiles, and not very distinct from existing forms, are added to the animal creation during the three periods of the Tertiary epoch. Chelonians were abundant within the British area during the older epoch. During the same epoch Birds are present, but in much fewer numbers than the Mammalia; here songsters, there birds of prey, in other cases domestic—or, rather, some appear to wait the yoke and domestication from man, the future supreme lord of the earth.

The seas were inhabited by a considerable number of beings of all classes, and nearly as varied as those now living; but we no longer find in the Tertiary seas those Ammonites, Belemnites, and [313] Hippurites which peopled the seas and multiplied with such astonishing profusion during the Secondary period. Henceforth the testaceous Mollusca approximate in their forms to those of the present time. The older and newer Tertiary Series contain few peculiar genera. But genera now found in warmer climates were greatly developed within the British area during the earlier Tertiary times, and *species* of cold climates mark the close of the later Tertiaries.

What occurs to us, however, as most remarkable in the Tertiary epoch is the prodigious increase of animal life; it seems as if it had then attained its fullest extension. Swarms of testaceous Mollusca of microscopic proportions—Foraminifera and Nummulites—must have inhabited the seas, crowding together in ranks so serried that the agglomerated remains of their shells form, in some places, beds hundreds of feet thick. It is the most extraordinary display which has appeared in the whole range of creation.

Vegetation during the Tertiary period presents well-defined characteristics. The Tertiary flora approaches, and is sometimes nearly identical with, that of our days. The class of dicotyledons shows itself there in its fullest development; it is the epoch of flowers. The surface of the earth is embellished by the variegated colours of the flowers and fruits which succeed them. The white spikes of the Gramineæ display themselves upon the verdant meadows without limit; they seem provocative of the increase of Insects, which now singularly multiply. In the woods crowded with flowering trees, with rounded tops, like our oak and birch, Birds become more numerous. The atmosphere, purified and disembarrassed of the veil of vapour which has hitherto pervaded it, now permits animals with such delicate pulmonary organs to live and multiply their race.

During the Tertiary period the influence of the central heat may have ceased to make itself felt, in consequence of the increased thickness of the terrestrial crust. By the influence of the solar heat, climates would be developed in the various latitudes; the temperature of the earth would still be nearly that of our present tropics, and at this epoch, also, cold would begin to make itself felt at the poles.

Abundant rains would, however, continue to pour upon the earth enormous quantities of water, which would give rise to important rivers; new lacustrine deposits of fresh water were formed in great numbers; and rivers, by means of their alluvial deposits, began to form new land. It is, in short, during the Tertiary epoch that we trace an alternate succession of beds containing organic beings of marine origin, with others peculiar to fresh water. It is at the end of this period that continents and seas take their respective places as we now see them, and that the surface of the [314] earth received its present form.

The Tertiary epoch, or series, embraces three very distinct periods, to which the names of *Eocene*, *Miocene*, and *Pliocene* have been given by Sir Charles Lyell. The etymology of these names is derived—Eocene, from the Greek ηως, *dawn*, and καινος, *recent*; Miocene, from μειον, *less*, καινος, *recent*; and Pliocene, from πλειον, *more*, καινος, *recent*; by which it is simply meant to express, that each of these periods contains a minor or greater proportion of recent species (of Testacea), or is more or less remote from the dawn of life and from the present time;[81] the expressions are in one sense forced and incorrect, but usage has consecrated them, and they have obtained universal currency in geological language, from their convenience and utility.

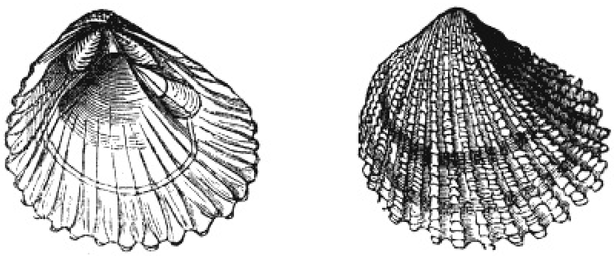


Fig. 148.—Trigonia margaritacea. (Living form.)

THE EOCENE PERIOD. [315]

During this period *terra firma* has vastly gained upon the domain of the sea; furrowed with streams and rivers, and here and there with great lakes and ponds, the landscape of this period presented the same curious mixture which we have noted in the preceding age, that is to say, a combination of the vegetation of the primitive ages with one analogous to that of our own times.

Alongside the birch, the walnut, the oak, the elm, and the alder, rise lofty palm-trees, of species now extinct, such as *Flabellaria* and *Palmacites*; with many evergreen trees (Conifers), for the most part belonging to genera still existing, as the *firs*, the *pines*, the *yews*, the *cypresses*, the *junipers*, and the *thuyas* or tree of life.

The *Cupanioides*, among the Sapindaceæ; the *Cucumites*, among the Cucurbitaceæ (species analogous to our bryony), climb the trunks of great trees, and hang in festoons of aerial garlands from their branches.

The Ferns were still represented by the genera *Pecopteris*, by the *Tæniopteris*, *Asplenium*, *Polypodium*. Of the mosses, some *Hepaticas* formed a humble but elegant and lively vegetation alongside the terrestrial and frequently ligneous plants which we have noted. *Equiseta* and *Charæ* would still grow in marshy places and on the borders of rivers and ponds.

It is not without some surprise that we observe here certain plants of our own epoch, which seem to have had the privilege of ornamenting the greater watercourses. Among these we may mention the Water Caltrop, *Trapa natans*, whose fine rosettes of green and dentated leaves float so gracefully in ornamental ponds, supported by their spindle-shaped petioles, its fruit a hard coriaceous nut, with four horny spines, known in France as *water-chestnuts*, which enclose a farinaceous grain not unpleasant to the taste; the pond-weed, *Potamogeton*, whose leaves form thick tufts of green, affording food and shelter to the fishes; *Nympheaceæ*, which spread beside their large round and hollow leaves, so admirably adapted for floating on the water, now the [316] deep-yellow flowers of the *Nenuphar* now the pure white flowers of the *Nymphæa*. Listen to Lecoq, as he describes the vegetation of the period:—“The Lower Tertiary period,” he says, “constantly reminds us of the tropical landscapes of the present epoch, in localities where water and heat together impress on vegetation a power and majesty unknown in our climates. The Algæ, which have already been observed in the marine waters at the close of the Cretaceous period, represented themselves under still more varied forms, in the earlier Tertiary deposits, when they have been formed in the sea. Hepaticas and Mosses grew in the more humid places; many pretty Ferns, as *Pecopteris*, *Tæniopteris*, and the *Equisetum stellare* (Pomel) vegetated in cool and humid places. The fresh waters are crowded with *Naiades*, *Chara*, *Potamogeton*, *Caulinites*, with *Zosterites*, and with *Halochloris*. Their leaves, floating or submerged, like those of our aquatic plants, concealed legions of Molluscs whose remains have also reached us.

“Great numbers of Conifers lived during this period. M. Brongniart enumerates forty-one different species, which, for the most part, remind us of living forms with which we are familiar—of Pines, Cypresses, Thuyas, Junipers, Firs, Yews, and Ephedra. Palms mingled with these groups of evergreen trees; the *Flabellaria Parisiensis* of Brongniart, *F. raphifolia* of Sternberg, *F. maxima* of Unger; and some *Palmacites*, raised their widely-spreading crowns near the magnificent *Hightea*; Malvaceæ, or *Mallows*, doubtless arborescent, as many among them, natives of very hot climates, are in our days.

“Creeping plants, such as the *Cucumites variabilis* (Brongn.), and the numerous species of *Cupanioïdes*—the one belonging to the Cucurbitaceæ, and the other to the Sapindaceæ—twined their slender stems round the trunks, doubtless ligneous, of various Leguminaceæ.

“The family of Betulaceæ of the order Cupuliferæ show the form, then new, of *Quercus*, the Oak; the Juglandeæ, and Ulmaceæ mingle with the Proteaceæ, now limited to the southern hemisphere. *Dermatophyllites*, preserved in amber, seem to have belonged to the family of the Ericineæ, and *Tropa Arcturæ* of Unger, of the group Œnothereæ, floated on the shallow waters in which grew the *Chara* and the *Potamogeton*.

“This numerous flora comprises more than 200 known species, of which 143 belonged to the Dicotyledons, thirty-three to the Monocotyledons, and thirty-three to the Cryptogams.

“Trees predominate here as in the preceding period, but the great numbers of aquatic plants of the period are quite in accordance with the geological facts, which show that the continents and [317] islands were intersected by extensive lakes and inland seas, while vast marine bays and arms of the sea penetrated deeply into the land.”

Fig. 149.—Branch of Eucalyptus restored.

It is moreover a peculiarity of this period that the whole of Europe comprehended a great number of those plants which are now confined to Australasia, and which give so strange an aspect to that country, which seems, in its vegetation, as in its animals, to have preserved in its warm latitudes the last vestiges of the organic creations peculiar to the primitive world. As a type of dicotyledonous trees of the epoch, we present here a restored branch of *Eucalyptus* (Fig. 149), with its flowers. All the family of the Proteaceæ, which comprehends the *Banksia*, the *Hakea*, the [318]
Gerilea protea, existed in Europe during the Tertiary period. The family of Mimosas, comprising the *Acacia* and *Inga*, which in our age are only natives of the southern hemisphere, abounded in Europe during the same geological period. A branch of *Banksia*, with its fructification, taken from impressions discovered in rocks of the period, is represented in Fig. 150—it is different from any [319]
species of Banksia living in our days.

Fig. 150.—Fruit-branch of Banksia restored.

Mammals, Birds, Reptiles, Fishes, Insects, and Molluscs, form the terrestrial fauna of the Eocene period. In the waters of the lakes, whose surfaces are deeply ploughed by the passage of large Pelicans, lived Molluscs of varied forms, as *Physa*, *Limnæa*, *Planorbis*; and Turtles swam about, as *Trionyx* and the *Emides*. Snipes made their retreat among the reeds which grew on the shore; sea-gulls skimmed the surface of the waters or ran upon the sands; owls hid themselves in the cavernous trunks of old trees; gigantic buzzards hovered in the air, watching for their prey; while heavy crocodiles slowly dragged their unwieldy bodies through the high marshy grasses. All these terrestrial animals have been discovered in England or in France, alongside the overthrown trunks of palm-trees. The temperature of these countries was then much higher than it is now. The Mammals which lived under the latitudes of Paris and London are only found now in the warmest countries of the globe.

The Pachyderms (from the Greek παχυς, *thick*, δερμα, *skin*) seem to have been amongst the earliest Mammals which appeared in the Eocene period, and they held the first rank from their importance in number of species as well as in size. Let us pause an instant over these Pachyderms. Their predominance over other fossil Mammals, which exceed considerably the number now living, is a fact much insisted on by Cuvier. Among them were a great number of intermediate forms, which we seek for in vain in existing genera. In fact, the Pachyderms are separated, in our days, by intervals of greater extent than we find in any other mammalian genera; and it is very curious to discover among the animals of the ancient world the broken link which connects the chain of these beings, which have for their great tomb the plaster-quarries of Paris, Montmartre and Pantin being their latest refuge.

Each block taken from those quarries encloses some fragment of a bone of these Mammals; and how many millions of these bones had been destroyed before attention was directed to the subject! The *Palæotherium* and the *Anoplotherium* were the first of these animals which Cuvier restored; and subsequent discoveries of other fragments of the same animals have only served to confirm what the genius of the great naturalist divined. His studies in the quarries of Montmartre gave the signal, as they became the model, for similar researches and restorations of the animals of the ancient world, all over Europe—researches which, in our age, have drawn geology from the [320] state of infancy in which it languished, in spite of the magnificent and persevering labours of Steno, Werner, Hutton, and Saussure.

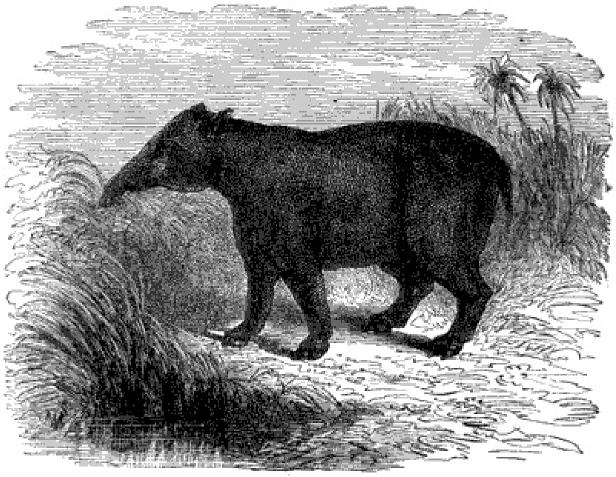


Fig. 151.—Palæotherium magnum restored.

The *Palæotherium*, *Anoplotherium*, and *Xiphodon* were herbivorous animals, which must have lived in great herds. They appear to have been intermediate, according to their organisation, between the Rhinoceros, the Horse, and the Tapir. There seem to have existed many species of them, of very different sizes. After the labours of Cuvier, nothing is easier than to represent the *Palæotherium* as it lived: the nose terminating in a muscular fleshy trunk, or rather snout, somewhat like that of the Tapir; the eye small, and displaying little intelligence; the head enormously large; the body squat, thick, and short; the legs short and very stout; the feet supported by three toes, enclosed in a hoof; the size, that of a large horse. Such was the great [321] Palæotherium, peaceful flocks of which must have inhabited the valleys of the plateau which surrounds the ancient basin of Paris; in the lacustrine formations of Orleans and Argenton; in the Tertiary formations of Issil and Puy-en-Velay, in the department of the Gironde; in the Tertiary formations near Rome; and in the beds of limestone[82] at the quarries of Binsted, in the Isle of Wight. Fig. 151 represents the great Palæotherium, after the design, in outline, given by Cuvier in his work on *fossil bones*.

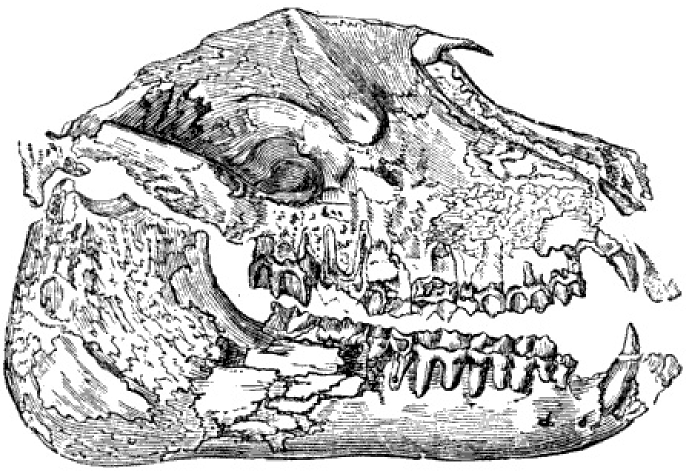


Fig. 152.—Skull of Palæotherium magnum.

The discovery and re-arrangement of these and other forms, now swept from the face of the globe, are the noblest triumphs of the great French zoologist, who gathered them, as we have

seen, from heaps of confused fragments, huddled together pell-mell, comprising the bones of a great many species of animals of a former age of the world, all unknown within the historic period. The generic characters of Palæotherium give them forty-four teeth, namely, twelve *molars*, two *canines*, and twenty-eight others, three toes, a short proboscis, for the attachment of which the bones of the nose were shortened, as represented in Fig. 153, leaving a deep notch below them. The molar teeth bear considerable resemblance to those of the Rhinoceros. In the structure of that part of the skull intended to support the short proboscis, and in the feet, the [322]
animal seems to have resembled the Tapir.

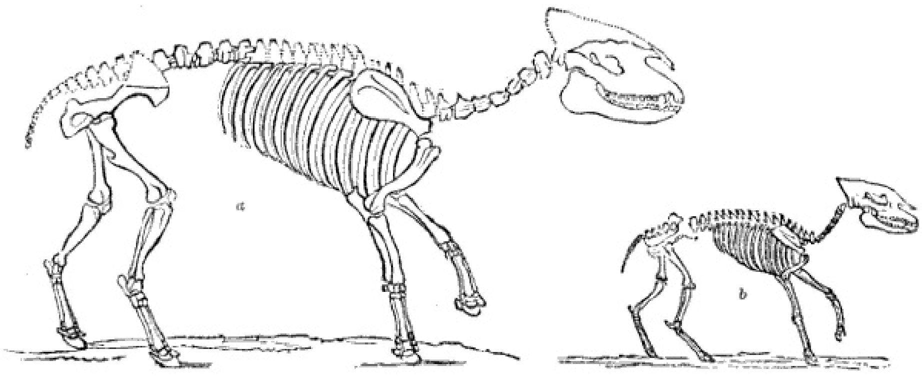


Fig. 153.—Skeletons of the Palæotherium magnum (*a*) and minimum (*b*) restored.

The geological place of the extinct Palæotherium seems to have been in the first great fresh-water formation of the Eocene period, where it is chiefly found with its allies, of which several species have been found and identified by Cuvier. Dr. Buckland is not singular in thinking that they lived and died on the margins of lakes and rivers, as the Rhinoceros and Tapir do now. He is also of opinion that some retired into the water to die, and that the dead carcases of others may have been drifted into the deeper parts in seasons of flood.

The *Palæotherium* varied greatly in size, some species being as large as the Rhinoceros, while others ranged between the size of the Horse and that of a Hog or a Roe. The smaller Palæotherium resembled the Tapir. Less in size than a Goat, with slim and light legs, it must have been very common in the north of France, where it would browse on the grass of the wild prairies. Another species, the *P. minimum*, scarcely exceeded the Hare in size, and it probably had all the lightness and agility of that animal. It lived among the bushy thickets of the environs of Paris, in Auvergne, and elsewhere.

All these animals lived upon seeds and fruits, on the green twigs, or subterranean stems, and the [323]
succulent roots of the plants of the period. They generally frequented the neighbourhood of fresh water.

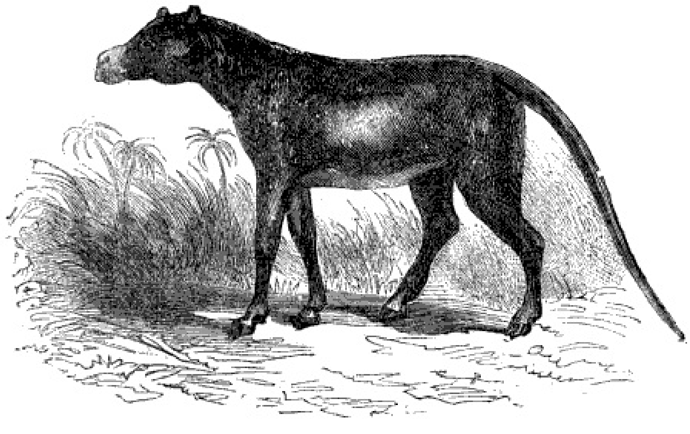


Fig. 154.—Anoplotherium commune. One-twentieth natural size.

The *Anoplotherium* (from ανοπλος, *defenceless*, θηριον, *animal*), had the posterior molar teeth analogous to those of the Rhinoceros, the feet terminating in two great toes, forming an equally divided hoof, like that of the Ox and other Ruminants, and the tarsus of the toes nearly like those of the Camel. It was about the size of the Ass; its head was light; but what would distinguish it most must have been an enormous tail of at least three feet in length, and very thick at its junction with the body. This tail evidently served it as a rudder and propeller when swimming in the lakes or rivers, which it frequented, not to seize fish (for it was strictly herbivorous), but in search of roots and stems of succulent aquatic plants. “Judging from its habits of swimming and diving,” says Cuvier, “the Anoplotherium would have the hair smooth, like the otter; perhaps its skin was even half naked. It is not likely either that it had long ears, which would be inconvenient in its aquatic kind of life; and I am inclined to think that, in this respect, it resembled the Hippopotamus and other quadrupeds which frequent the water much.” To this description Cuvier had nothing more to add. His memoir upon the *pachydermatous fossils* of Montmartre is accompanied by a design in outline of *Anoplotherium commune*, which has been closely followed in Fig. 154.

There were species of Anoplotherium of very small size. *A. leporinum* (or the Hare-Anoplotherium), whose feet are evidently adapted for speed; *A. minimum* and *A. obliquum* were of still smaller dimensions; the last, especially, scarcely exceeded the size of a rat. Like the Water-rats, this species inhabited the banks of brooks and small rivers. [324]

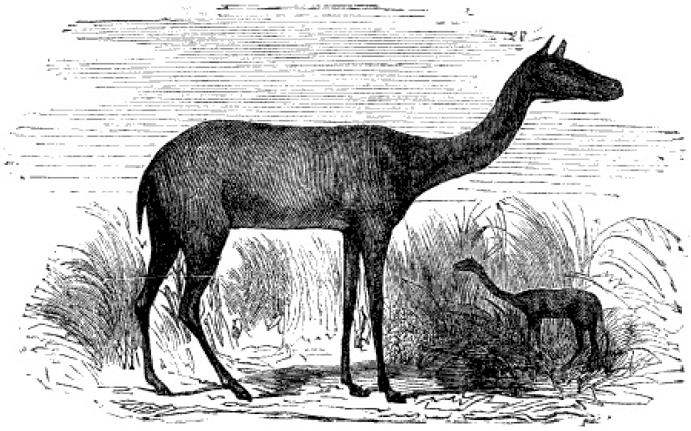


Fig. 155.—Xiphodon gracile.

The *Xiphodon* was about three feet in height at the withers, and generally about the size of the Chamois, but lighter in form, and with a smaller head. In proportion as the appearance of the *Anoplotherium commune* was heavy and sluggish, so was that of *Xiphodon gracile* graceful and active; light and agile as the Gazelle or the Goat, it would rapidly run round the marshes and ponds, depasturing on the aromatic herbs of the dry lands, or browsing on the sprouts of the young shrubs. "Its course," says Cuvier, in the memoir already quoted, "was not embarrassed by a long tail; but, like all active herbivorous animals, it was probably timid, and with large and very mobile ears, like those of the stag, announcing the slightest approach of danger. Neither is there any doubt that its body was covered with short smooth hair; and consequently we only require to know its colour in order to paint it as it formerly existed in this country, where it has been dug up after so many ages." Fig. 155 is a reproduction from the design in outline with which Cuvier accompanied the description of this animal, which he classes with the Anoplotherium, and which [325] has received in our days the name of *Xiphodon gracile*.

The gypsum-quarries of the environs of Paris include, moreover, the remains of other Pachyderms: the *Chæropotamus*, or River-hog (from χοιρος ποταμος), which has some analogy with the living Pecari, though much larger; the *Adapis*, which reminds us, in its form, of the Hedgehog, of which, however, it was three times the size. It seems to have been a link between the Pachyderms and the Insectivorous Carnivora. The *Lophiodon*, the size of which varied with the species, from that of the Rabbit to that of the Rhinoceros, was still more closely allied to the Tapir than to the Anoplotherium; it is found in the lower beds of the gypseous formation, that is to say in the "Calcaire Grossier."

A Parisian geologist, M. Desnoyers, librarian of the Museum of Natural History there, has discovered in the gypseous beds of the valley of Montmorency, and elsewhere in the neighbourhood of Paris, as at Pantin, Clichy, and Dammartin, the imprints of the footsteps of some Mammals, of which there seems to be some question, especially with regard to the Anoplotherium and Palæotherium. Footprints of Turtles, Birds, and even of Carnivora, sometimes accompany these curious traces, which have a sort of almond-shape more or less lobed, according to the divisions of the hoof of the animal, and which recall to mind completely, in their mode of production and preservation, those imprints of the steps of the Labyrinthodon which have been mentioned as occurring in rocks of the Triassic period. This discovery is interesting, as it furnishes a means of comparison between the imprints and the animals which have produced them. It brings into view, as it were, the material traces left in their walks upon the soil by animals now annihilated, but who once occupied the mysterious sites of an earlier world. (See Fig. 1, p. 12.)

It is interesting to picture in imagination the vast pasturages of the Tertiary period swarming with Herbivora of all sizes. The country now surrounding the city of Paris belongs to the period in question, and not far from its gates, the woods and plains were crowded with "game" of which the Parisian sportsman little dreams, but which would nevertheless singularly animate the earth at this distant epoch. The absence of great Carnivora explains the rapid increase of the agile and graceful denizens of the wood, whose race seems to have been so multiplied then, but which was ultimately annihilated by the ferocious beasts of prey which afterwards made their appearance.

The same novelty, riches, and variety which distinguished the Mammals of the Tertiary period extended to other classes of animals. The class of Birds, of which we can only name the most [326] remarkable, was represented by the curious fossil known as the "*Bird of Montmartre*." The bones of other birds have been obtained from Hordwell, as well as the remains of quadrupeds. Among the latter the *Hyænodon*, supposed to be the oldest known example of a true carnivorous animal in the series of British fossils, and the fossil Bat known as the *Vespertilio Parisiensis*. Among

Reptiles the Crocodile, which bears the name of Isle of Wight Alligator, *Crocodilus Toliapicus*. Among the Turtles the *Trionyx*, of which there is a fine specimen in the Museum of Natural History in Paris (Fig. 156).

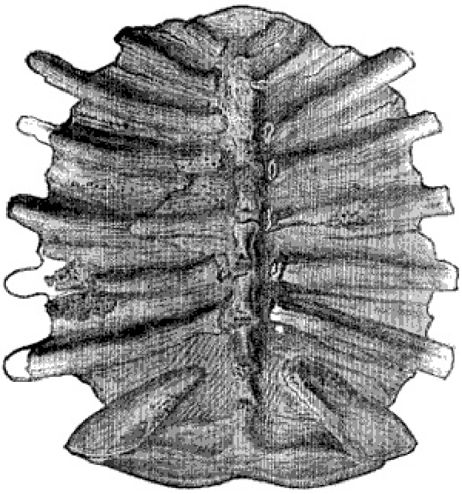
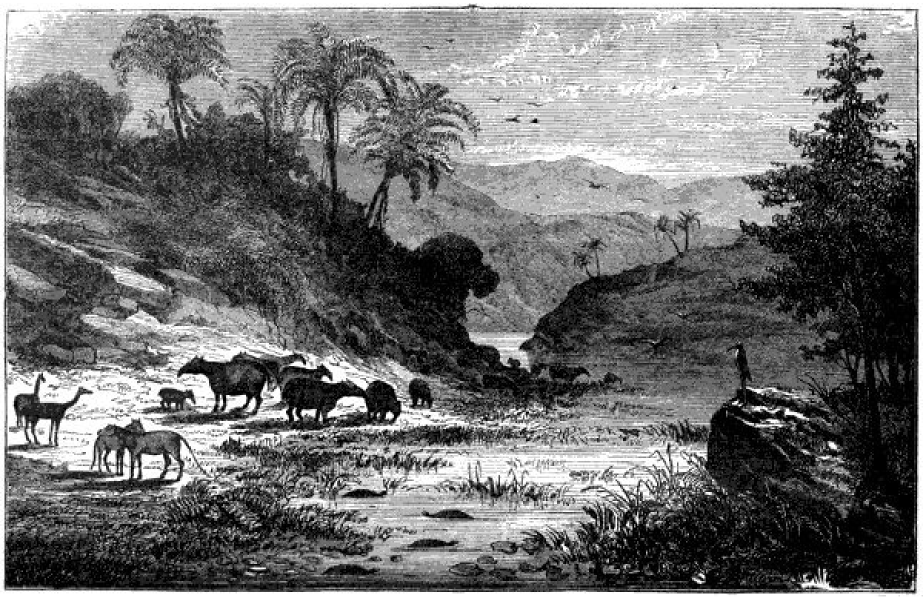


Fig. 156.—Trionyx, or Turtle, of the Tertiary period.

In the class Fishes we now see the *Pleuronectes*, or flat-fish, of which *Platax altissimus* and *Rhombus minimus* are well-known examples. Among the Crustaceans we see the earliest crabs. At the same time multitudes of new Mollusca make their appearance: *Oliva*, *Triton*, *Cassis*, *Harpa*, *Crepidula*, &c.

[328]



XXIII.—Ideal Landscape of the Eocene Period.

The hitherto unknown forms of *Schizaster* are remarkable among Echinoderms; the Zoophytes are also abundant, especially the *Foraminifera*, which seem to make up by their numbers for their deficiency in size. It was in this period, in the bosom of its seas, and far from shore, that the *Nummulites* existed, whose calcareous envelopes play such a considerable part as the elements of some of the Tertiary formations. The shelly agglomerates of these Protozoan Rhizopods constitute now very important rocks. The Nummulitic limestone forms, in the chain of the Pyrenees, entire mountains of great height; in Egypt it forms strata of considerable extent, and it is of these rocks that the ancient pyramids were built. What an enormous time must have been [329] necessary to convert the remains of these little shells into beds many hundreds of feet thick! The *Miliola* were also so abundant in the Eocene seas as to constitute the greater part of calcareous rocks[83] out of which Paris has been built. Agglomerated in this manner, these little shells form the continuous beds of limestone which are quarried for building purposes in the environs of Paris, at Gentilly, Vaugirard, and Châtillon.

On the opposite page we present, in Plate XXIII., an imaginary landscape of the Eocene period. We remark amongst its vegetation a mixture of fossil species with others belonging to the present time. The Alders, the Wych-elms, and the Cypresses, mingle with *Flabellaria*; the Palms of extinct species. A great Bird—a wader, the *Tantalus*—occupies the projecting point of a rock on the right; the Turtle (*Trionyx*), floats on the river, in the midst of Nymphæas, Nenuphars, and other aquatic plants; whilst a herd of Palæotheria, Anoplotheria, and Xiphodon peacefully browse the grass of the natural meadows of this peaceful oasis.

With a general resemblance in their fossils, nothing can be more dissimilar, on the whole, than the lithological or mineral characters of the Eocene deposits of France and England; “those of our own island,” says Lyell,[84] “being almost exclusively of mechanical origin—accumulations of mud, sand, and pebbles; while in the neighbourhood of Paris we find a great succession of strata composed of limestones, some of them siliceous, and of crystalline gypsum and siliceous sandstone, and sometimes of pure flint used for millstones. Hence it is by no means an easy task to institute an exact comparison between the various members of the English and French series. It is clear that, on the sites both of Paris and London, a continual change was going on in the fauna and flora by the coming in of new species and the dying out of others; and contemporaneous changes of geographical conditions were also in progress in consequence of the rising and sinking of the land and bottom of the sea. A particular subdivision, therefore, of time was occasionally represented in one area by land, in another by an estuary, in a third by sea; and even where the conditions were in both areas of a marine character, there was often shallow water in one, and deep sea in another, producing a want of agreement in the state of animal life.” [330]
The Eocene rocks, as developed in France and England, may be tabulated as follows, in descending order:—

	English.		French.
Upper Eocene.	Hempstead beds.	Fluvio-marine series.	Calcaire de la Beauce. Grès de Fontainebleau.
	Bembridge beds.		Calcaire silicieux or Calcaire Lacustre Moyen. Gypseous series of Montmartre.
Middle Eocene.	Osborne beds. Headon beds.		Grès de Beauchamp and Calcaire Marin.
	Upper Bagshot sand.		Upper Sables Moyens.
	Barton clay. Bracklesham beds.	Middle Bagshot.	Lower Sables Moyens, Lower Calcaire Grossier, and Glauconie Grossière.
	Lower Bagshot beds.		Lits coquillières. Glauconie Moyenne.
Lower Eocene.	London clay.		Wanting.
	Woolwich and Reading beds, or Plastic clay.		Argile Plastique. Glauconie Inférieure.
	Oldhaven beds.		
	Thanet sands.		Sables Inférieurs.

The Woolwich and Reading Beds, or the Plastic Clay of older writers, consists of extensive beds of sand with occasional beds of potter’s clay, which lie at the base of the Tertiary formation in both England and France. Generally variegated, sometimes grey or white, it is employed as a potter’s earth in the manufacture of delf-ware.

In England the red-mottled clay of the Woolwich and Reading Beds in Hampshire and the Isle of Wight is often seen in contact with the chalk; but in the south-eastern part of the London basin, Mr. Prestwich shows that the Thanet Sand (consisting of a base of fine, light-coloured sand, mixed with more or less argillaceous matter) intervenes between the Chalk and the Oldhaven Beds, or in their absence the Woolwich and Reading beds, which lie below the London Clay. The Thanet Sands derive their name from their occurrence in the Isle of Thanet, in Kent, in the eastern part of which county they attain their greatest development. Under London and its southern suburbs the Thanet sand is from thirteen to forty-four feet thick, but it becomes thinner [331]
in a westerly direction, and does not occur beyond Ealing.[85]

The Woolwich and Reading beds in the Hampshire basin rest immediately on the Chalk, and separate it from the overlying London Clay, as may be seen in the fine exposure of the Tertiary strata in Alum Bay, at the western extremity of the Isle of Wight, and in Studland Bay, on the western side of the Isle of Purbeck, in Dorsetshire.

In the London basin the Woolwich and Reading beds also rest on the Chalk, where the Thanet Sands are absent, as is the case, for the most part, over the area west of Ealing and Leatherhead.

The beds in question are very variable in character, but may be generally described as irregular alternations of clays and sands—the former mostly red, mottled with white, and from their plastic nature suitable for the purposes of the potter; the latter also of various colours, but sometimes pure white, and sometimes containing pebbles of flint.

The Woolwich and Reading beds are called after the localities of the same names; they are fifty feet thick at Woolwich, and from sixty to seventy feet at Reading.

The Oldhaven beds (so termed by Mr. W. Whitaker from their development at the place of the same name in Kent) are a local deposit, occurring beneath the London Clay on the south side of the London basin, from Croydon eastward, at the most eastern part of Surrey, and through Kent —in the north-western corner of which county they form some comparatively broad tracts. The beds consist of rounded flint pebbles, in a fine sandy base, or of fine light-coloured sand, and are from eighty to ninety feet thick under London.

The London Clay, which has a breadth of twenty miles or more about London, consists of tenacious brown and bluish-grey clay, with layers of the nodular concretions, called Septaria, which are well known on the Essex and Hampshire coasts, where they are collected for making Roman cement. The London Clay has a maximum thickness of nearly 500 feet. The fossils of the London Clay are of marine genera, and very plentiful in some districts. Taken altogether they seem to indicate a moderate, rather than a tropical climate, although the Flora is, as far as can be judged, certainly tropical in its affinities.[86] The number of species of extinct Turtles obtained from the Isle of Sheppey alone, is stated by Prof. Agassiz to exceed that of all the species of [332]
Chelone now known to exist throughout the globe. Above this great bed lie the Bracklesham and Bagshot beds, which consist of light-yellow sand with an intermediate layer of dark-green and brown clay, over which lie the Barton Clay (in the Hampshire basin) and the white Upper Bagshot Sands, which are succeeded by the Fluvio-marine series comprising the Headon, Bembridge, and Hempstead series, and consisting of limestones, clays, and marls, of marine, brackish, and fresh-water origin.[87] For fuller accounts of the Tertiary strata of England, the reader is recommended to the numerous excellent memoirs of Mr. Prestwich, to the memoir "On the Tertiary Fluvio-marine Formations of the Isle of Wight," by Professor Edward Forbes, and to the memoir "On the Geology of the London Basin," by Mr. W. Whitaker.

At the base of the *Argile Plastique* of France is a conglomerate of chalk and of divers calcareous substances, in which have been found at Bas-Meudon some remains of Reptiles, Turtles, Crocodiles, Mammals, and, more lately, those of a large Bird, exceeding the Ostrich in size, the *Gastornis*, which Professor Owen classes among the wading rather than among aquatic birds. In the Soissonnais there is found, at the same horizon, a great mass of lignite, enclosing some shells and bones of the most ancient Pachyderm yet discovered, the *Coryphodon*, which resembles at once both the Anoplotherium and the Pig. The *Sables Inférieurs*, or Bracheux Sands, form a marine bed of great thickness near Beauvais; they are principally sands, but include beds of calciferous clay and banks of shelly sandstone, and are considered to be older than the plastic clay and lignite, and to correspond with the Thanet Sands of England. They are rich in shells, including many Nummulites. At La Fère, in the Department of the Aisne, a fossil skull of *Arctocyon primævus*, supposed to be related both to the Bear and to the Kinkajou, and to be the oldest known Tertiary Mammal, was found in a deposit of this age. This series seems to have been formed chiefly in fresh water.

The *Calcaire grossier*, consisting of marine limestones of various kinds, and with a coarse, sometimes compact, grain, is suitable for mason-work. These deposits, which form the most characteristic member of the Paris basin, naturally divide themselves into three groups of strata, [333]
characterised, the first, by *Nummulites*; the second by *Miliolites*; and the third or upper beds by *Cerithia*. The beds are also sometimes named Nummulite limestone, Miliolite limestone, and Cerithium limestone. Above these a great mass, generally sandy, is developed. It is marine at the base, and there are indications of brackish water in its upper parts; it is called Beauchamp Sandstone, or Sables Moyens (*Grès de Beauchamp*). These sands are very rich in shells. The *siliceous limestone*, or lower travertin, is a compact siliceous limestone extending over a wide area, and resembles a precipitate from mineral waters. The *gypseous* formation consists of a long series of marly and argillaceous beds, of a greyish, green, or white colour, in the intervals between which a thick deposit of gypsum, or sulphate of lime, is intercalated. This gypsum bed is found in its greatest thickness in France at Montmartre and Pantin near Paris. The formation of this gypsum is probably due to the action of free sulphuric acid upon the carbonate of lime of the formation; the sulphuric acid itself being produced by the transformation of the gaseous masses of sulphuretted hydrogen emanating from volcanic vents, into that acid, by the action of air and water. It was, as we have already said, in the gypsum-quarries of Montmartre that the numerous bones of Palæotherium and Anoplotherium were found. It is exclusively at this horizon that we find the remains of these animals, which seem to have been preceded by the *Coryphodon*, and afterwards by the *Lophiodon*; the order of succession in the appearance of these animals is now perfectly established. It may be added that round Paris the Eocene formation, from its lowest beds to the highest, is composed of beds of plastic clay, of the *Calcaire grossier* with its *Nummulites*, *Miliolites*, and *Alveolites*, followed by the gypseous formation; the series terminating in the Fontainebleau Sandstone, remarkable for its thickness and also for its fine scenery, as well as for its usefulness in furnishing paving-stone for the capital. In Provence the same series of rocks are continued, and attain an enormous thickness. This upper part of the Eocene deposit is entirely of lacustrine formation. Grignon has procured from a single spot, where they were embedded in a calcareous sand, no less than 400 fossils, chiefly formed of comminuted shells, in which, however, were well-preserved species both of marine, terrestrial, and fresh-water shells. Of the Paris basin, Sir Charles Lyell says: "Nothing is more striking in this assemblage of fossil testacea than the great proportion of species referable to the genus *Cerithium*. There occur no less than 137 species of this genus in the Paris basin, and almost all of [334]
them in the *Calcaire grossier*. Most of the living *Cerithia* (Figs. 157 and 168) inhabit the sea near the mouths of rivers, where the waters are brackish; so that their abundance in the marine strata now under consideration is in harmony with the hypothesis that the Paris basin formed a gulf into which several rivers flowed."[88]

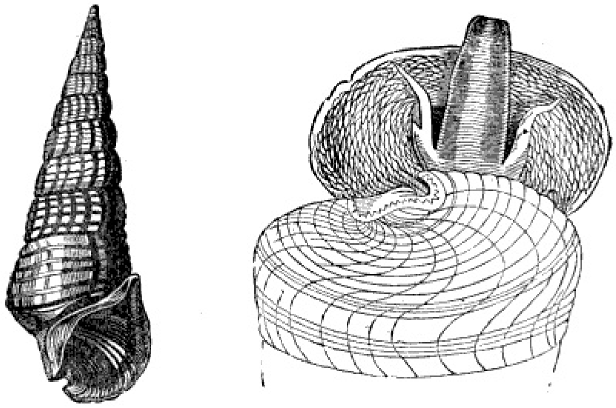


Fig. 157.—Cerithium telescopium.
(Living form.)

To give the reader some idea of the formation, first come the limestones and lower marls, which contain fine lignite or wood-coal produced from vegetable matter buried in moist earth, and excluded from all access of air, a material which is worked in some parts of the south of France as actively as a coal-mine. In these lignites *Anodon* and other fresh-water shells are found.

From the base of Sainte-Victoire to the other side of Aix, we trace a conglomerate characterised by its red colour, but which dies away in its prolongation westward. This conglomerate contains land-snails (*Helix*) of various sizes, mixed with fresh-water shells. Upon this conglomerate, comprising therein the marls, rests a thick deposit of limestone with the gypsum of Aix and Manosque, which is believed to correspond with that of Paris. Some of the beds are remarkably rich in sulphur. The calcareous marly laminæ which accompany the gypsum of Aix contain Insects of various kinds, and Fishes resembling *Lebias cephalotes*. Finally, the whole terminates at Manosque in a fresh series of marls and sandstones, alternating with beds of limestone with *Limnæa* and *Planorbis*. At the base of this series are found three or four beds of lignite more inflammable than coal, which also give out a very sulphurous oil. We may form some estimate of the thickness of this last stage, if we add that, above the beds of fusible lignite, we may reckon sixty others of dry lignite, some of them capable of being very profitably worked if this part of Provence were provided with more convenient roads.

“The Nummulitic formation, with its characteristic fossils,” says Lyell,[89] “plays a far more conspicuous part than any other Tertiary group in the solid framework of the earth’s crust, whether in Europe, Asia, or Africa. It often attains a thickness of many thousand feet, and extends from the Alps to the Carpathians, and is in full force in the north of Africa, as, for example, in Algeria and Morocco. It has been traced from Egypt, where it was largely quarried of old for the building of the Pyramids, into Asia Minor, and across Persia, by Bagdad, to the mouth of the Indus. It occurs not only in Cutch, but in the mountain ranges which separate Scinde from Persia, and which form the passes leading to Caboul; and it has been followed still further [335]
eastward into India, as far as eastern Bengal and the frontiers of China.”

“When we have once arrived at the conclusion,” he adds, “that the Nummulitic formation occupies a middle place in the Eocene series, we are struck with the comparatively modern date to which some of the greatest revolutions in the physical geography of Europe, Asia, and northern Africa must be referred. All the mountain chains, such as the Alps, Pyrenees, Carpathians, and Himalayas, into the composition of whose central and loftiest parts the Nummulitic strata enter bodily, could have had no existence till after the Middle Eocene period.”

The Eocene strata, Professor Ramsay thinks, extended in their day *much further* west, “because,” he says, “here, at the extreme edge of the chalk escarpments, you find outlying fragments of them,” from which he argues that they were originally deposited all over the Chalk as far as these points, but being formed of soft strata they were “denuded” backwards.

The Beloptera represented in Fig. 195 are curious Belemnite-like organisms, occurring in Tertiary strata, and evidently the internal bone of a Cephalopod, having a wing-like projection or process on each side. As a genus it holds a place intermediate between the Cuttle-fish and the Belemnite.

THE MIOCENE PERIOD. [336]

The Miocene formation is not present in England; unless we suppose, with Sir Charles Lyell, that it is represented by the Hempstead beds of the Isle of Wight.

It is on the European continent that we find the most striking characteristics of the Miocene period. In our own islands traces of it are few and far between. In the Island of Mull certain beds of shale, interstratified with basalt and volcanic ash, are described by the Duke of Argyll as of Miocene date;[90] and Miocene clay is found interstratified with bands of imperfect coal at Bovey Tracey. The vegetation which distinguished the period is a mixture of the vegetable forms peculiar to the burning climate of the present tropical Africa, with such as now grow in temperate Europe, such as Palms, Bamboos, various kinds of Laurels, Combretaceæ (Terminalia), with the grand Leguminales of warm countries (as *Phaseolites*, *Erythrina*, *Bauhinia*, *Mimosites*, *Acacia*); Apocyneæ analogous to the genera of our tropical regions; a *Rubiacea* altogether tropical (*Steinhauera*) mingle with some Maples, Walnut-trees, Beeches, Elms, Oaks, and Wych-elms, genera now confined to temperate and even cold countries.

Besides these, there were, during the Miocene period, mosses, mushrooms, charas, fig-trees, plane-trees, poplars, and evergreens. "During the second period of the Tertiary epoch," says Lecoq, "the Algæ and marine Monocotyledons were less abundant than in the preceding age; the Ferns also diminished, the mass of Conifers were reduced, and the Palms multiplied in species. Some of those cited in the preceding period seem still to belong to this, and the magnificent *Flabellaria*, with the fine *Phœnicites*, which we see now for the first time, gave animation to the landscape. Among the Conifers some new genera appear; among them we distinguish *Podocarpens*, a southern form of vegetation of the present age. Almost all the arborescent families have their representatives in the forests of this period, where for the first time types so [337] different are united. The waters are covered with *Nymphæa Arithnæa* (Brongniart); and with *Myriophyllites capillifolius* (Unger); *Culmites animalis* (Brongniart); and *C. Gœpperti* (Munster), spring up in profusion upon their banks, and the grand *Bambusinites sepultana* throws the shadow of its long articulated stem across them. Some analogous species occupy the banks of the great rivers of the New World; one Umbellifera is even indicated, by Unger, in the *Pimpinellites zizioides*.

Of this period date some beds of lignite resulting from the accumulation, for ages, of all these different trees. It seems that arborescent vegetation had then attained its apogee. Some *Smilacites* interlaced like the wild vines with these grand plants, which fell on the ground where they grew, from decay; some parts of the earth, even now, exhibit these grand scenes of vegetation. They have been described by travellers who have traversed the tropical regions, where Nature often displays the utmost luxury, under the screen of clouds which does not allow the rays of the sun to reach the earth. M. D'Orbigny cites an interesting instance which is much to the point. "I have reached a zone," he says (speaking of Rio Chapura in South America), "where it rains regularly all the year round. We can scarcely perceive the rays of the sun, at intervals, through the screen of clouds which almost constantly veils it. This circumstance, added to the heat, gives an extraordinary development to the vegetation. The wild vines fall on all sides, in garlands, from the loftiest branches of trees whose summits are lost in the clouds."

The fossil species of this period, to the number of 133, begin to resemble those which enrich our landscapes. Already tropical plants are associated with the vegetables of temperate climates; but they are not yet the same as existing species. Oaks grow side by side with Palms, the Birch with Bamboos, Elms with Laurels, the Maples are united to the Combretaceæ, to the Leguminales, and to the tropical Rubiaceæ. The forms of the species, belonging to temperate climates, are rather American than European.

The luxuriance and diversity of the Miocene flora has been employed by a German savant in identifying and classifying the Middle Tertiary or Miocene strata of Switzerland. We are indebted to Professor Heer, of Zurich, for the restoration of more than 900 species of plants, which he classified and illustrated in his "Flora Tertiaria Helvetiæ." In order to appreciate the value of the learned Professor's undertaking, it is only necessary to remark that, where Cuvier had to study the position and character of a bone, the botanist had to study the outline, nervation, and [338] microscopic structure of a leaf. Like the great French naturalist, he had to construct a new science at the very outset of his great work.

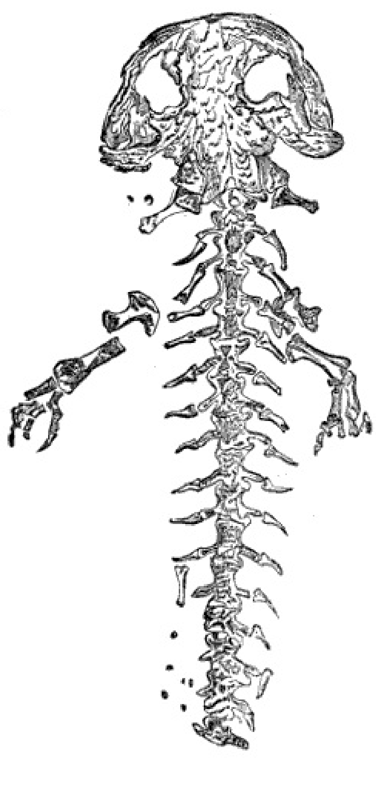


Fig. 158.—Andrias Scheuchzeri.

The Miocene formations of Switzerland are called *Molasse* (from the French *mol*, soft), a term which is applied to a *soft*, incoherent, greenish sandstone, occupying the country between the Alps and the Jura, and they may be divided into lower, middle, and upper Miocene; the middle one is marine, the other two being fresh-water formations. The upper fresh-water Molasse is best seen at Œningen, in the Rhine valley, where, according to Sir Roderick Murchison, it ranges ten miles east and west from Berlingen, on the right bank, to Waugen and to Œningen, near Stein, on the left bank. In this formation Professor Heer enumerates twenty-one beds. No. 1, a bluish-grey marl seven feet thick, without organic remains, resting on No. 2, limestone, with fossil plants, including leaves of poplar, cinnamon, and pond-weed (*Potamogeton*). No. 3, bituminous rock, with *Mastodon angustidens*. No. 5, two or three inches thick, containing fossil Fishes. No. 9, the stone in which the skeleton of the great Salamander *Andrias Scheuchzeri* (Fig. 158) was found. Below this, other strata with Fishes, Tortoises, the great Salamander, as before, with fresh-water Mussels, and plants. In No. 16, Sir R. Murchison obtained the fossil fox of Œningen, *Galacynus Œningensis* (Owen). In these beds Professor Heer had, as early as 1859, determined 475 species [339] of fossil plants, and 900 insects.

The plants of the Swiss Miocene period have been obtained from a country not one-fifth the size of Switzerland, yet such an abundance of species, which Heer reckons at 3,000, does not exist in any area of equal extent in Europe. It exceeds in variety, he considers, after making every allowance for all not having existed at the same time, and from other considerations, the Southern American forests, and rivals such tropical countries as Jamaica and Brazil. European plants occupy a secondary place, while the evergreen Oaks, Maples, Poplars, and Plane-trees, Robinias, and Taxodiums of America and the smaller Atlantic islands, occupy such an important place in the fossil flora that Unger was induced to suggest the hypothesis, that, in the Miocene period the present basin of the Atlantic was dry land—and this hypothesis has been ably advocated by Heer.

The terrestrial animals which lived in the Miocene period were Mammals, Birds, and Reptiles. Many new Mammals had appeared since the preceding period; among others, Apes, Cheiropteras (Bats), Carnivora, Marsupials, Rodents, Dogs. Among the first we find *Pithecus antiquus* and *Mesopithecus*; the Bats, Dogs, and Coati inhabited Brazil and Guiana; the Rats North America; the Genettes, the Marmots, the Squirrels, and Opossums having some affinity to the Opossums of America. Thrushes, Sparrows, Storks, Flamingoes, and Crows, represent the class Birds. Among the Reptiles appear several Snakes, Frogs, and Salamanders. The lakes and rivers were inhabited by Perches and Shad. But it is among the Mammals that we must seek for the most interesting species of animals of this period. They are both numerous and remarkable for their dimensions and peculiarities of form; but the species which appeared in the Miocene period, as in those which preceded it, are now only known by their fossil remains and bones.

The *Dinotherium* (Fig. 159), one of the most remarkable of these animals, is the largest terrestrial Mammal which has ever lived. For a long time we possessed only very imperfect portions of the skeleton of this animal, upon the evidence of which Cuvier was induced erroneously to place it among the Tapirs. The discovery of a lower jaw, nearly perfect, armed with defensive tusks descending from its lower jaw, demonstrated that this hitherto mysterious animal was the type of an altogether new and singular genus. Nevertheless, as it was known that there were some animals of the ancient world in which both jaws were armed, it was thought for some time that such was the case with the Dinotherium. But in 1836, a head, nearly entire, was [340] found in the already celebrated beds at Eppelsheim, in the Grand Duchy of Hesse Darmstadt. In 1837 this fine fragment was carried to Paris, and exposed to public view. It was nearly a yard and a half long, and above a yard wide. The defences, it was found, were enormous, and were carried at the anterior extremity of the lower maxillary bone, and much curved inwards, as in the Morse. The molar teeth were in many respects analogous to those of the Tapir, and the great suborbital apertures, joined to the form of the nasal bone, rendered the existence of a proboscis or trunk very probable. But the most remarkable bone belonging to the Dinotherium which has yet been found is an omoplate or scapula, which by its form reminds us of that of the Mole.

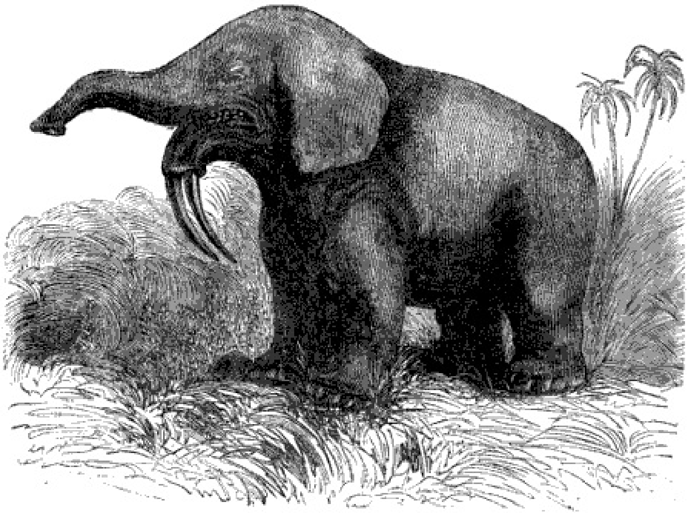


Fig. 159.—Dinotherium.

This colossus of the ancient world, respecting which there has been so much argument, somewhat approaches the Mastodon; it seems to announce the appearance of the Elephant; but [341] its dimensions were infinitely greater than those of existing Elephants, and superior even to those of the Mastodon and of the Mammoth, both fossil Elephants, the remains of which we shall have to describe presently.

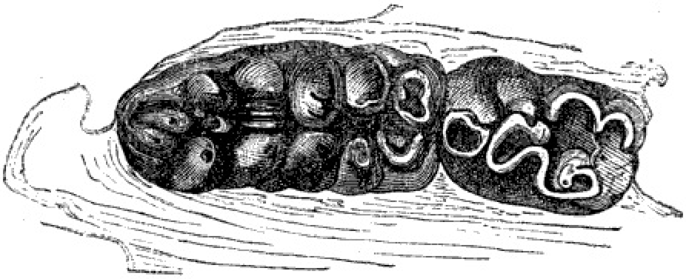


Fig. 160.—Teeth of Mastodon.

From its kind of life, and its frugal regimen, this Pachyderm scarcely merited the formidable name of Dinotherium which has been bestowed on it by naturalists (from δεινος, *terrible*, θηριον, *animal*). Its size was, no doubt, frightful enough, but its habits seem to have been peaceful. It is supposed to have inhabited fresh-water lakes, or the mouths of great rivers and the marshes bordering their banks by preference. Herbivorous, like the Elephant, it employed its proboscis probably in seizing the plants which hung suspended over the waters, or floated on their surface. We know that the elephants are very partial to the roots of herbaceous plants which grow in flooded plains. The Dinotherium appears to have been organised to satisfy the same tastes. With the powerful natural mattock which Nature had supplied him for penetrating the soil, he would be able to tear from the bed of the river, or lake, feculent roots like those of the Nymphæa, or even much harder ones, for which the mode of articulation of the jaws, and the powerful muscles intended to move them, as well as the large surface of the teeth, so well calculated for grinding, were evidently intended (Fig. 160).

The *Mastodon* was, to all appearance, very nearly of the size and form of our Elephant—his body, however, being somewhat longer, while his limbs, on the contrary, were a little thicker. He had tusks, and very probably a trunk, and is chiefly distinguished from the existing Elephant by the [342] form of his molar teeth, which form the most distinctive character in his organisation. These teeth are nearly rectangular, and present on the surface of their crown great conical tuberosities, with rounded points disposed in pairs to the number of four or five, according to the species. Their form is very distinct, and may be easily recognised. They do not bear any resemblance to those of the carnivora, but are like those of herbivorous animals, and particularly those of the Hippopotamus. The molar teeth are at first sharp and pointed, but when the conical points are ground down by mastication, they assume the appearance presented in Fig. 161. When, from continued grinding, the conical teat-like points are more deeply worn, they begin to assume the appearance shown in Fig. 160. In Fig. 162 we represent the head and lower jaw of the Miocene Mastodon; from which it will appear that the animal had two projecting tusks in the lower jaw, corresponding with two of much larger dimensions which projected from the upper jaw.

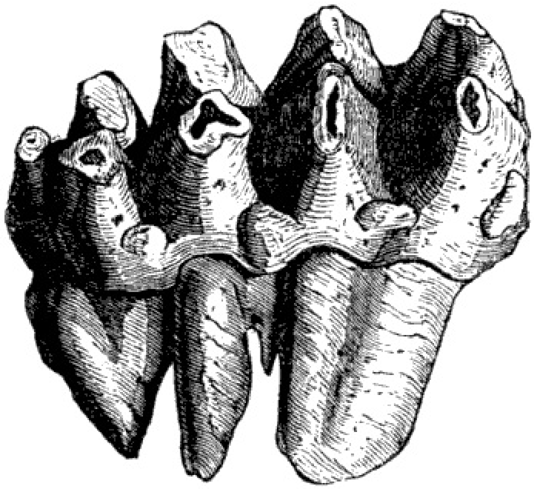


Fig. 161.—Molar teeth of Mastodon, worn.

It was only towards the middle of the last century that the Mastodon first attracted attention in Europe. About the year 1705, it is true, some bones of this animal had been found at Albany, now the capital of New York, but the discovery attracted little attention. In 1739, a French officer, M. de Longueil, traversed the virgin forests bordering the great river Ohio, in order to reach the great river Mississippi, and the savages who escorted him accidentally discovered on the borders of a marsh various bones, some of which seemed to be those of unknown animals. In this turfy marsh, which the natives designated the Great Salt Lake, in consequence of the many streams charged with salt which lose themselves in it, herds of wild ruminants still seek its banks, attracted by the salt—for which they have a great fondness—such being the reason probably which had caused the accumulation, at this point, of the remains of so large a number of quadrupeds belonging to these remote ages in the history of the globe. M. de Longueil carried some of these bones with him, and, on his return to France, he presented them to Daubenton and Buffon; they consisted of a femur, one extremity of a tusk, and three molar teeth. Daubenton, after mature examination, declared the teeth to be those of a Hippopotamus; the tusk and the [343] gigantic femur, according to his report, belonged to an Elephant; so that they were not even considered to be parts of one and the same animal. Buffon did not share this opinion, and he was not long in converting Daubenton, as well as other French naturalists, to his views. Buffon declared that the bones belonged to an Elephant, whose race had lived only in the primitive ages of the globe. It was then, only, that the fundamental notion of extinct species of animals, exclusively peculiar to ancient ages of the world, began to be entertained for the first time by naturalists—a notion which laid dormant during nearly a century, before it bore the admirable fruits which have since so enriched the natural sciences and philosophy.

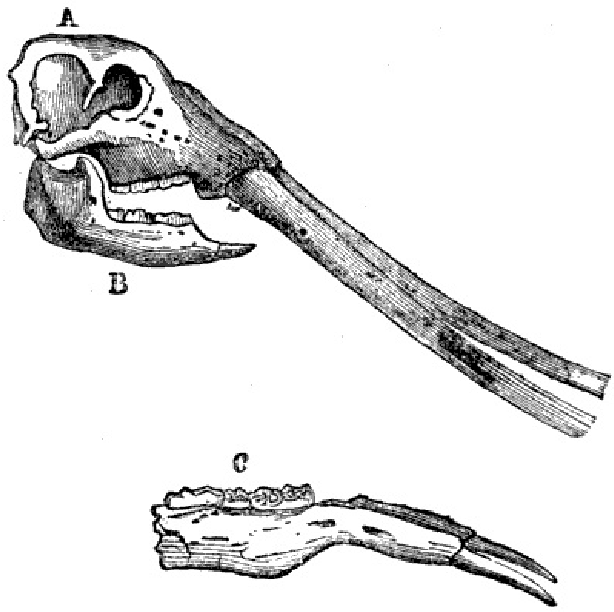


Fig. 162.—Head of the Mastodon of the Miocene period.
A, B, the whole head; C, lower jaw.

Buffon gave the fossil the name of the *Animal or Elephant of the Ohio*, but he deceived himself as to its size, believing it to be from six to eight times the size of our existing Elephant; an estimate which he was led to make by an erroneous notion with regard to the number of the Elephant's teeth. The *Animal of the Ohio* had only four molars, while Buffon imagined that it might have as many as sixteen, confounding the germs, or supplementary teeth, which exist in the young animal, with the permanent teeth of the adult individual. In reality, however, the Mastodon was not much larger than the existing species of African Elephant.

The discovery of this animal had produced a great impression in Europe. Becoming masters of Canada by the peace of 1763, the English sought eagerly for more of these precious remains. The geographer Croghan traversed anew the region of the Great Salt Lake, pointed out by De Longueil, and found there some bones of the same nature. In 1767 he forwarded many cases to London, addressing them to divers naturalists. Collinson, among others, the friend and correspondent of Franklin, who had his share in this consignment, took the opportunity of sending a molar tooth to Buffon. [344]

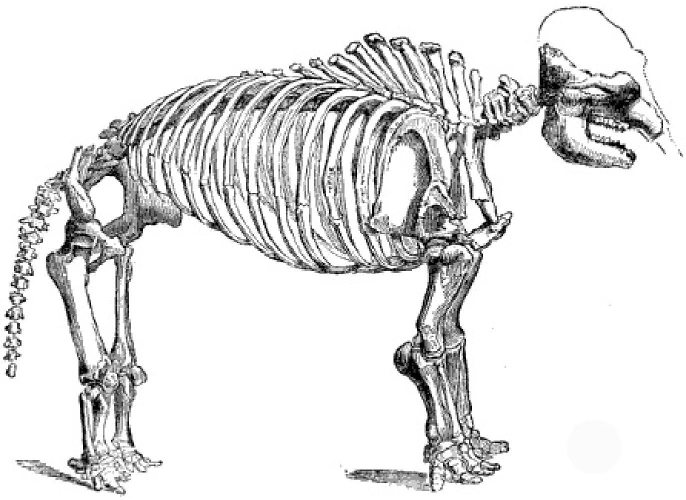


Fig. 163.—Skeleton of Mastodon giganteus.

It was not, however, till 1801 that the remains of the perfect skeleton were discovered. An American naturalist, named Peale, was fortunate enough to get together two nearly complete skeletons of this important animal. Having been apprised that many large bones had been found in the marly clay on the banks of the Hudson, near Newburg, in the State of New York, Mr. Peale proceeded to that locality. In the spring of 1801 a considerable part of one skeleton was found by the farmer who had dug it out of the ground, but, unfortunately, it was much mutilated by his awkwardness, and by the precipitancy of the workmen. Having purchased these fragments, Mr. Peale sent them on to Philadelphia. [345]

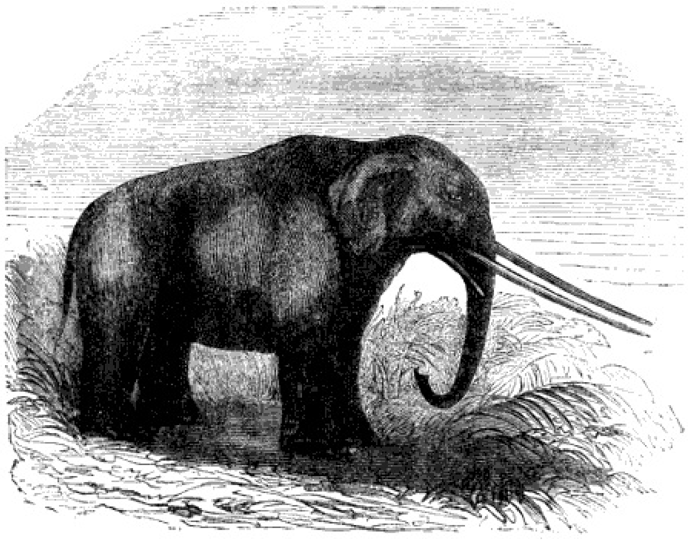


Fig. 164.—Mastodon restored.

In a marsh, situated five leagues west of the Hudson, the same gentleman discovered, six months after, a second skeleton of the Mastodon, consisting of a perfect jaw and a great number of bones. With the bones thus collected, the naturalist managed to construct two nearly complete skeletons. One of these still remains in the Museum of Philadelphia; the other was sent to London, where it was exhibited publicly. [346]

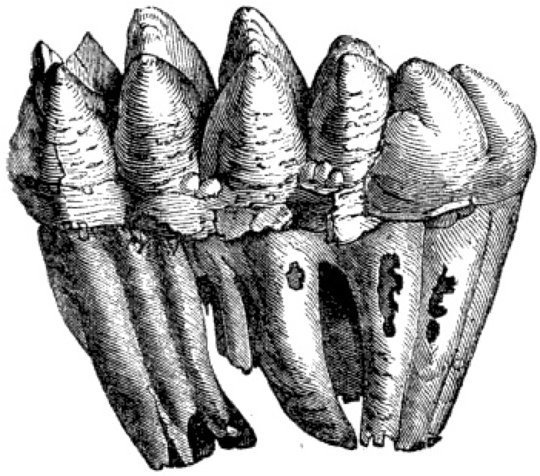


Fig. 165.—Molar tooth of Mastodon.

Discoveries nearly analogous to these followed, the most curious of which was made in this manner by Mr. Barton, a Professor of the University of Pennsylvania. At a depth of six feet in the ground, and under a great bank of chalk, bones of the Mastodon were found sufficient to form a skeleton. One of the teeth found weighed about seventeen pounds (Fig. 165); but the circumstance which made this discovery the more remarkable was, that in the middle of the bones, and enveloped in a kind of sac which was probably the stomach of the animal, a mass of vegetable matter was discovered, partly bruised, and composed of small leaves and branches, among which a species of rush has been recognised which is yet common in Virginia. We cannot doubt that these were the undigested remains of the food, which the animal had browsed on just before its death.

The aboriginal natives of North America called the Mastodon the *father of the ox*. A French officer named Fabri wrote thus to Buffon in 1748. The natives of Canada and Louisiana, where these remains are abundant, speak of the Mastodon as a fantastic creature which mingles in all their traditions and in their ancient national songs. Here is one of these songs, which Fabri heard in Canada: “When the great *Manitou* descended to the earth, in order to satisfy himself that the creatures he had created were happy, he interrogated all the animals. The bison replied that he would be quite contented with his fate in the grassy meadows, where the grass reached his belly, if he were not also compelled to keep his eyes constantly turned towards the mountains to catch the first sight of the *father of oxen*, as he descended, with fury, to devour him and his [347] companions.”

The Cheyenne Indians have a tradition that these great animals lived in former times, conjointly with a race of men whose size was proportionate to their own, but that the *Great Being* destroyed both by repeated strokes of his terrible thunderbolts.

The native Indians of Virginia had another legend. As these gigantic Elephants destroyed all other animals specially created to supply the wants of the Indians, God, the thunderer, destroyed them; a single one only succeeded in escaping. It was “the great male, which presented its head to the thunderbolts and shook them off as they fell; but being at length wounded in the side, he took to flight towards the great lakes, where he remains hidden to this day.” All these simple fictions prove, at least, that the Mastodon has lived upon the earth at some not very distant period. We shall see, in fact, that it was contemporaneous with the Mammoth, which, it is now supposed, may have been co-existent with the earlier races of mankind, or only preceded a little the appearance of man.

Buffon, as we have said, gave to this great fossil animal the name of the Elephant of the Ohio; it has also been called the Mammoth of the Ohio. In England it was received with astonishment. Dr. Hunter showed clearly enough, from the thigh-bone and the teeth, that it was no Elephant; but having heard of the existence of the Siberian Mammoth, he at once came to the conclusion that they were bones of that animal. He then declared the teeth to be carnivorous, and the idea of a *carnivorous elephant* became one of the wonders of the day. Cuvier at once dissipated the clouds of doubt which surrounded the subject, pointing out the osteological differences between the several species, and giving to the American animal the appropriate name of Mastodon (from μαστος, *a teat*, and οδους, *a tooth*), or teat-like-toothed animal.

Many bones of the Mastodon have been found in America since that time, but remains are rarely met with in Europe, except as fragments—as the portion of a jaw-bone discovered in the Red Crag near Norwich, which Professor Owen has named *Mastodon angustidens*. It was even thought, for a long time, with Cuvier, that the Mastodon belonged exclusively to the New World; but the discovery of many of the bones mixed with those of the Mammoth, (*Elephas primigenius*) has dispelled that opinion. Bones of Mastodon have been found in great numbers in the Val d’Arno. In 1858 a magnificent skeleton was discovered at Turin.

The form of the teeth of the Mastodon shows that it fed, like the Elephant, on the roots and [348] succulent parts of vegetables; and this is confirmed by the curious discovery made in America by Barton. It lived, no doubt, on the banks of rivers and on moist and marshy lands. Besides the great Mastodon of which we have spoken, there existed a Mastodon one-third smaller than the

Elephant, and which inhabited nearly all Europe.

There are some curious historical facts in connection with the remains of the Mastodon which ought not to be passed over in silence. On the 11th of January, 1613, the workmen in a sand-pit situated near the Castle of Chaumont, in Dauphiny, between the cities of Montricourt and Saint-Antoine, on the left bank of the Rhône, found some bones, many of which were broken up by them. These bones belonged to some great fossil Mammal, but the existence of such animals was at that time wholly unknown. Informed of the discovery, a country surgeon named Mazuyer purchased the bones, and gave out that he had himself discovered them in a tomb, thirty feet long by fifteen broad, built of bricks, upon which he found the inscription TEUTOBOCCHUS REX. He added that, in the same tomb, he found half a hundred medals bearing the effigy of Marius. This Teutobocchus was a barbarian king, who invaded Gaul at the head of the Cimbri, and who was vanquished near *Aquæ Sextiæ* (Aix in Provence) by Marius, who carried him to Rome to grace his triumphal procession. In the notice which he published in confirmation of this story, Mazuyer reminded the public that, according to the testimony of Roman authors, the head of the Teuton king exceeded in dimensions all the trophies borne upon the lances in the triumph. The skeleton which he exhibited was five-and-twenty feet in length and ten broad.

Mazuyer showed the skeleton of the pretended Teutobocchus in all the cities of France and Germany, and also to Louis XIII., who took great interest in contemplating this marvel. It gave rise to a long controversy, or rather an interminable dispute, in which the anatomist Riolan distinguished himself—arguing against Habicot, a physician, whose name is all but forgotten. Riolan attempted to prove that the bones of the pretended king were those of an Elephant. Numerous pamphlets were exchanged by the two adversaries, in support of their respective opinions. We learn also from Gassendi, that a Jesuit of Tournon, named Jacques Tissot, was the author of the notice published by Mazuyer. Gassendi also proves that the pretended medals of Marius were forgeries, on the ground that they bore Gothic characters. It seems very strange that these bones, which are still preserved in the cases of the Museum of Natural History in [349]
Paris, where anybody may see them, should ever have been mistaken, for a single moment, for human remains. The skeleton of Teutobocchus remained at Bordeaux till 1832, when it was sent to the Museum of Natural History in Paris, where M. de Blainville declared that it belonged to a Mastodon.

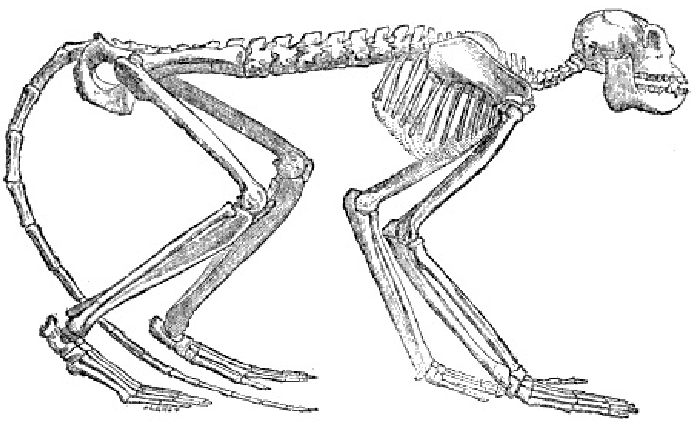


Fig. 166.—Skeleton of Mesopithecus.

The Apes made their appearance at this period. In the ossiferous beds of Sansan M. Lartet [350]
discovered the *Dryopithecus*, as well as *Pithecus antiquus*, but only in imperfect fragments. M. Albert Gaudry was more fortunate: in the Miocene rocks of Pikermi, in Greece, he discovered the entire skeleton of *Mesopithecus*, which we present here (Fig. 166), together with the same animal restored (Fig. 167). In its general organisation it resembles the dog-faced baboon or ape, a piece of information which has guided the artist in the restoration of the animal.

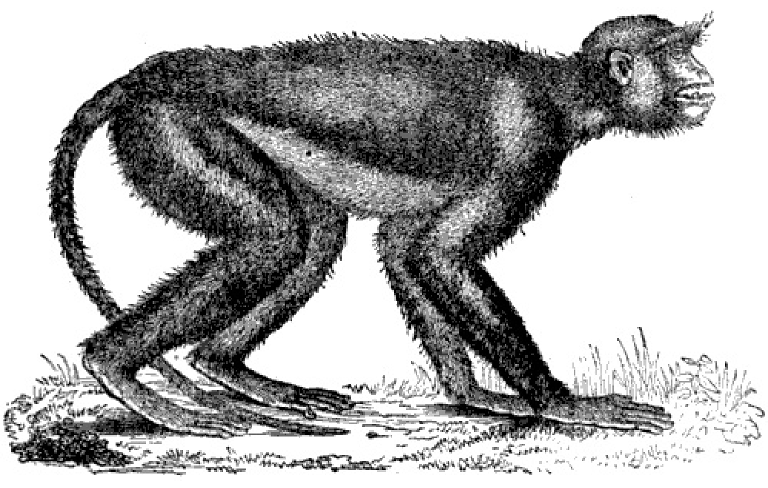


Fig. 167.—Mesopithecus restored. One-fifth natural size.

The seas of the Miocene period were inhabited by great numbers of beings altogether unknown in earlier formations; we may mention no less than ninety marine genera which appear here for the first time, and some of which have lived down to our epoch. Among these, the molluscous Gasteropods, such as *Conus*, *Turbinella*, *Ranella*, *Murex* (Fig. 169), and *Dolium* are the most abundant; with many Lamellibranchiata.

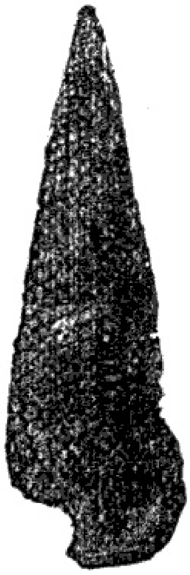


Fig. 168.—Cerithium plicatum.

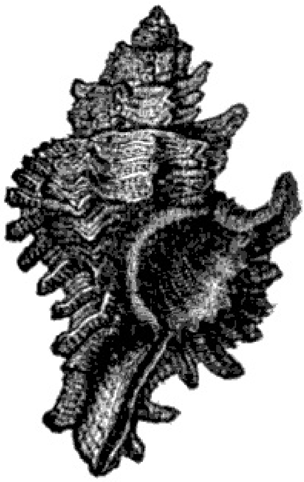


Fig. 169.—Murex Turonensis.

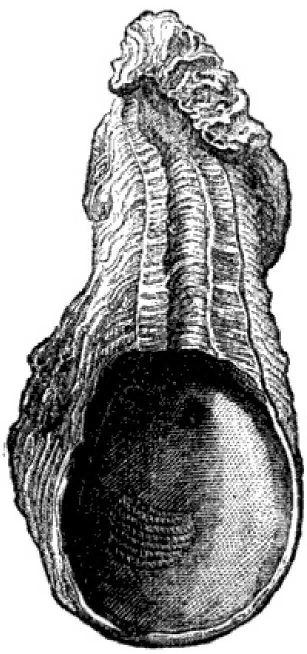
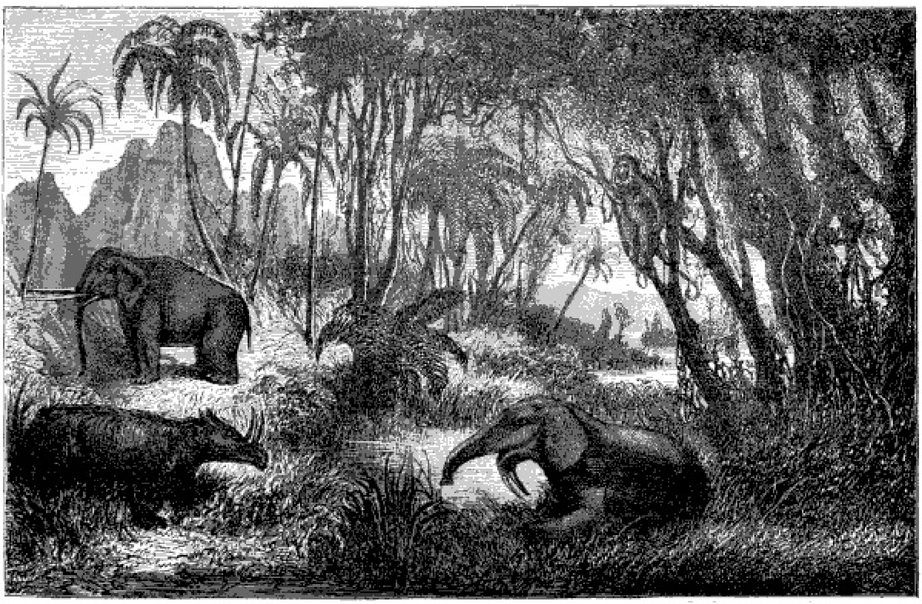


Fig. 170.—Ostrea longirostris. One quarter

natural size.
Living form.

The Foraminifera are also represented by new genera, among which are the Bolivina, Polystomella, and Dentritina.

[352]



XXIV.—Ideal Landscape of the Miocene Period.

Finally, the Crustaceans include the genera *Pagurus* (or the Hermit crabs); *Astacus*. (the lobster); and *Portunus* (or paddling crabs). Of the first, it is doubtful if any fossil species have been found; of the last, species have been discovered bearing some resemblance to *Podophthalmus vigil*, as *P. Defrancii*, which only differs from it in the absence of the sharp spines which terminate the lateral angles of the carapace in the former; while *Portunus leucodon* (Desmarest) bears some analogy to Lupea. [353]

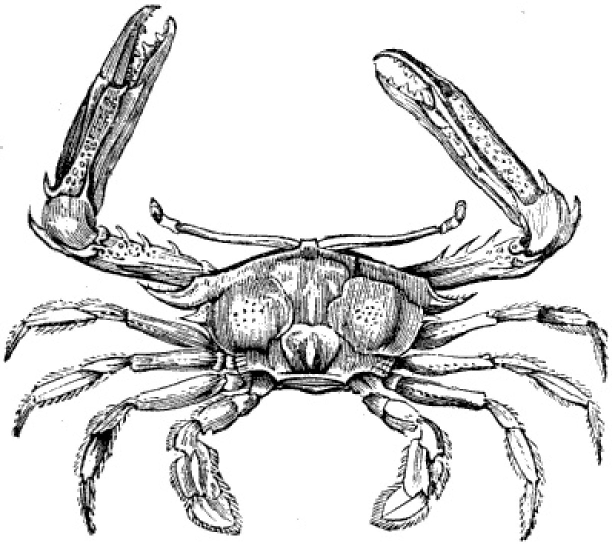


Fig. 171.—Podophthalmus vigil.

An ideal landscape of the Miocene period, which is given on the opposite page (Plate XXIV.), represents the Dinotherium lying in the marshy grass, the Rhinoceros, the Mastodon, and an Ape of great size, the *Dryopithecus*, hanging from the branches of a tree. The products of the vegetable kingdom are, for the greater part, analogous to those of the present time. They are remarkable for their abundance, and for their graceful and serried vegetation; and still remind us in some respects, of the vegetation of the Carboniferous period. It is, in fact, a continuation of the characteristics of that period, and from the same cause, namely, the submersion of land under marshy waters, which has given birth to a sort of coal which is often found in the Miocene formation, and which we call *lignite*. This imperfect coal does not quite resemble that of the Carboniferous, or true Coal-measure period, because it is of much more recent date, and because [354] it has not been subjected to the same internal heat, accompanied by the same pressure of superincumbent strata, which produced the older coal-beds of the Primary epoch.

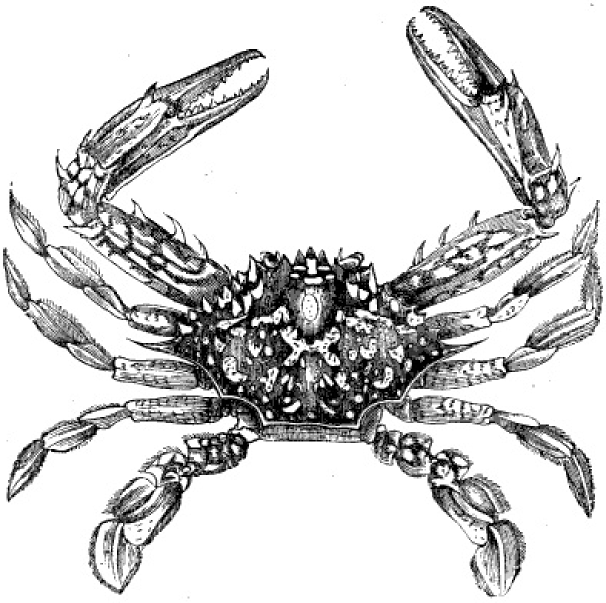


Fig. 172.—Lupea pelagica.

The *lignites*, which we find in the Miocene, as in the Eocene period, constitute, however, a combustible which is worked and utilised in many countries, especially in Germany, where it is made in many places to serve in place of coal. These beds sometimes attain a thickness of above twenty yards, but in the environs of Paris they form beds of a few inches only, which alternate with clays and sands. We cannot doubt that lignites, like true coal, are the remains of the buried forests of an ancient world; in fact, the substance of the woods of our forests, often in a state perfectly recognisable, is frequently found in the lignite beds; and the studies of modern botanists have demonstrated, that the species of which the lignites are formed, belong to a [355] vegetation closely resembling that of Europe in the present day.

Another very curious substance is found with the lignite—yellow amber. It is the mineralised resin, which flowed from certain extinct pine-trees of the Tertiary epoch; the waves of the Baltic Sea, washing the amber out of the deposits of sand and clay in which it lies buried, this substance, being very little heavier than water, is thrown by the waves upon the shore. For ages the Baltic coast has supplied commerce with amber. The Phœnicians ascended its banks to collect this beautiful fossil resin, which is now chiefly found between Dantzic and Memel, where it is a government monopoly in the hands of contractors, who are protected by a law making it theft to gather or conceal it.

Amber,[91] while it has lost none of its former commercial value, is, besides, of much palæontological interest; fossil insects, and other extraneous bodies, are often found enclosed in the nodules, where they have been preserved in all their original colouring and integrity of form. As the poet says—

> "The things themselves are neither rich nor rare,
> The wonder's how the devil they got there."

The natural aromatic qualities of the amber combined with exclusion of air, &c., have embalmed them, and thus transmitted to our times the smaller beings and the most delicate organisms of earlier ages.

The Miocene rocks, of marine origin, are very imperfectly represented in the Paris basin, and their composition changes with the localities. They are divided into two groups of beds: 1. *Molasse*, or soft clay; 2. *Faluns*, or shelly marl.

In the Paris basin the *Molasse* presents, at its base, quartzose sands of great thickness, sometimes pure, sometimes a little argillaceous or micaceous. They include beds of sandstone (with some limestone), which are worked in the quarries of Fontainebleau, d'Orsay, and Montmorency, for paving-stone for the streets of Paris and the neighbouring towns. This last formation is altogether marine. To these sands and sandstones succeeds a fresh-water deposit, formed of a whitish and partly siliceous limestone, which forms the ground of the plateau of La Beauce, between the valleys of the Seine and the Loire: this is called the *Calcaire de la Beauce*. It is there mixed with a reddish and more or less sandy clay, containing small blocks of burrh-stone used for millstones, easily recognised by their yellow-ochreous colour, and the numerous cavities [356] or hollows with which their texture is honeycombed.

This grit, or *silex meulier*, is much used in Paris for the arches of cellars, underground conduits, sewers, &c.

The *Faluns* in the Paris basin consist of divers beds formed of shells and Corals, almost entirely broken up. In many parts of the country, and especially in the environs of Tours and Bordeaux, they are dug out for manuring the land. To the Falun series belong the fresh-water marl, limestone, and sand, which composed the celebrated mound of Sansan, near Auch, in the Department of Gers, in which M. Lartet found a considerable number of bones of Turtles, Birds, and especially Mammals, such as *Mastodon* and *Dinotherium*, together with a species of long-armed ape, which he named *Pithecus antiquus*, from the circumstance of its affording the earliest instance of the discovery of the remains of the quadrumana, or monkey-tribe, in Europe. Isolated masses of Faluns occur, also, near the mouth of the Loire and to the south of Tours, and in Brittany.

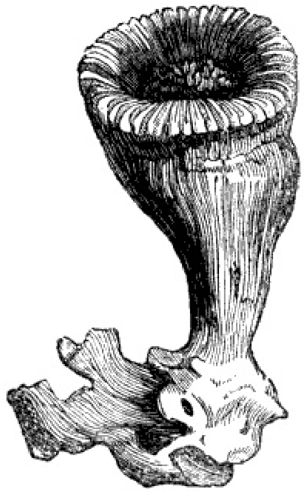


Fig. 173.—Caryophylla cyathus.

PLIOCENE PERIOD. [357]

This last period of the Tertiary epoch was marked, in some parts of Europe, by great movements of the terrestrial crust, always due to the same cause—namely, the continual and gradual cooling of the globe. This leads us to recall what we have repeatedly stated, that this cooling, during which the outer zone of the fluid mass passed to the solid state, produced irregularities and inequalities in the external surface, sometimes accompanied by fractures through which the semi-fluid or pasty matter poured itself; leading afterwards to the upheaval of mountain ranges through these gaping chasms. Thus, during the Pliocene period, many mountains and mountain-chains were formed in Europe by basaltic and volcanic eruptions. These upheavals were preceded by sudden and irregular movements of the elastic mass of the crust—by earthquakes, in short—phenomena which have been already sufficiently explained.

In order to understand the nature of the vegetation of the period, as compared with that with which we are familiar, let us listen to M. Lecoq: “Arrived, finally,” says that author, “at the last period which preceded our own epoch—the epoch in which the temperate zones were still embellished by tropical forms of vegetation, which were, however, slowly declining, driven out as it were by a cooling climate and by the invasion of more vigorous species—great terrestrial commotions took place: mountains are covered with eternal snow; continents now take their present forms; but many great lakes, now dried up, still existed; great rivers flowed majestically through smiling countries, whose surface man had not yet come to modify.

“Two hundred and twelve species compose this rich flora, in which the Ferns of the earlier ages of the world are scarcely indicated, where the Palms seem to have quite disappeared, and we see forms much more like those which are constantly under our observation. The *Culmites arundinaceus* (Unger) abounds near the water, where also grows the *Cyperites tertiarius* [358] (Unger), where floats *Dotamogeton geniculatus* (Braun), and where we see submerged *Isoctites Brunnii* (Unger). Great Conifers still form the forests. This fine family has, as we have seen, passed through every epoch, and still presents us with its elegant forms and persistent evergreen foliage; *Taxodites*, *Thuyoxylum*, *Abietites*, *Pinites*, *Eleoxylon*, and *Taxites* being still the forms most abundant in these old natural forests.

“The predominating character of this period is the abundance of the group of the Amentaceæ; whilst the Conifers are thirty-two in number, of the other we reckon fifty-two species, among which are many European genera, such as *Alnus*; *Quercus*, the oak; *Salix*, the willow; *Fagus*, the beech; *Betula*, the birch, &c.

“The following families constitute the arborescent flora of the period besides those already mentioned:—Balsaminaceæ, Lauraceæ, Thymelæaceæ, Santalaceæ, Cornaceæ, Myrtaceæ, Calycanthaceæ, Pomaceæ, Rosaceæ, Amygdaleæ, Leguminosæ, Anacardiaceæ, Juglandaceæ, Rhamnaceæ, Celastrinaceæ, Sapindaceæ, Meliaceæ, Aceraceæ, Tiliaceæ, Magnoliaceæ, Capparidaceæ, Sapoteaceæ, Styracaceæ, Oleaceæ, Juncaceæ, Ericaceæ.

“In all these families great numbers of European genera are found, often even more abundant in species than now. Thus, as Brongniart observes, in this flora we reckon fourteen species of Maple; three species of Oak; and these species proceed from two or three very circumscribed localities, which would not probably, at the present time, represent in a radius of several leagues more than three or four species of these genera."

An important difference distinguishes the Pliocene flora, as compared with those of preceding epochs, it is the absence of the family of Palms in the European flora, as noted by Lecoq, which forms such an essential botanical feature in the Miocene period. We mention this, because, in spite of the general analogy which exists between the vegetation of the Pliocene period and that of temperate regions in the present day, it does not appear that there is a single species of the former period absolutely identical with any one now growing in Europe. Thus, the European vegetation, even at the most recent geological epoch, differs specifically from the vegetation of our age, although a general resemblance is observable between the two.

[359]

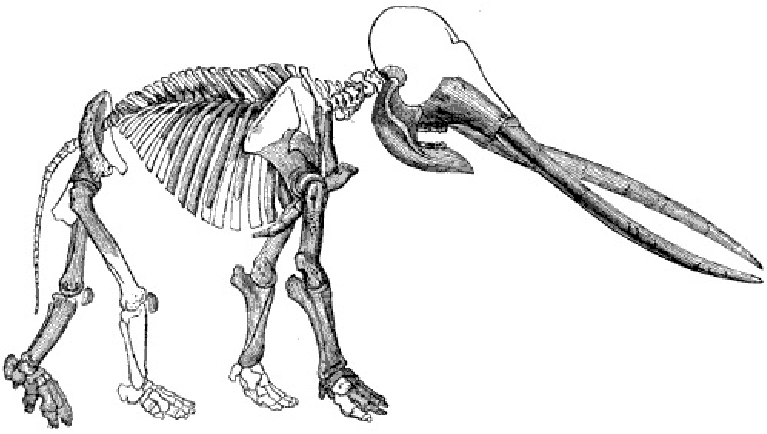


Fig. 174.—Skeleton of the Mastodon of Turin.

The terrestrial animals of the Pliocene period present us with a great number of creatures alike remarkable from their proportions and from their structure. The Mammals and the batrachian Reptiles are alike deserving of our attention in this epoch. Among the former the Mastodon, which makes its first appearance in the Miocene formations, continues to be found, but becomes [360] extinct apparently before we reach the upper beds. Others present themselves of genera totally unknown till now, some of them, such as the *Hippopotamus*, the *Camel*, the *Horse*, the *Ox*, and the *Deer*, surviving to the present day. The fossil horse, of all animals, is perhaps that which presents the greatest resemblance to existing individuals; but it was small, not exceeding the ass in size.

The *Mastodon*, which we have considered in our description of the preceding period, still existed in Pliocene times; in Fig. 174 the species living in this latter age is represented—it is called the Mastodon of Turin. As we see, it has only two projecting tusks or defences in the upper jaw, instead of four, like the American species, which is described in page 343. Other species belonging to this period are not uncommon; the portion of an upper jaw-bone with a tooth which was found in the Norwich Crag at Postwick, near Norwich, Dr. Falconer has shown to be a Pliocene species, first observed in Auvergne, and named by Messrs. Croizet and Jobert, its discoverers, *Mastodon Arvernensis*.

The *Hippopotamus*, *Tapir*, and *Camel*, which appear during the Pliocene period, present no peculiar characteristics to arrest our attention.

The Apes begin to abound in species; the Stags were already numerous.

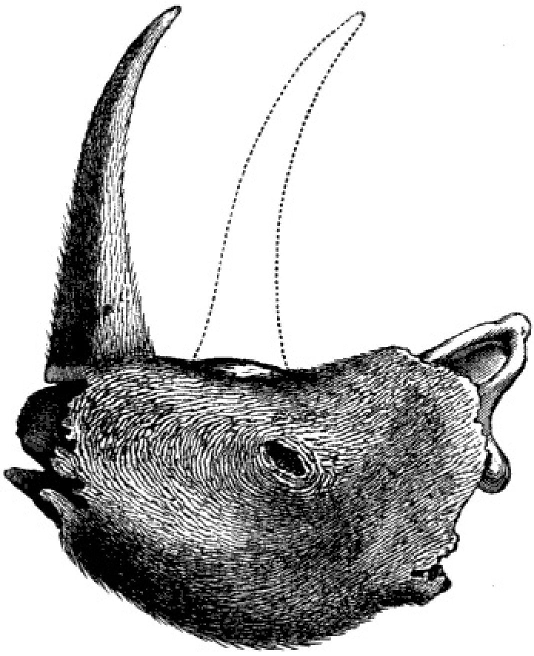


Fig. 175.—Head of Rhinoceros tichorhinus, partly restored under the direction of Eugene Deslongchamps.

The *Rhinoceros*, which made its appearance in the Miocene period, appears in greater numbers in the Pliocene deposits. The species peculiar to the Tertiary epoch is *R. tichorhinus*, which is descriptive of the bony partition which separated its two nostrils, an anatomical arrangement [361] which is not found in our existing species. Two horns surmount the nose of this animal, as represented in Fig. 175. Two living species, namely, the Rhinoceros of Africa and Sumatra, have two horns, but they are much smaller than those of *R. tichorhinus*. The existing Indian Rhinoceros has only one horn.

The body of *R. tichorhinus* was covered with very thick hair, and its skin was without the rough and callous scales which we remark on the skin of the living African species.

Contemporaneously with this gigantic species there existed a dwarf species about the size of our Hog; and along with it several intermediate species, whose bones are found in sufficient numbers to enable us to reconstruct the skeleton. The curvature of the nasal bone of the fossil Rhinoceros and its gigantic horn have given rise to many tales and popular legends. The famous bird, the *Roc*, which played so great a part in the fabulous myths of the people of Asia, originated in the discovery in the bosom of the earth of the cranium and horns of a fossil Rhinoceros. The famous dragons of western tradition have a similar origin.

In the city of Klagenfurth, in Carinthia, is a fountain on which is sculptured the head of a monstrous dragon with six feet, and a head surmounted by a stout horn. According to the popular tradition still prevalent at Klagenfurth, this dragon lived in a cave, whence it issued from time to time to frighten and ravage the country. A bold cavalier kills the dragon, paying with his life for this proof of his courage. It is the same legend which is current in every country, from that of the valiant St. George and the Dragon and of St. Martha, who nearly about the same age conquered the fabulous *Tarasque* of the city of Languedoc, which bears the name of Tarascon.

But at Klagenfurth the popular legend has happily found a mouth-piece—the head of the pretended dragon, killed by the valorous knight, is preserved in the Hôtel de Ville, and this head has furnished the sculptor for his fountain with a model for the head of his statue. Herr Unger, of Vienna, recognised at a glance the cranium of the fossil Rhinoceros; its discovery in some cave had probably originated the fable of the knight and the dragon. And all legends are capable of some such explanation when we can trace them back to their sources, and reason upon the circumstances on which they are founded.

The traveller Pallas gives a very interesting account of a *Rhinoceros tichorhinus* which he saw, with his own eyes, taken out of the ice in which its skin, hair, and flesh had been preserved. It was in December, 1771, that the body of the Rhinoceros was observed buried in the frozen sand [362] upon the banks of the Viloui, a river which discharges itself into the Lena below Yakutsk, in Siberia, in 64° north latitude. “I ought to speak,” the learned naturalist says, “of an interesting discovery which I owe to the Chevalier de Bril. Some Yakouts hunting this winter near the Viloui found the body of a large unknown animal. The Sieur Ivan Argounof, inspector of the Zimovic, had sent on to Irkutsk the head and a fore and hind foot of the animal, all very well preserved.” The Sieur Argounof, in his report, states that the animal was half buried in the sand; it measured as it lay three ells and three-quarters Russian in length, and he estimated its height at three and a half; the animal, still retaining its flesh, was covered with skin which resembled tanned leather; but it was so decomposed that he could only remove the fore and hind foot and the head, which he sent to Irkutsk, where Pallas saw them. “They appeared to me at first glance,” he says, “to belong to a Rhinoceros; the head especially was quite recognisable, since it was covered with its leathery skin, and the skin had preserved all its external characters, and many short hairs. The eyelids had even escaped total decay, and in the cranium here and there, under the skin, I perceived some matter which was evidently the remains of putrefied flesh. I also remarked in the feet the remains of the tendons and cartilages where the skin had been removed. The head was without its horn, and the feet without hoofs. The place of the horn, and the raised skin which had surrounded it, and the division which existed in both the hind and fore feet, were evident proofs of its being a Rhinoceros. In a dissertation addressed to the Academy of St. Petersburg, I have given a full account of this singular discovery. I give there reasons which prove that a Rhinoceros had penetrated nearly to the Lena, in the most northern regions, and which have led to the discovery of the remains of other strange animals in Siberia. I shall confine myself here to a description of the country where these curious remains were found, and to the cause of their long preservation.

"The country watered by the Viloui is mountainous; all the stratification of these mountains is horizontal. The beds consist of selenitic and calcareous schists and beds of clay, mixed with numerous beds of pyrites. On the banks of the Viloui we meet with coal much broken; probably coal-beds exist higher up near to the river. The brook Kemtendoï skirts a mountain entirely formed of selenite or crystallised sulphate of lime and of rock-salt, and this mountain of alabaster is more than 300 versts (about 200 miles), in ascending the Viloui, from the place where the Rhinoceros was found. Opposite to the place we see, near the river, a low hill, about a hundred feet high, which, though sandy, contains some beds of millstone. The body of the Rhinoceros had [363]
been buried in coarse gravelly sand near this hill, and the nature of the soil, which is always frozen, had preserved it. The soil near the Viloui never thaws to a great depth, for, although the rays of the sun soften the soil to the depth of two yards in the more elevated sandy places, in the valleys, where the soil is half sand and half clay, it remains frozen at the end of summer half an ell below the surface. Without this intense cold the skin of the animal and many parts of it would long since have perished. The animal could only have been transported from some southern country to the frozen north at the epoch of the Deluge, for the most ancient chronicles speak of no changes of the globe more recent, to which we could attribute the deposit of these remains and of the bones of elephants which are found dispersed all over Siberia."[92]

In this extract the author refers to a memoir previously published by himself, in the "Commentarii" of the Academy of St. Petersburg. This memoir, written in Latin, and entitled "Upon some Animals of Siberia," has never been translated. After some general considerations, the author thus relates the circumstances attending the discovery of the fossil Rhinoceros, with some official documents affirming their correctness, and the manner in which the facts were brought under his notice by the Governor of Irkutsk, General Bril: "The skin and tendons of the head and feet still preserved considerable flexibility, imbued as it were with humidity from the earth; but the flesh exhaled a fetid ammoniacal odour, resembling that of a latrine. Compelled to cross the Baïkal Lake before the ice broke up, I could neither draw up a sufficiently careful description nor make sketches of the parts of the animal; but I made them place the remains, without leaving Irkutsk, upon a furnace, with orders that after my departure they should be dried by slow degrees and with the greatest care, continuing the process for some time, because the viscous matter which incessantly oozed out could only be dissipated by great heat. It happened, unfortunately, that during the operation the posterior part of the upper thigh and the foot were burnt in the overheated furnace, and they were thrown away; the head and the extremity of the hind foot only remained intact and undamaged by the process of drying. The odour of the softer parts, which still contained viscous matter in their interior, was changed by the desiccation into one resembling that of flesh decomposed in the sun.

"The Rhinoceros to which the members belonged was neither large for its species nor advanced
in age, as the bones of the head attest, yet it was evidently an adult from the comparison made of [364]
the size of the cranium as compared with that of others of the same species more aged, which were afterwards found in a fossil state in divers parts of Siberia. The entire length of the head from the upper part of the nape of the neck to the extremity of the denuded bone of the jaw was thirty inches; the horns were not with the head, but we could still see evident vestiges of two horns, the nasal and frontal. The front, unequal and a little protuberant between the orbits, and of a rhomboidal egg-shape, is deficient in the skin, and only covered by a light horny membrane, bristling with straight hairs as hard as horn.

"The skin which covers the greater part of the head is in the dried state, a tenacious, fibrous substance, like curried leather, of a brownish-black on the outside and white in the inside; when burnt, it had the odour of common leather; the mouth, in the place where the lips should have been soft and fleshy, was putrid and much lacerated; the extremities of the maxillary bone were bare. Upon the left side, which had probably been longest exposed to the air, the skin was here and there decomposed and rubbed on the surface; nevertheless, the greater part of the mouth was so well preserved on the right side that the pores, or little holes from which doubtless the hairs had fallen, were still visible all over that side, and even in front. In the right side of the jaw there were still in certain places numerous hairs grouped in tufts, for the most part rubbed down to the roots, and here and there of two or three lines still retaining their full length. They stand erect, are stiff, and of an ashy colour, but with one or two black, and a little stiffer than the others, in each bunch.

"What was most astonishing, however, was the fact that the skin which covered the orbits of the eyes, and formed the eyelids, was so well preserved and so healthy that the openings of the eyelids could be seen, though deformed and scarcely penetrable to the finger; the skin which

surrounded the orbits, though desiccated, formed circular furrows. The cavities of the eyes were filled with matter, either argillaceous or animal, such as still occupied a part of the cavity of the cranium. Under the skin the fibres and tendons still remained, and above all the remains of the temporal muscles; finally, in the throat hung some great bundles of muscular fibres. The denuded bones were young and less solid than in other fossil crania of the same species. The bone which gave support to the nasal horn was not yet attached to the *vomer*; it was unprovided with articulations like the processes of the young bones. The extremities of the jaws preserved no vestige either of teeth or sockets, but they were covered here and there with the remains of the [365]
integument. The first molar was distant about four inches from the extreme edge of the jaw.

"The foot which remains to me, and which, if I am not mistaken, belongs to the left hind limb, has not only preserved its skin quite intact and furnished with hairs, or their roots, as well as the tendons and ligaments of the heel in all their strength, but also the skin itself quite whole as far as the bend in the knee. The place of the muscles was filled with black mud. The extremity of the foot is cloven into three angles, the bony parts of which, with the periosteum, still remain here and there; the horny hoofs had been detached. The hairs adhering in many places to the skin were from one to three lines in length, tolerably stiff and ash-coloured. What remains of it proves that the foot was covered with bunches of hair, which hung down.

"We have never, so far as I know, observed so much hair on any rhinoceros which has been brought to Europe in our times, as appears to have been presented by the head and feet we have described. I leave you then to decide if our rhinoceros of the Lena was born or not in the temperate climate of Central Asia. In fact, the rhinoceros, as I gather from the relations of travellers, belongs to the forests of Northern India; and it is likely enough that these animals differ in a more hairy skin from those which live in the burning zones of Africa, just in the same way that other animals of a hotter climate are less warmly covered than those of the same genera in temperate countries."[93]

Of all fossil ruminants one of the largest and most singular is the *Sivatherium*, whose remains have been found in the valley of Murkunda, in the Sewalik branch of the Sub-Himalayan Mountains. Its name is taken from that of Siva, the Indian deity worshipped in that part of India.

The *Sivatherium giganteum* had a body as bulky as that of an ox, and bore a sort of resemblance to the living Elk. It combined in itself the characteristics of different kinds of Herbivores, at the same time that it was marked by individual peculiarities. The massive head possessed four deciduous, hollow horns, like the Prongbuck; two front ones conical, smooth, and rapidly rising to a point, and two hinder ones of larger size, and branched, projected forward above the eyes.[94]
Thus it differed from the deer, whose solid horns annually drop off, and from the antelope tribe, [366]
sheep and oxen, whose hollow horns are persistent, and resembled only one living ruminant, the prongbuck, in having had hollow horns subject to shedding. Fig. 176 is a representation of the *Sivatherium* restored, in so far, at least, as it is possible to do so in the case of an animal of which only the cranium and a few other bones have been discovered.

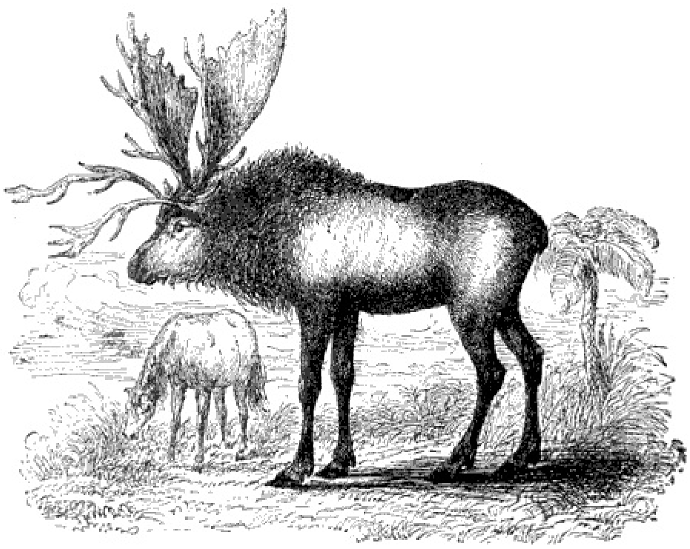


Fig. 176.—Sivatherium restored.

As if to rival these gigantic Mammals, great numbers of Reptiles seem to have lived in the Pliocene period, although they are no longer of the same importance as in the Secondary epoch. Only one of these, however, need occupy our attention, it is the *Salamander*. The living Salamanders are amphibious Batrachians, with smooth skins, and rarely attaining the length of twenty inches. The Salamander of the Tertiary epoch had the dimensions of a Crocodile; and its [367]
discovery opens a pregnant page in the history of geology. The skeleton of this Reptile was long considered to be that of a human victim of the deluge, and was spoken of as "*homo diluvii testis*." It required all the efforts of Camper and Cuvier to eradicate this error from the minds of the learned, and probably in the minds of the vulgar it survived them both.

Upon the left bank of the Rhine, not far from Constance, a little above Stein, and near the village of Œningen, in Switzerland, there are some fine quarries of schistose limestone. In consequence of their varied products these quarries have often been described by naturalists; they are of Tertiary age, and were visited, among others, by Horace de Saussure, by whom they are described in the third volume of his "Voyage dans les Alpes."

In 1725, a large block of stone was found, incrusted in which a skeleton was discovered, remarkably well preserved; and Scheuchzer, a Swiss naturalist of some celebrity, who added to his scientific pursuits the study of theology, was called upon to give his opinion as to the nature of this relic of ancient times. He thought he recognised in the skeleton that of a man. In 1726 he published a description of these fossil remains in the "Philosophical Transactions" of London; and in 1731 he made it the subject of a special dissertation, entitled "*Homo diluvii testis*"—Man, a witness of the Deluge. This dissertation was accompanied by an engraving of the skeleton. Scheuchzer returned to the subject in another of his works, "Physica Sacra," saying: "It is certain that this schist contains the half, or nearly so, of the skeleton of a man; that the substance even of the bones, and, what is more, of the flesh and of parts still softer than the flesh, are there incorporated in the stone; in a word, it is one of the rarest relics which we have of that accursed race which was buried under the waters. The figure shows us the contour of the frontal bone, the orbits with the openings which give passage to the great nerves of the fifth pair. We see there the remains of the brain, of the sphenoidal bone, of the roots of the nose, a notable fragment of the maxillary bone, and some vestiges of the liver."

And our pious author exclaims, this time taking the lyrical form—

> "Betrübtes Beingerüst von einem altem Sünder
> Erweiche, Stein, das Herz der neuen Bosheitskinder!"

> "O deplorable skeleton of an accursed ancient,
> Mayst thou soften the hearts of the late children of wickedness!"

The reader has before him the fossil of the Œningen schist (Fig. 177). It is obviously impossible to [368]
see in this skeleton what the enthusiastic savant wished to perceive. And we can form an idea from this instance, of the errors to which a preconceived idea, blindly followed, may sometimes lead. How a naturalist of such eminence as Scheuchzer could have perceived in this enormous head, and in these upper members, the least resemblance to the osseous parts of a man is incomprehensible!

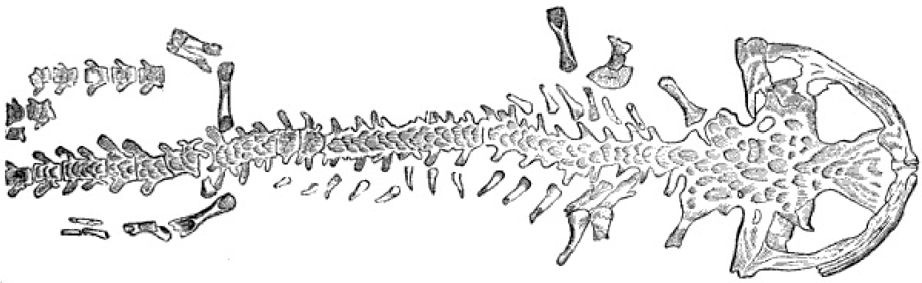


Fig. 177.—Andrias Scheuchzeri.

The Pre-Adamite "witness of the deluge" made a great noise in Germany, and no one there dared to dispute the opinion of the Swiss naturalist, under his double authority of theologian and savant. This, probably, is the reason why Gesner in his "Traité des Pétrifactions," published in 1758, describes with admiration the fossil of Œningen, which he attributes, with Scheuchzer, to the *antediluvian man*.

Pierre Camper alone dared to oppose this opinion, which was then universally professed throughout Germany. He went to Œningen in 1787 to examine the celebrated fossil animal; he had no difficulty in detecting the error into which Scheuchzer had fallen. He recognised at once that it was a Reptile; but he deceived himself, nevertheless, as to the family to which it belonged;
he took it for a Saurian. "A petrified lizard," Camper wrote; "could it possibly pass for a man?" It [369]
was left to Cuvier to place in its true family the fossil of Œningen; in a memoir on the subject he demonstrated that this skeleton belonged to one of the amphibious batrachians called Salamanders. "Take," he says in his memoir, "a skeleton of a Salamander and place it alongside the fossil, without allowing yourself to be misled by the difference of size, just as you could easily do in comparing a drawing of the salamander of the natural size with one of the fossil reduced to a sixteenth part of its dimensions, and everything will be explained in the clearest manner."

"I am even persuaded," adds the great naturalist, in a subsequent edition of this memoir, "that, if we could re-arrange the fossil and look closer into the details, we should find still more numerous proofs in the articular faces of the vertebræ, in those of the jaws, in the vestiges of very small teeth, and even in the labyrinth of the ear." And he invited the proprietors or depositaries of the precious fossil to proceed to such an examination. Cuvier had the gratification of making, personally, the investigation he suggested. Finding himself at Haarlem, he asked permission of the Director of the Museum to examine the stone which contained the supposed fossil man. The operation was carried on in the presence of the director and another naturalist. A drawing of the skeleton of a Salamander was placed near the fossil by Cuvier, who had the satisfaction of recognising, as the stone was chipped away under the chisel, each of the bones, announced by the drawing, as they made their appearance. In the natural sciences there are few instances of such triumphant results—few demonstrations so satisfactory as this, of the certitude of the methods of observation and induction on which palæontology is based.

During the Pliocene period Birds of very numerous species, and which still exist, gave animation to the vast solitudes which man had not yet occupied. Vultures and Eagles, among the rapacious birds; and among other genera of birds, gulls, swallows, pies, parroquets, pheasants, jungle-fowl, ducks, &c.

In the marine Pliocene fauna we see, for the first time, aquatic Mammals or Cetaceans—the *Dolphin* and *Balæna* belonging to the period. Very little, however, is known of the fossil species belonging to the two genera. Some bones of Dolphins, found in different parts of France, apprise us, however, that the ancient species differed from those of our days. The same remark may be made respecting the Narwhal. This Cetacean, so remarkable for its long tusk, or tooth, in the [370] form of a horn, has at all times been an object of curiosity.

The Whales, whose remains are found in the Pliocene rocks, differ little from those now living. But the observations geologists have been able to make upon these gigantic remains of the ancient world are too few to allow of any very precise conclusion. It is certain, however, that the fossil differs from the existing Whale in certain characters drawn from the bones of the cranium. The discovery of an enormous fragment of a fossil Whale, made at Paris in 1779, in the cellar of a wine-merchant in the Rue Dauphine, created a great sensation. Science pronounced, without much hesitation, on the true origin of these remains; but the public had some difficulty in comprehending the existence of a whale in the Rue Dauphine. It was in digging some holes in his cellars that the wine-merchant made this interesting discovery. His workmen found, under the pick, an enormous piece of bone buried in a yellow clay. Its complete extraction caused him a great deal of labour, and presented many difficulties. Little interested in making further discoveries, our wine-merchant contented himself with raising, with the help of a chisel, a portion of the monstrous bone. The piece thus detached weighed 227 pounds. It was exhibited in the wine-shop, where large numbers of the curious went to see it. Lamanon, a naturalist of that day, who examined it, conjectured that the bone belonged to the head of a whale. As to the bone itself, it was purchased for the Teyler Museum, at Haarlem, where it still remains.

There exists in the Museum of Natural History in Paris only a copy of the bone of the whale of the Rue Dauphine, which received the name of *Balænodon Lamanoni*. The examination of this figure by Cuvier led him to recognise it as a bone belonging to one of the antediluvian Balænæ, which differed not only from the living species, but from all others known up to this time.

Since the days of Lamanon, other bones of Balæna have been discovered in the soil in different countries, but the study of these fossils has always left something to be desired. In 1806 a fossil Balæna was disinterred at Monte-Pulgnasco by M. Cortesi. Another skeleton, seventy-two feet long, was found on the banks of the river Forth, near Alloa, in Scotland. In 1816 many bones of this animal were discovered in a little valley formed by a brook running into the Chiavana, one of the affluents of the Po.

Cuvier has established, among the cetacean fossils, a particular genus, which he designates under the name of *Ziphius*. The animals to which he gave the name, however, are not identical either with the Whales (*Balænæ*), the Cachelots or Sperm Whales, or with the Hyperoodons. They [371] hold, in the order of Cetaceans, the place that the Palæotherium and Anoplotherium occupy among the Pachyderms, or that which the Megatherium and Megalonyx occupy in the order of the Edentates. The *Ziphius* still lives in the Mediterranean.

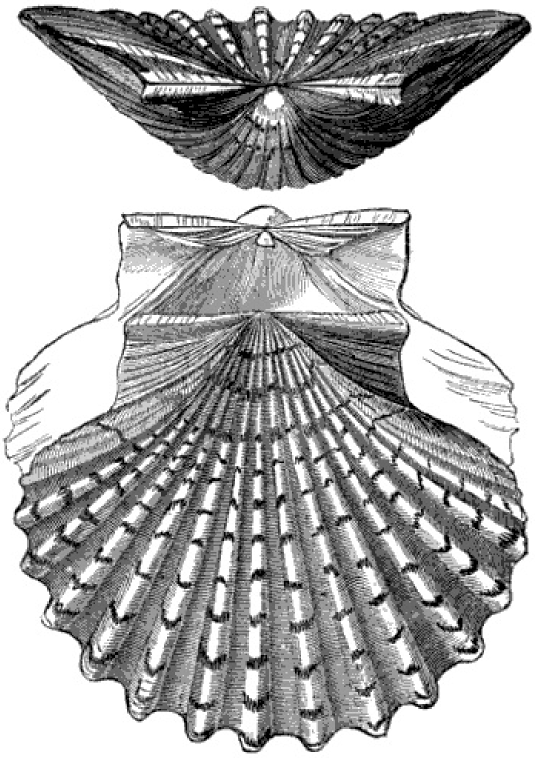


Fig. 178.—Pecten Jacobæus.
(Living species.)

The genera of Mollusca, which distinguish this period from all others, are very numerous. They include the Cardium, Panopæa, Pecten (Fig. 178), Fusus, Murex, Cypræa, Voluta, Chenopus, Buccinum, Nassa, and many others. [372]

The *Pliocene* series prevails over Norfolk, Suffolk, and Essex, where it is popularly known as the Crag. In Essex it rests directly on the London Clay. Near Norwich it rests on the Chalk.

The *Pliocene rocks* are divided into lower and upper. The *Older Pliocene* comprises the White or Coralline Crag, including the Red Crag of Suffolk, containing marine shells, of which sixty per cent. are of extinct species. The *Newer Pliocene* is represented by the Fluvio-marine or Norwich Crag, which last, according to the Rev. Osmond Fisher, is overlaid by Chillesford clay, a very variable and more arctic deposit, often passing suddenly into sands without a trace of clay.

The Norfolk Forest Bed rests upon the Chillesford clay, when that is not denuded.

A ferruginous bed, rich in mammalian remains, and known as the Elephant bed, overlies the Forest Bed, of which it is considered by the Rev. John Gunn to be an upper division.

The Crag, divided into three portions, is a local deposit of limited extent. It consists of variable beds of sand, gravel, and marl; sometimes it is a shelly ferruginous grit, as the Red Crag; at others a soft calcareous rock made up of shells and bryozoa, as the Coralline Crag.

The *Coralline Crag*, of very limited extent in this country, ranges over about twenty miles between the rivers Stour and Alde, with a breadth of three or four. It consists of two divisions—an upper one, formed chiefly of the remains of Bryozoa, and a lower one of light-coloured sands, with a profusion of shells. The upper division is about thirty-six feet thick at Sudbourne in Suffolk, where it consists of a series of beds almost entirely composed of comminuted shells and remains of Bryozoa, forming a soft building-stone. The lower division is about forty-seven feet thick at Sutton; making the total thickness of the Coralline Crag about eighty-three feet.

Many of the Coralline Crag Mollusca belong to living species; they are supposed to indicate an equable climate free from intense cold—an inference rendered more probable by the prevalence of northern forms of shells, such as *Glycimeris*, *Cyprina*, and *Astarte*. The late Professor Edward Forbes, to whom science is indebted for so many philosophical deductions, points out some remarkable inferences drawn from the fauna of the Pliocene seas.[95] It appears that in the glacial [373] period, which we shall shortly have under consideration, many shells, previously established in the temperate zone, retreated southwards, to avoid an uncongenial climate. The Professor gives a list of fifty which inhabited the British seas while the Coralline and Red Crag were forming, but which are all wanting in the glacial deposits;[96] from which he infers that they migrated at the approach of the glacial period, and returned again northwards, when the temperate climate was restored.[97]

In the Upper or Mammaliferous (or Norwich) Crag, of which there is a good exposure in a pit near the asylum at Thorpe, bones of Mammalia are found with existing species of shells. The greater number of the Mammalian remains have been supposed, until lately, to be extraneous fossils; but they are now considered by Mr. Prestwich as truly contemporaneous. The peculiar mixture of southern forms of life with others of a more northern type lead to the inference that, at this early period, a lowering of temperature began gradually to set in from the period of the Coralline Crag to that of the Forest Bed, which marks the commencement of the Glacial Period.

The distinction between the Mammaliferous Crag of Norwich and the Red Crag of Suffolk is purely palæontological, no case of superposition having yet been discovered, and they are now generally considered as contemporaneous. Two Proboscidians abundant during the Crag period were the *Mastodon Arvernensis* and the *Elephas meridionalis*. In the Red Crag the Mastodon is stated by the Rev. John Gunn to be more abundant than the Elephant, while in the Norwich beds their proportions are nearly equal.

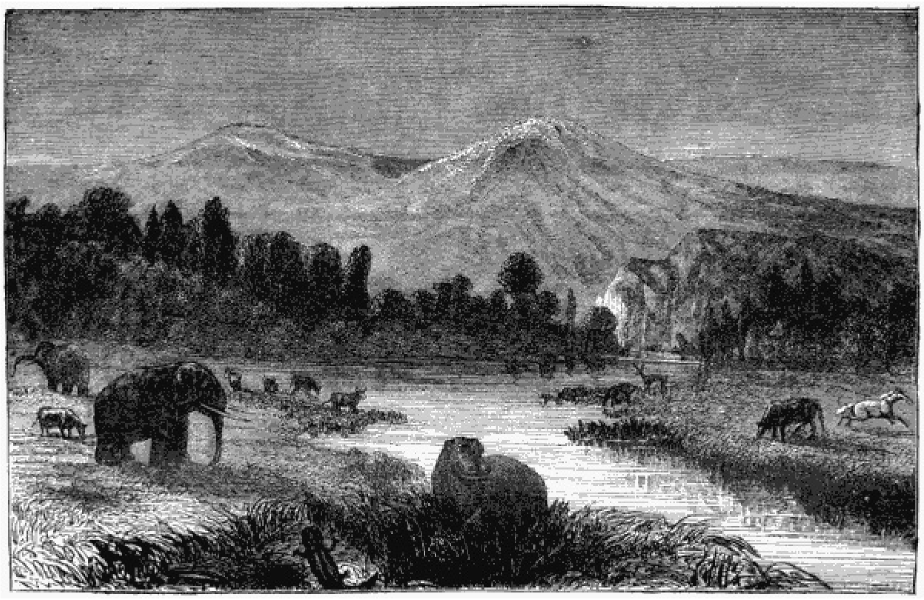
At or near the base of the Red Crag there is a remarkable accumulation, varying in thickness from a few inches to two feet, of bones, teeth, and phosphatic nodules (called coprolites), which are worked for making superphosphate of lime for agricultural manure.

The foreign equivalents of the older Pliocene are found in the *sub-Apennine strata*. These rocks are sufficiently remarkable in the county of Suffolk, where they consist of a series of marine beds of quartzose sand, coloured red by ferruginous matter.

At the foot of the Apennine chain, which forms the backbone, as it were, of Italy, throwing out many spurs, the formations on either side, and on both sides of the Adriatic, are Tertiary strata; they form in many cases, low hills lying between the Apennines of Secondary formation and the sea, the strata generally being a light-brown or bluish marl covered with yellow calcareous sand and gravel, with some fossil shells, which, according to Brocchi, are found all over Italy. But this wide range includes some older Tertiary formations, as in the strata of the Superga near Turin, which are Miocene. [374]

The *Antwerp* Crag, which is of the same age with the Red and Coralline Crag of Suffolk, forms great accumulations upon divers points of Europe: at Antwerp in Belgium, at Carentan and Perpignan, and, we believe, in the basin of the Rhône, in France. The thickest deposits of this rock consist of clay and sand, alternating with marl and arenaceous limestone. These constitute the sub-Apennine hills, alluded to above as extending on both slopes of the Apennines. This deposit occupies the Upper Val d’Arno, above Florence. Its presence is recognised over a great part of Australia. Finally, the seven hills of Rome are composed, in part, of marine Tertiary rocks belonging to the Pliocene period.

[375]



XXV.—Ideal Landscape of the Pliocene Period.

In Plate XXV. an ideal landscape of the Pliocene period is given under European latitudes. In the background of the picture, a mountain, recently thrown up, reminds us that the period was one of frequent convulsions, in which the land was disturbed and upheaved, and mountains and mountain-ranges made their appearance. The vegetation is nearly identical with the present. We see assembled in the foreground the more important animals of the period—the fossil species, as well as those which have survived to the present time.

At the close of the Pliocene period, and in consequence of the deposits left by the seas of the Tertiary epoch, the continent of Europe was nearly what it is now; few permanent changes have occurred since to disturb its general outline. Although the point does not admit of actual proof, there is strong presumptive evidence that in this period, or in that immediately subsequent to it, the entire European area, with some trifling exceptions, including the Alps and Apennines, emerged from the deep. In Sicily, Newer Pliocene rocks, covering nearly half the surface of the island, have been raised from 2,000 to 3,000 feet above the level of the sea. Fossil shells have been observed at the height of 8,000 feet in the Pyrenees; and, as if to fix the date of upheaval, there are great masses of granite which have penetrated the Lias and the Chalk. Fossil shells of the period are also found at a height of 10,000 feet in the Alps, at 13,000 feet in the Andes, and at 18,000 feet in the Himalayas.

In the mountainous regions of the Alps it is always difficult to determine the age of beds, in consequence of the disturbed state of the strata; for instance, the lofty chain of the Swiss Jura consists of many parallel ridges, with intervening longitudinal valleys; the ridges formed of contorted fossiliferous strata, which are extensive in proportion to the number and thickness of the formations which have been exposed on upheaval. The proofs which these regions offer of comparatively recent elevation are numerous. In the central Alps, Cretaceous, Oolitic, Liassic, and Eocene strata are found at the loftiest summits, passing insensibly into metamorphic rocks of granular limestone, and into talcose and mica-schists. In the eastern parts of the chain the older fossiliferous rocks are recognised in similar positions, presenting signs of intense Plutonic action. Oolitic and Cretaceous strata have been raised 12,000 feet, Eocene 10,000, and Miocene 4,000 and 5,000 feet above the level of the sea. Equally striking proofs of recent elevation exist in the Apennines; the celebrated Carrara marble, once supposed—from its crystalline texture and the absence of fossils, and from its resting—1. on talcose schists, 2. on quartz and gneiss—to be very ancient, now turns out to be an altered limestone of the Oolitic series, and the underlying crystalline rocks to be metamorphosed Secondary sandstones and shales. Had all these rocks undergone complete metamorphism, another page in the earth's history would have been obscured. As it is, the proofs of what we state are found in the gradual approach of the rocks to their unaltered condition as the distance from the intrusive rock increases. This intrusive rock, however, does not always reach the surface, but it exists below at no great depth, and is observed piercing through the talcose gneiss, and passing up into Secondary strata. [377]

At the close of this epoch, therefore, there is every probability that Europe and Asia had pretty nearly attained their present general configuration.

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[81] Lyell's "Elements of Geology," p. 187.

[82] This limestone belongs to the Bembridge beds, and forms part of the Fluvio-marine series. See "Survey Memoir on the Geology of the Isle of Wight," by H. W. Bristow.

[83] Similar beds of Miliolite limestone are found in the Middle Bagshot beds on the coast of Sussex, off Selsey—the only instance in England of the occurrence of such calcareous deposits of Middle Eocene age.—H. W. B.

[84] "Elements of Geology," p. 292.

[85] "Memoir of the Geological Survey of Great Britain. The Geology of Middlesex, &c.;" by W. Whitaker, p. 9.

[86] Prestwich. *Quart. Jour. Geol. Soc.*, vol. x., p. 448.

[87] Detailed sections of the whole of the Tertiary strata of the Isle of Wight have been constructed by Mr. H. W. Bristow from actual measurement of the beds in their regular order of succession, as displayed at Hempstead, Whitecliff Bay, Colwell and Tolland's Bays, Headon Hill, and Alum Bay. These sections, published by the Geological Survey of Great Britain, show the thickness, mineral character, and organic remains found in each stratum, and are accompanied by a pamphlet in explanation.

[88] "Elements of Geology," p. 300.

[89] Ibid., p. 305.

[90] *Quarterly Journal of Geol. Soc.*, vol. vii., p. 89.

[91] See Bristow's "Glossary of Mineralogy," p. 11.

[92] "Pallas's Voyage," vol. iv., pp. 130-134.

[93] "Commentarii Academiæ Petersburgicæ," p. 3.

[94] Dr. James Murie, *Geological Magazine*, vol. viii., p. 438.

[95] Edward Forbes in "Memoirs of the Geological Survey of Great Britain," vol. i., p. 336.

[96] For full information on these deposits the reader is referred to the "Memoirs on the Structure of the Crag-beds of Norfolk and Suffolk," by J. Prestwich, F.R.S., in the *Quart. Jour. Geol. Soc.*, vol. xxvii., pp. 115, 325, and 452 (1871). Also to the many Papers by the Messrs. Searles Wood published in the *Quar. Jour. Geol. Soc.*, the *Ann. Nat. Hist.*, the *Phil. Mag.*, &c.

[97] Lyell's "Elements of Geology," p. 203.

QUATERNARY EPOCH. [378]

The Quaternary epoch of the history of our globe commences at the close of the Tertiary epoch, and brings the narrative of its revolutions down to our own times.

The tranquillity of the globe was only disturbed during this era by certain cataclysms whose sphere was limited and local, and by an interval of cold of very extended duration; the *deluges* and the *glacial* period—these are the two most remarkable peculiarities which distinguished this epoch. But the fact which predominates in the Quaternary epoch, and distinguishes it from all other phases of the earth's history is the appearance of man, the culminating and supreme work of the Creator of the universe.

In this last phase of the history of the earth geology recognises three chronological divisions:—

1. The European Deluges.

2. The Glacial Period.

3. The creation of man and subsequent Asiatic Deluge.

Before describing the three orders of events which occurred in the Quaternary epoch, we shall present a brief sketch of the organic kingdoms of Nature, namely, of the animals and vegetables which flourished at this date, and the new formations which arose. Lyell, and some other geologists, designate this the Post-Tertiary Epoch, which they divide into two subordinate groups. —1. *The Post-Pliocene Period*; 2. *The Recent or Pleistocene Period.*

Post-Pliocene Period.

In the days of Cuvier the Tertiary formations were considered as a mere chaos of superficial deposits, having no distinct relations to each other. It was reserved for the English geologists, with Sir Charles Lyell at their head, to throw light upon this obscure page of the earth's history; from the study of fossils, science has not only re-animated the animals, it has re-constructed the [379] theatre of their existence. We see the British Islands now a straggling archipelago, and then the mouth of a vast river, of which the continent is lost; for, says Professor Ramsay, "We are not of necessity to consider Great Britain as having always been an island; it is an accident that it is an island now, and it has been an island many times before." In the Tertiary epoch we see it surrounded, then, by shallow seas swarming with numerous forms of animal life; islands covered with bushy Palms; banks on which Turtles basked in the sun; vast basins of fresh or brackish water, in which the tide made itself felt, and which abounded with various species of sharks; rivers in which Crocodiles increased and multiplied; woods which sheltered numerous Mammals and some Serpents of large size; fresh-water lakes which received the spoils of numerous shells. Dry land had increased immensely. Groups of ancient isles we have seen united and become continents, with lakes, bays, and perhaps inland seas. Gigantic Elephants, vastly larger than any now existing, close the epoch, and probably usher in the succeeding one; for we are not to suppose any sudden break to distinguish one period from another in Nature, although it is convenient to arrange them so for the purposes of description. If we may judge from their remains, these animals must have existed in great numbers, for it is stated that on the coast of Norfolk alone the fishermen, in trawling for oysters, dredged up between 1820 and 1833, no less than 2,000 molar teeth of Elephants. If we consider how slowly these animals multiply, these quarries of ivory, as we may call them, must have required many centuries for their production and accumulation.

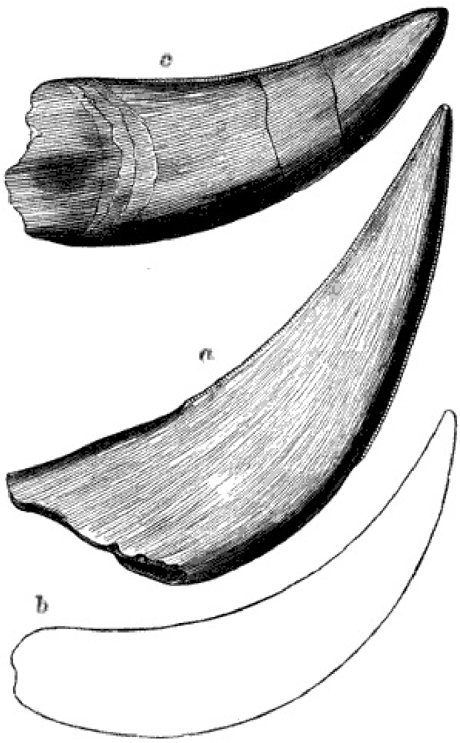


Fig. 179.—*a*, Tooth of Machairodus, imperfect below, natural size; *b*, outline of cast of tooth, perfect, half natural size; *c*, tooth of Megalosaurus, natural size.

The same lakes and rivers were at this time occupied, also, by the Hippopotamus, as large and as formidably armed as that now inhabiting the African solitudes; also the two-horned Rhinoceros; and three species of Bos, one of which was hairy and bore a mane. Some Deer of gigantic size, as compared with living species, bounded over the plains. In the same savannahs lived the Reindeer, the Stag, a Horse of small size, the Ass, the Bear, and the Roe, for Mammals had succeeded the Ichthyosauri of a former age. Nevertheless, the epoch had its tyrants also. A Lion, as large as the largest of the Lions of Africa, hunted its prey in the British jungles. Another animal of the feline race, the *Machairodus* (Fig. 179), was probably the most ferocious and destructive of Carnivora; bands of Hyænas and a terrible Bear, surpassing in size that of the Rocky Mountains, had established themselves in the caverns; two species of Beaver made their appearance on the scene.

The finding of the remains of most of these animals in caverns was perhaps among the most interesting discoveries of geology. The discovery was first made in the celebrated Kirkdale Cave in Yorkshire, which has been described by Dr. Buckland; and afterwards at Kent's Hole, near Torquay. This latter pleasant Devonshire town is built in a creek, shut out from exposure on all sides except the south. In this creek, hollowed out of the rocks, is the great fissure or cavern known as Kent's Hole; like that of Kirkdale, it has been under water, from whence, after a longer or shorter interval, it emerged, but remained entirely closed till the moment when chance led to its discovery. The principal cavern is 600 feet in length, with many crevices or fissures of smaller extent traversing the rock in various directions. A bed of hard stalagmite of very ancient formation, which has been again covered with a thin layer of soil, forms the floor of the cavern, which is a red sandy clay. From this bed of red loam or clay was disinterred a mass of fossil bones belonging to extinct species of Bear, Lion, Rhinoceros, Reindeer, Beaver, and Hyæna. [380] [381]

Such an assemblage gave rise to all sorts of conjectures. It was generally thought that the dwelling of some beasts of prey had been discovered, which had dragged the carcases of elephants, deer, and others into these caves, to devour them at leisure. Others asked if, in some cases, instinct did not impel sick animals, or animals broken down by old age, to seek such places for the purpose of dying in quiet; while others, again, suggested that these bones might have been engulfed pell-mell in the hole during some ancient inundation. However that may be, the remains discovered in these caves show that all these Mammals existed at the close of the Tertiary epoch, and that they all lived in England. What were the causes which led to their extinction?

It was the opinion of Cuvier and the early geologists that the ancient species were destroyed in some great and sudden catastrophe, from which none made their escape. But recent geologists trace their extinction to slow, successive, and determinative action due to local causes, the chief one being the gradual lowering of the temperature. We have seen that at the beginning of the Tertiary epoch, in the older Eocene age, palms, cocoa-nuts, and acacias, resembling those now met with in countries more favoured by the sun, grew in our island. The Miocene flora presents indications of a climate still warm, but less tropical; and the Pliocene period, which follows, contains remains which announce an approach to our present climate. In following the vegetable productions of the Tertiary epoch, the botanist meets with the floras of Africa, South America, and Australia, and finally settles in the flora of temperate Europe. Many circumstances demonstrate this decreasing temperature, until we arrive at what geologists call the *glacial period*—one of the winters of the ancient world.

But before entering on the evidences which exist of the glacial era we shall glance at the picture presented by the animals of the period; the vegetable products we need not dwell on—it is, in fact, that of our own era, the flora of temperate regions in our own epoch. The same remark would apply to the animals, but for some signal exceptions. In this epoch Man appears, and some of the Mammals of the last epoch, but of larger dimensions, have long disappeared. The more remarkable of these extinct animals we shall describe, as we have those belonging to anterior ages. They are not numerous; those of our hemisphere being the Mammoth, *Elephas primigenius*; the Bear, *Ursus spelæus*; gigantic Lion, *Felis spelæa*; Hyæna, *Hyæna spelæa*; Ox, *Bison priscus*, *Bos primigenius*; the gigantic Stag, *Cervus megaceros*; to which we may add the *Dinornis* and *Epiornis*, among birds. In America there existed in the Quaternary epoch some Edentates of colossal dimensions and of very peculiar structure, these were *Megatherium*, *Megalonyx*, and *Mylodon*; we shall pass these animals in review, beginning with those of our own hemisphere. [382]

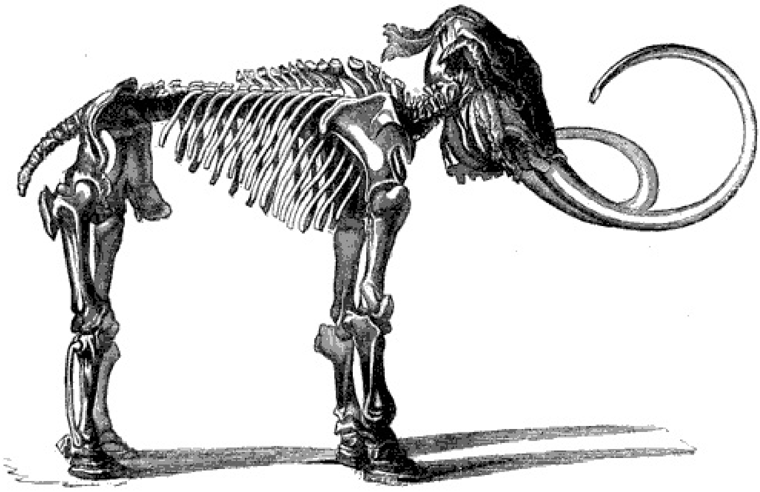


Fig. 180.—Skeleton of the Mammoth, Elephas primigenius.

The Mammoth, the skeleton of which is represented in Fig. 180, surpassed the largest existing Elephants of the tropics in size, for it was from sixteen to eighteen feet in height. The teeth, and the size of the monstrous tusks, much curved, and with a spiral turn outwards, and which were from ten to fifteen feet in length, serve to distinguish the Mammoth from the two Elephants living at the present day, the African and the Indian. The form of its teeth permits of its being distinguished from its ally, the Mastodon; for while the teeth of the latter have rough mammillations on their surface, those of the Mammoth, like those of the living Indian Elephant, have a broad united surface, with regular furrowed lines of large curvature. The teeth of the Mammoth are four in number, like the Elephants, two in each jaw when the animal is adult, its head is elongated, its forehead concave, its jaws curved and truncated in front. It has been an easy task, as we shall see, to recognise the general form and structure of the Mammoth, even to its skin. We know beyond a doubt that it was thickly covered with long shaggy hair, and that a copious mane floated upon its neck and along its back; its trunk resembled that of the Indian Elephant; its body was heavy, with a tail naked to the end, which was covered with thick tufty hair, and its legs were comparatively shorter than those of the latter animal, many of the habits of which it nevertheless possessed. Blumenbach gave it the specific name of *Elephas primigenius*.

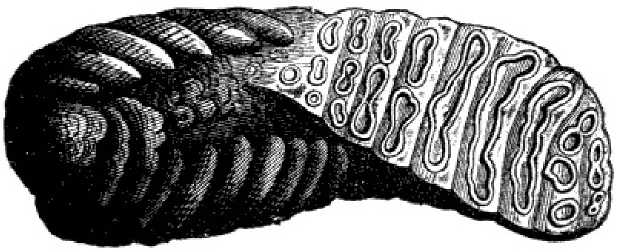


Fig. 181.—Tooth of the Mammoth.

In all ages, and in almost all countries, chance discoveries have been made of fossil bones of elephants in the soil. [383] Pliny has transmitted to us a tradition, recorded by the historian Theophrastus, who wrote 320 years before Jesus Christ, of the existence of bones of fossil ivory in the soil of Greece, that the bones were sometimes transformed into stones. [384] "These bones," the historian gravely tells us, "were both black and white, and born of the earth." Some of the elephant's bones having a slight resemblance to those of man, they have often been mistaken for human bones. In the earlier historic times these great bones, accidentally disinterred, have passed as having belonged to some hero or demigod; at a later period they were thought to be the bones of giants. We have already spoken of the mistake made by the Greeks in taking the patella of a fossil elephant for the knee-bone of Ajax; in the same manner the bones revealed by an earthquake, and attributed by Pliny to a giant, belonged, no doubt, to a fossil elephant. To a similar origin we may assign the pretended body of Orestes, thirteen feet in length, which was discovered at Tegea by the Spartans; those of Asterius, the son of Ajax, discovered in the Isle of Ladea, of ten cubits in length (about eighteen feet), according to Pausanius; finally, such were the great bones found in the Isle of Rhodes, of which Phlegon of Tralles speaks in his "Mundus Subterraneus."

We might fill volumes with the history of the remains of pretended giants found in ancient tombs. The books, in fact, which exist, formed a voluminous literature in the middle ages—entitled *Gigantology*. All the facts, more or less real, true or imaginative, may be explained by the accidental discovery of the bones of some of these gigantic animals. We find in works on Gigantology, the history of a pretended giant, discovered in the 4th century, at Trapani in Sicily, of which Boccaccio speaks, and which may be taken for Polyphemus; of another, found in the 16th century, according to Fasellus, near Palermo; others, according to the same author, at Melilli between Leontium and Syracuse, Calatrasi and Petralia, at each of which places the bones [385] of supposed giants were disinterred. P. Kircher speaks of three other giants being found in Sicily, of which only the teeth remained perfect.

In 1577, a storm having uprooted an oak near the cloisters of Reyden, in the Canton of Lucerne, in Switzerland, some large bones were exposed to view. Seven years after, the celebrated physician and Professor at Basle, Felix Pläten, being at Lucerne, examined these bones, and declared they could only be those of a giant. The Council of Lucerne consented to send the bones to Basle for more minute examination, and Pläten thought himself justified in attributing to the giant a height of nineteen feet. He designed a human skeleton on this scale, and returned the bones with the drawing to Lucerne. In 1706 there only remained of these bones a portion of the scapula and a fragment of the wrist bone; the anatomist Blumenbach, who saw them at the beginning of the century, easily recognised in them the bones of an Elephant. Let us not omit to add, as a complement to this story, that since the sixteenth century, the inhabitants of Lucerne have adopted the image of this fabulous giant as the supporter of the city arms.

Spanish history preserves many stories of giants. The supposed tooth of St. Christopher, shown at Valence, in the church dedicated to the saint, was certainly the molar tooth of a fossil Elephant; and in 1789, the canons of St. Vincent carried through the streets in public procession, to procure rain, the pretended arm of a saint, which was nothing more than the femur of an Elephant.

In France, in the reign of Charles VII. (1456), some of these bones of imaginary giants appeared in the bed of the Rhône. A repetition of the phenomenon occurred near Saint-Peirat, opposite Valence, when the Dauphin, afterwards Louis XI., then residing at the latter place, caused the bones to be gathered together and sent to Bourges, where they long remained objects of public curiosity in the interior of the Sainte-Chapelle. In 1564 a similar discovery took place in the same neighbourhood. Two peasants observed on the banks of the Rhône, along a slope, some great bones sticking out of the ground. They carried them to the neighbouring village, where they were examined by Cassanion, who lived at Valence. It was no doubt apropos to this that Cassanion wrote his treatise "De Gigantibus." The description given by the author of a tooth sufficed, according to Cuvier, to prove that it belonged to an Elephant; it was a foot in length, and weighed eight pounds. It was also on the banks of the Rhône, but in Dauphiny, as we have seen, that the [386]
skeleton of the famous Teutobocchus, of which we have spoken in a previous chapter, was found.

In 1663 Otto de Guericke, the illustrious inventor of the air-pump, witnessed the discovery of the bones of an Elephant, buried in the shelly limestone, or Muschelkalk. Along with it were found its enormous tusks, which should have sufficed to establish its zoological origin. Nevertheless they were taken for horns, and the illustrious Leibnitz composed, out of the remains, a strange animal, carrying a horn in the middle of its forehead, and in each jaw a dozen molar teeth a foot long. Having fabricated this fantastic animal, Leibnitz named it also—he called it the *fossil unicorn*. In his "Protogæa," a work remarkable besides as the first attempt at a theory of the earth, Leibnitz gave the description and a drawing of this imaginary animal. During more than thirty years the unicorn of Leibnitz was universally accepted throughout Germany; and nothing less than the discovery of the entire skeleton of the Mammoth in the valley of the Unstrut was required to produce a change of opinion. This skeleton was at once recognised by Tinzel, librarian to the Duke of Saxe-Gotha, as that of an Elephant, and was established as such; not, however, without a keen controversy with adversaries of all kinds.

In 1700 a soldier of Würtemberg accidentally observed some bones showing themselves projecting out of the earth, in an argillaceous soil, near the city of Canstadt, not far from the banks of the Necker. Having addressed a report to the reigning Duke, the latter caused the place to be excavated, which occupied nearly six months. A veritable cemetery of elephants was discovered, in which were not less than sixty tusks. Those which were entire were preserved; the fragments were abandoned to the court physician, and they became a mere vulgar medicine. In the last century the fossil bones of bears, which were abundant in Germany, were administered in that country medicinally, as an absorbent, astringent, and sudorific. It was then called by the German doctors the *Ebur fossile*, or *Unicornu fossile*, *Licorn fossil*. The magnificent tusks of the Mammoth found at Canstadt helped to combat fever and colic. What an intelligent man this court physician of Würtemberg must have been!

Numerous discoveries like those we have quoted distinguished the 18th century; but the progress of science has now rendered such mistakes as we have had to relate impossible. These bones were at length universally recognised as belonging to an Elephant, but erudition now intervened, and helped to obscure a subject which was otherwise perfectly clear. Some learned pedant declared that the bones found in Italy and France were the remains of the Elephants which [387]
Hannibal brought from Carthage with the army in his expedition against the Romans. The part of France where the most ancient bones of these Elephants were found is in the environs of the Rhône, and consequently on the route of the Carthaginian general, and this consideration appeared to these terrible savants to be a particularly triumphant answer to the naturalist's reasoning. Again, at a later period, Domitius Ænobarbus conducted the Carthaginian armies, which were followed by a number of Elephants, armed for war. Cuvier scarcely took the trouble to refute this insignificant objection. It is merely necessary to read, in his learned dissertation, of the number of elephants which could remain to Hannibal when he had entered Gaul.

But the best reply that can be made to this strange objection raised by the learned, is to show how extensively these fossil bones of Elephants are scattered, not in Europe only, but over the world—there are few regions of the globe in which their remains are not found. In the north of Europe, in Scandinavia, in Ireland, in Belgium, in Germany, in Central Europe, in Poland, in

Middle Russia, in South Russia, in Greece, in Italy, in Africa, in Asia, and, as we have seen, in England. In the New World remains of the Mammoth are also met with. What is most singular is that these remains exist more especially in great numbers in the north of Europe, in the frozen regions of Siberia—regions altogether uninhabitable for the Elephant in our days. “There is not,” says Pallas, “in all Asiatic Russia, from the Don to the extremity of the promontory of Tchutchis, a stream or river, especially of those which flow in the plains, on the banks of which some bones of Elephants and other animals foreign to the climate have not been found. But in the more elevated regions, the primitive and schistose chains, they are wanting, as are marine petrifactions. But in the lower slopes and in the great muddy and sandy plains, above all, in places which are swept by rivers and brooks, they are always found, which proves that we should not the less find them throughout the whole extent of the country if we had the same means of searching for them.”

Every year in the season when thaw takes place, the vast rivers which descend to the Frozen Ocean in the north of Siberia sweep down with their waters numerous portions of the banks, and expose to view bones buried in the soil and in the excavations left by the rushing waters. Cuvier gives a long list of places in Russia in which interesting discoveries have been made of Elephants’ bones; and it is certainly curious that the more we advance towards the north in Russia the more numerous and extensive do the bone depositories become. In spite of the oft-repeated and [388]
undoubted testimony of numerous travellers, we can scarcely credit the statements made respecting some of the islands of the glacial sea near the poles, situated opposite the mouth of the Lena and of the Indighirka. Here, for example, is an extract from “Billing’s Voyage” concerning these isles: “The whole island (which is about thirty-three leagues in length), except three or four small rocky mountains, is a mixture of ice and sand; and as the shores fall, from the heat of the sun’s thawing them, the tusks and bones of the mammont are found in great abundance. To use Chvoinoff’s own expression, the island is formed of the bones of this extraordinary animal, mixed with the horns and heads of the buffalo, or something like it, and some horns of the rhinoceros.”

New Siberia and the Lächow Islands off the mouth of the river Lena, are, for the most part, only an agglomeration of sand, ice, and Elephants’ teeth. At every tempest the sea casts ashore new quantities of mammoths’ tusks, and the inhabitants of Siberia carry on a profitable commerce in this fossil ivory. Every year, during the summer, innumerable fishermen’s barks direct their course towards this *isle of bones*; and, during winter, immense caravans take the same route, all the convoys drawn by dogs, returning charged with the tusks of the Mammoth, each weighing from 150 to 200 pounds. The fossil ivory thus withdrawn from the frozen north is imported into China and Europe, where it is employed for the same purposes as ordinary ivory, which is furnished, as we know, by the existing Elephant and Hippopotamus of Africa and Asia.

The *Isle of Bones* has served as a quarry of this valuable material, for export to China, for 500 years; and it has been exported to Europe for upwards of 100. But the supply from these strange diggings apparently remains practically undiminished. What a number of accumulated generations of these bones and tusks does not this profusion imply!

It was in Siberia that the fossil Elephant received the name of the *Mammoth*, and its tusks that of *mammoth horns*. The celebrated Russian savant, Pallas, who gave the first systematic description of the Mammoth, asserts that the name is derived from the word *mama*, which in the Tartar idiom signifies the *earth*. According to others, the name is derived from *behemoth*, mentioned in the Book of Job; or from the epithet *mahemoth*, which the Arabs add to the word “elephant,” to designate one of unusual size. A curious circumstance enough is, that this same legend of an animal living exclusively under ground, exists amongst the Chinese. They call it *tien-schu*, and we [389]
read, in the great Chinese work on natural history, which was written in the sixteenth century: “The animal named *tien-schu*, of which we have already spoken in the ancient work upon the ceremonial entitled “Lyki” (a work of the fifth century before Jesus Christ), is called also *tyn-schu* or *yn-schu*, that is to say, *the mouse which hides itself*. It always lives in subterranean caverns; it resembles a mouse, but is of the size of a buffalo or ox. It has no tail; its colour is dark; it is very strong, and excavates caverns in places full of rocks, and forests.” Another writer, quoting the same passage, thus expresses himself: “The *tyn-schu* haunts obscure and unfrequented places. It dies as soon as it is exposed to the rays of the sun or moon; its feet are short in proportion to its size, which causes it to walk badly. Its tail is a Chinese ell in length. Its eyes are small, and its neck short. It is very stupid and sluggish. When the inundations of the river *Tamschuann-tuy* took place (in 1571), a great many tyn-schu appeared in the plain; it fed on the roots of the plant *fu-kia*.”

The existence in Russia of the bones and tusks of the Mammoth is sufficiently confirmed by the following extract from an old Russian traveller, Ysbrants Ides, who, in 1692, was sent by Peter the Great as ambassador to the Emperor of China. In the extract which follows, we remark the very surprising fact of the discovery of a head and foot of the Mammoth which had been preserved in ice with all the flesh. “Amongst the hills which are situate north-east of the river Kata,” says the traveller, “the Mammuts’ tongues and legs are found, as they are also particularly on the shores of the river Jenize, Trugan, Mongamsea, Lena, and near Jakutskoi, even as far as the Frozen Ocean. In the spring, when the ice of this river breaks, it is driven in such vast quantities and with such force by the high swollen waters, that it frequently carries very high banks before it, and breaks off the tops of hills, which, falling down, discover these animals whole, or their teeth only, almost frozen to the earth, which thaw by degrees. I had a person with me who had annually gone out in search of these bones; he told it to me as a real truth, that he and his companions found the head of one of these animals, which was discovered by the fall of such a frozen piece of earth. As soon as he opened it, he found the greatest part of the flesh rotten, but it was not without difficulty that they broke out his teeth, which were placed in the fore-part of his mouth, as those of the Elephants are; they also took some bones out of his head, and afterwards came to his fore-foot, which they cut off, and carried part of it to the city of Trugan, the circumference of it being as large as that of the waist of an ordinary man. The bones [390] of the head appeared somewhat red, as though they were tinctured with blood.

“Concerning this animal there are very different reports. The heathens of Jakuti, Tungusi, and Ostiacki, say that they continually, or at least, by reason of the very hard frosts, mostly live under ground, where they go backwards and forwards; to confirm which they tell us, that they have often seen the earth heaved up when one of these beasts was upon the march, and after he was passed, the place sink in, and thereby make a deep pit. They further believe, that if this animal comes so near to the surface of the frozen earth as to smell the air, he immediately dies, which they say is the reason that several of them are found dead on the high banks of the river, where they unawares came out of the ground.

“This is the opinion of the Infidels concerning these beasts, which are never seen.

“But the old Siberian Russians affirm, that the Mammuth is very like the Elephant, with this difference only, that the teeth of the former are firmer, and not so straight as those of the latter. They also are of opinion that there were Elephants in this country before the Deluge, when this climate was warmer, and that their drowned bodies, floating on the surface of the water of that flood, were at last washed and forced into subterranean cavities; but that after this universal deluge, the air, which before was warm, was changed to cold, and that these bones have lain frozen in the earth ever since, and so are preserved from putrefaction till they thaw, and come to light, which is no very unreasonable conjecture, though it is not absolutely necessary that this climate should have been warmer before the Flood, since the carcases of the drowned elephants were very likely to float from other places several hundred miles distant to this country in the great deluge which covered the surface of the whole earth. Some of these teeth, which doubtless have lain the whole summer on the shore, are entirely black and broken, and can never be restored to their former condition. But those which are found in good case, are as good as ivory, and are accordingly transported to all parts of Muscovy, where they are used to make combs, and all other such-like things, instead of ivory.

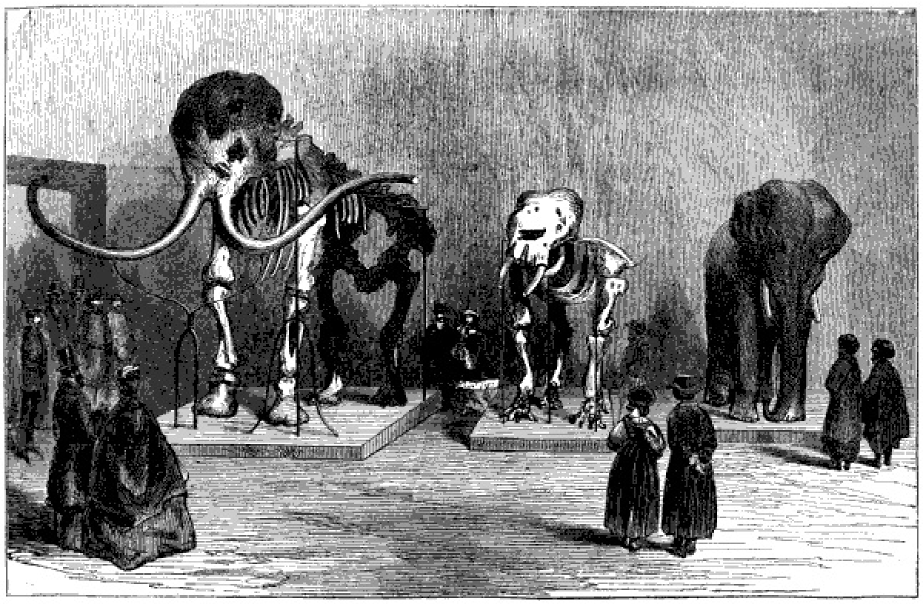
“The above-mentioned person also told me that he once found two teeth in one head that weighed above twelve Russian pounds, which amount to four hundred German pounds; so that these animals must of necessity be very large, though a great many lesser teeth are found. By all that I could gather from the heathens, no person ever saw one of these beasts alive, or can give any account of its shape; so that all we heard said on this subject arises from bare conjecture [391] only.”

It is possible this recital may seem suspicious to some readers. We have ourselves felt some difficulty in believing that this head and foot were taken from the ice, with the flesh and skin, when we consider that the animal to which they belonged has been extinct probably more than ten thousand years. But the assertion of Ysbrants Ides is confirmed by respectable testimony of more recent date. In 1800, a Russian naturalist, Gabriel Sarytschew, travelled in northern Siberia. Having arrived in the neighbourhood of the Frozen Ocean, he found upon the banks of the Alasœia, which discharges itself into this sea, the entire body of a Mammoth enveloped in a mass of ice. The body was in a complete state of preservation, for the permanent contact of the ice had kept out the air and prevented decomposition. It is well known that at zero and below it, animal substances will not putrefy, so that in our households we can preserve all kinds of animal food as long as we can surround them with ice; and this is precisely what happened to the Mammoth found by Gabriel Sarytschew in the ice of the Alasœia. The rolling waters had disengaged the mass of ice which had imprisoned the monstrous pachyderm for thousands of years. The body, in a complete state of preservation and covered with its flesh as well as its entire hide, to which long hairs adhered in certain places, found itself, again, nearly erect on its four feet.

The Russian naturalist Adams, in 1806, made a discovery quite as extraordinary as the preceding. We borrow his account from a paper by Dr. Tilesius in the “Memoirs of the Imperial Academy of Sciences of St. Petersburg” (vol. v.). In 1799, a Tungusian chief, Ossip Schumachoff, while seeking for mammoth-horns on the banks of the lake Oncoul, perceived among the blocks of ice a shapeless mass, not at all resembling the large pieces of floating wood which are commonly found there. The following year he noticed that this mass was more disengaged from the blocks of ice, and had two projecting parts, but he was still unable to make out what it could be. Towards the end of the following summer one entire side of the animal and one of his tusks were quite free from the ice. But the succeeding summer of 1802, which was less warm and more windy than common, caused the Mammoth to remain buried in the ice, which had scarcely melted at all. At length, towards the end of the fifth year (1803), the ice between the earth and the Mammoth having melted faster than the rest, the plane of its support became inclined; and this enormous mass fell by its own weight on a bank of sand. In the month of March, 1804, [392] Schumachoff cut off the horns (the tusks), which he exchanged with the merchant Bultenof for goods of the value of fifty roubles (not quite eight pounds sterling). It was not till two years after this that Mr. Adams, of the St. Petersburg Academy, who was travelling with Count Golovkin, sent by the Czar of Russia on an embassy to China, having been told at Jakutsk of the discovery of an animal of extraordinary magnitude on the shores of the Frozen Ocean, near the mouth of the river Lena, betook himself to the place. He found the Mammoth still in the same place, but altogether mutilated. The Jakoutskis of the neighbourhood had cut off the flesh, with which they fed their dogs; wild beasts, such as white bears, wolves, wolverines, and foxes, had also fed upon it, and traces of their footsteps were seen around. The skeleton, almost entirely cleared of its flesh, remained whole, with the exception of one fore-leg. The spine of the back, one scapula, the pelvis, and the other three limbs were still held together by the ligaments and by parts of the skin; the other scapula was found not far off. The head was covered with a dry skin; one of the ears was furnished with a tuft of hairs; the balls of the eyes were still distinguishable; the brain still occupied the cranium, but seemed dried up; the point of the lower lip had been gnawed and the upper lip had been destroyed so as to expose the teeth; the neck was furnished with a long flowing mane; the skin, of a dark-grey colour, covered with black hairs and a reddish wool, was so heavy that ten persons found great difficulty in transporting it to the shore. There was collected, according to Mr. Adams, more than thirty-six pounds' weight of hair and wool which the white bears had trod into the ground, while devouring the flesh. This Mammoth was a male so fat and well fed, according to the assertion of the Tungusian chief, that its belly hung down below the joints of its knees. Its tusks were nine feet six inches in length, measured along the curve, and its head without the tusks weighed 414 pounds avoirdupois.

Mr. Adams took every care to collect all that remained of this unique specimen of an ancient creation, and forwarded the parts to St. Petersburg, a distance of 11,000 versts (7,330 miles). He succeeded in re-purchasing what he believed to be the tusks at Jakutsk, and the Emperor of Russia, who became the owner of this precious relic, paid him 8,000 roubles. The skeleton is deposited in the Museum of the Academy of St. Petersburg, and the skin still remains attached to the head and the feet. "We have yet to find," says Cuvier, "any individual equal to it."

[394]



XXVI.—Skeleton of the Mammoth in the St. Petersburg Museum.

Beside the skeleton of this famous Mammoth there is placed that of an Indian Elephant, and another Elephant with skin and hair, in order that the visitor may have a proper appreciation of the vast proportions of the Mammoth, as compared with them. Plate XXVI., on the opposite page, represents the saloon of the Museum of St. Petersburg, which contains these three interesting remains. [395]

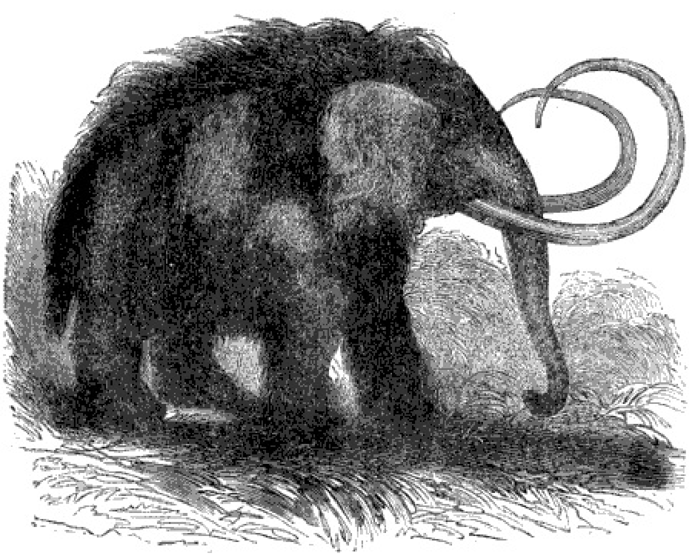


Fig. 182.—Mammoth restored.

In 1860 a great number of bones of the Mammoth, with remains of Hyæna, Horse, Reindeer, Rhinoceros-megarhinus, and Bison, were found in Belgium in digging a canal at Lierre, in the province of Antwerp. An entire skeleton of a young Mammoth, eleven feet six inches high (to the shoulder), has been reconstructed from these remains by M. Dupont, and is now placed in the Royal Museum of Natural History in Brussels.[98]

We cannot doubt, after such testimony, of the existence in the frozen north, of the almost entire [396]
remains of the Mammoth. The animals seem to have perished suddenly; enveloped in ice at the moment of their death, their bodies have been preserved from decomposition by the continued action of the cold. If we suppose that one of those animals had sunk into a marsh which froze soon afterwards, or had fallen accidentally into the crevasse of some glacier, it would be easy for us to understand how its body, buried immediately under eternal ice, had remained there for thousands of years without undergoing decomposition.

In Cuvier's great work on *fossil bones*, he gives a long and minute enumeration of the various regions of Germany, France, Italy, and other countries, which have furnished in our days bones or tusks of the Mammoth. We venture to quote two of these descriptions:—"In October, 1816," he says, "there was discovered at Seilberg, near Canstadt, in Würtemberg, near which some remarkable discoveries were made in 1700, a very remarkable deposit, which the king, Frederick I., caused to be excavated, and its contents collected with the greatest care. We are even assured that the visit which the prince, in his ardour for all that was great, paid to this spot, aggravated the malady of which he died a few days after. An officer, Herr Natter, commenced some excavations, and in four-and-twenty hours discovered twenty-one teeth or fragments of teeth of elephant, mixed with a great number of bones. The king having ordered him to continue the excavations, on the second day they came upon a group of thirteen tusks heaped close upon each other, and along with them some molar teeth, lying as if they had been packed artificially. It was on this discovery that the king caused himself to be transported thither, and ordered all the surrounding soil to be dug up, and every object to be carefully preserved in its original position. The largest of the tusks, though it had lost its points and its roots, was still eight feet long and one foot in diameter. Many isolated tusks were also found, with a quantity of molar teeth, from two inches to a foot in length, some still adhering to the jaws. All these fragments were better preserved than those of 1700, which was attributed to the depth of the bed, and, perhaps, to the nature of the soil. The tusks were generally much curved. In the same deposit some bones of Horses and Stags were found, together with a quantity of teeth of the Rhinoceros, and others which were thought to belong to a Bear, and one specimen which was attributed to the Tapir. The place where this discovery was made is named Seilberg; it is about 600 paces from the city of Canstadt, but on the opposite side of the Necker.

"All the great river basins of Germany have, like those of the Necker, yielded fossil bones of the [397]
Elephant; those especially abutting on the Rhine are too numerous to be mentioned, nor is Canstadt the only place in the valley of the Necker where they are found."

But of all parts of Europe, that in which they are found in greatest numbers is the valley of the Upper Arno. We find there a perfect cemetery of Elephants. These bones were at one time so common in this valley, that the peasantry employed them, indiscriminately with stones, in constructing walls and houses. Since they have learned their value, however, they reserve them for sale to travellers.

The bones and tusks of the Mammoth are met with in America as well as in the Old World, scattered through Canada, Oregon, and the Northern States as far south as the Gulf of Mexico. Cuvier enumerates several places on that continent where their remains are met with, mingled with those of the Mastodon. The Russian Lieutenant Kotzebue found them on the north coast of America, in the cliffs of frozen mud in Eschsholtz Bay, within Behring's Strait, and in other distant parts of the shores of the Arctic Seas, where they were so common that the sailors burnt many pieces in their fires.

It is very strange that the East Indies, that is, one of the only two regions which is now the home of the Elephant, should be almost the only country in which the fossil bones of these animals have not been discovered. In short, from the preceding enumeration, it appears that, during the geological period whose history we are recording the gigantic Mammoth inhabited most regions of the globe. Now-a-days, the only climates which are suited for the existing race of Elephants are those of Africa and India, that is to say, tropical countries; from which we must draw the conclusions to which so many other inferences lead, that, at the epoch in which these animals lived, the temperature of the earth was much higher than in our days; or, more probably, the extinct race of Elephants must have been adapted for living in a colder climate than that which they now require.

Among the antediluvian Carnivora, one of the most formidable seems to have been the *Ursus spelæus*, or Cave-bear (Fig. 183). This species must have been a fifth, if not a fourth, larger than the Brown Bear of our days. It was also more squat: some of the skeletons we possess are from nine to ten feet long, and only about six feet high. The *U. spelæus* abounded in England, France,
Belgium, and Germany; and so extensively in the latter country, that the teeth of the antediluvian [398]
Bear, as we have already stated, formed for a long time part of its materia medica, under the name of *fossil licorn*. Fig. 183 represents the skull of the Cave-bear.

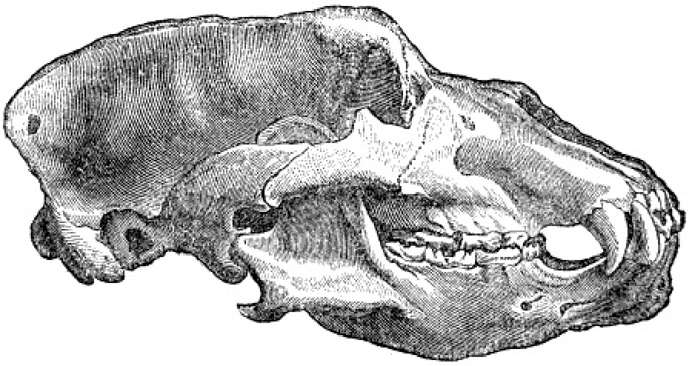


Fig. 183.—Head of Ursus spelæus.

At the same time with the *Ursus spelæus* another Carnivore, the *Felis spelæus*, or Cave-lion, lived in Europe. This animal is specifically identical with the living Lion of Asia and Africa: but since in these early times he had not to contend with the hunter for food, he was, on the whole, considerably larger than any Lion now existing on the earth.

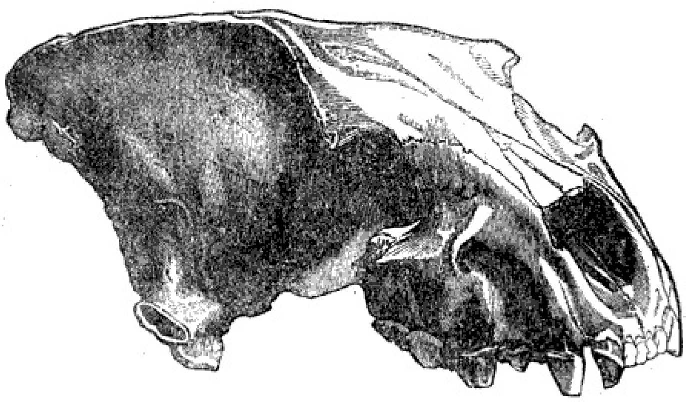


Fig. 184.—Head of Hyæna spelæa.

The Hyænas of our age consist of two species, the striped and the spotted Hyænas. The last presents considerable conformity in its structure with that of the Post-pliocene period, which Cuvier designates under the name of the fossil Spotted Hyæna. It seems to have been only a little larger than the existing species. Fig. 184 represents the head of the *Hyæna spelæa*, whose remains, with those of others, were found in the caves of Kirkdale and Kent's Hole; the remains of about 300 being found in the former. Dr. Buckland satisfied himself, from the quantity of their dung, that the Hyænas had lived there. In the cave were found remains of the ox, young elephant, rhinoceros, horse, bear, wolf, hare, water-rat, and several birds. All the bones present an appearance of having been broken and gnawed by the teeth of the Hyænas, and they occur confusedly mixed in loam or mud, or dispersed through the crust of stalagmite which covered the contents of the cave.

The Horse dates from the Quaternary epoch, if not from the last period of the Tertiary epoch. Its [399] remains are found in the same rocks with those of the Mammoth and the Rhinoceros. It is distinguished from our existing Horse only by its size, which was smaller—its remains abound in the Post-pliocene rocks, not only in Europe, but in America; so that an aboriginal Horse existed in the New World long before it was carried thither by the Spaniards, although we know that it was unknown at the date of their arrival. "Certainly it is a marvellous fact in the history of the Mammalia, that in South America, a native horse should have lived and disappeared, to be succeeded in after ages by the countless herds descended from the few introduced with the Spanish colonists!"[99]

The Oxen of the period, if not identical with, were at least very near to our living species. There were three species: the *Bison priscus*, *B. primigenius*, and *B. Pallasii*; the first with slender legs, with convex frontal, broader than it was high, and differing but slightly from the *Aurochs*, except in being taller and by having larger horns. The remains of *Bison priscus* are found in England, France, Italy, Germany, Russia, and America. *Bison primigenius* was, according to Cuvier, the source of our domestic cattle. The *Bos Pallasii* is found in America and in Siberia, and resembles in many respects the Musk-ox of Canada.

Where these great Mammals are found we generally discover the fossil remains of several species of Deer. The palæontological question as regards these animals is very obscure, and it is [400] often difficult to determine whether the remains belong to an extinct or an existing species. This doubt does not extend, however, to the gigantic forest-stag, *Cervus megaceros*, one of the most magnificent of the antediluvian animals, whose remains are still frequently found in Ireland in the neighbourhood of Dublin; more rarely in France, Germany, Poland, and Italy. Intermediate between the Fallow-deer and the Elk, the *Cervus megaceros* partakes of the Elk in its general proportions and in the form of its cranium, but it approaches the Fallow-deer in its size and in the disposition of its horns. These magnificent appendages, however, while they decorated the head of the animal and gave a most imposing appearance to it, must have sadly impeded its progress through the thick and tangled forests of the ancient world. The length of these horns was between nine and ten feet; and they were so divergent that, measured from one extremity to the other, they occupied a space of between three and four yards.

The skeleton of the *Cervus megaceros* is found in the deposits of calcareous tufa, which underlie the immense peat moss of Ireland; sometimes in the turf itself, as near the Curragh in Kildare; in which position they sometimes occur in little mounds piled up in a small space, and nearly always in the same attitude, the head aloft, the neck stretched out, the horns reversed and thrown downwards towards the back, as if the animal, suddenly immersed into marshy ground, had been under the necessity of throwing up its head in search of respirable air. In the Geological Cabinet of the Sorbonne, at Paris, there is a magnificent skeleton of *Cervus megaceros*; another belongs to the College of Surgeons in London; and there is a third at Vienna.

The most remarkable creatures of the period, however, were the great Edentates—the Glyptodon, the gigantic Megatherium, the Mylodon and the Megalonyx. The order of Edentates is more particularly characterised by the absence of teeth in the fore part of the mouth. The masticating apparatus of the Edentates consists only of molars, the incisors and canine teeth being, with a few exceptions, absent altogether, as the animals composing this order feed chiefly on insects or the tender leaves of plants. The Armadillo, Anteater and Pangolin, are the living examples of the order. We may add, as still further characteristics, largely developed claws at the extremities of the toes. The order seems thus to establish itself as a zoological link in the chain between the hoofed Mammals and the ungulated animals, or those armed with claws. All these animals are [401]
peculiar to the continent of America.

The *Glyptodon*, which appears during the Quaternary period, belonged to the family of Armadilloes, and their most remarkable feature was the presence of a hard, scaly shell, or coat of mail six feet in length, and composed of numerous segments, which covered the entire upper service of the animal from the head to the tail. It was, in short, a mammiferous animal, which appears to have been enclosed in a shell like that of a Turtle; it resembled in many respects the *Dasypus* or Anteater, and had sixteen teeth in each jaw. These teeth were channelled laterally with two broad and deep grooves, which divided the surface of the molars into three parts, whence it was named the Glyptodon. The hind feet were broad and massive, and evidently designed to support a vast incumbent mass; it presented phalanges armed with short thick and depressed nails or claws. The animal was, as we have said, enveloped in, and protected by, a cuirass, or solid carapace, composed of plates which, seen from beneath, appeared to be hexagonal and united by denticulated sutures: above they represented double rosettes. The habitat of *Glyptodon clavipes* was the pampas of Buenos Ayres, and the banks of an affluent of the Rio Santo, near Monte Video; specimens have been found not less than nine feet in length.

The tesselated carapace of the Glyptodon was long thought to belong to the Megatherium; but Professor Owen shows, from the anatomical structure of the two animals, that the cuirass belonged to one of them only, namely, the Glyptodon.

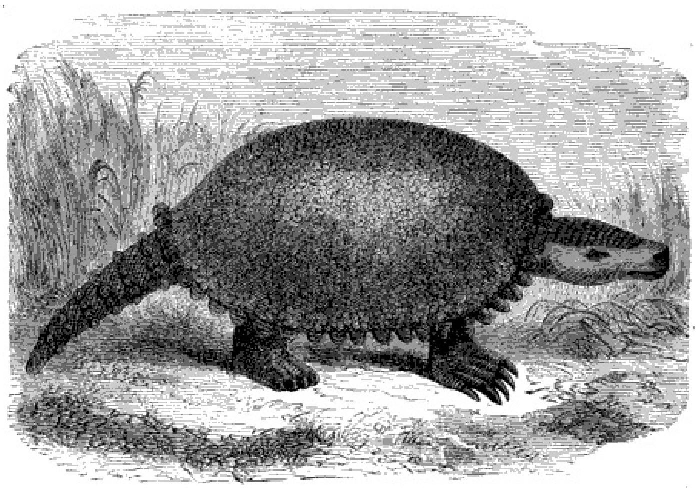


Fig. 185.—Schistopleuron typus. One-twentieth natural size.

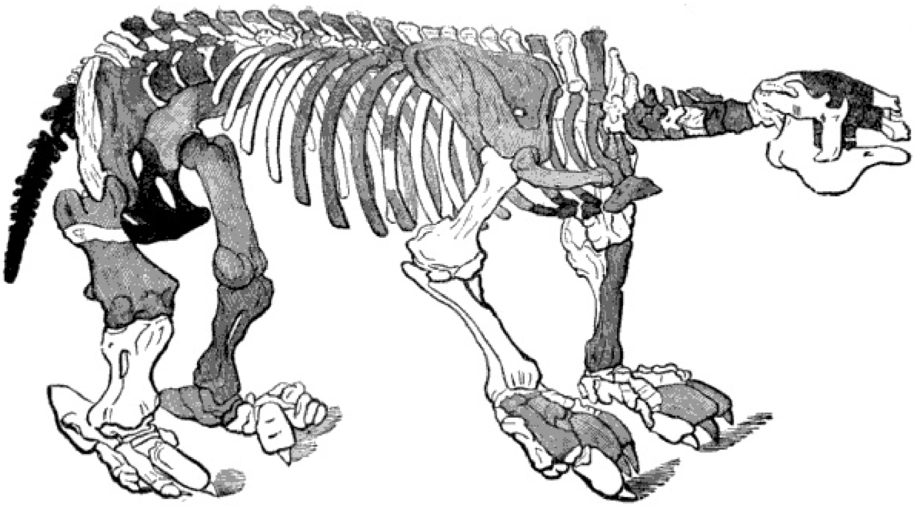
The *Schistopleuron* does not differ essentially from the Glyptodon, but is supposed to have been a different species of the same genus; the chief difference between the two animals being in the structure of the tail, which is massive in the first and in the other composed of half a score of rings. In other respects the organisation and habits are similar, both being herbivorous, and feeding on roots and vegetables. Fig. 185 represents the *Schistopleuron typus* restored, and as it appeared when alive.

Some of the fossil Tortoises discovered in the sub-Himalayan beds possessed a carapace twelve feet long by six feet in breadth, which must have corresponded to an animal from eighteen to twenty feet in length; and the bones of the legs were as massive as those of the Rhinoceros.

The *Megatherium*, or Animal of Paraguay, as it was called, is, at first view, the oddest and most remarkable animal we have yet had under consideration, where all have been, according to our notions, strange, extraordinary, and formidable. The animal creation still goes on as if— [402]

"Nature made them and then broke the die."

[403]



XXVII.—Skeleton of the Megatherium (Clift).

If we cast a glance at the skeleton figured on the opposite page (Plate XXVII.), which was found in Paraguay, at Buenos Ayres, in 1788, and which is now placed, in a perfect state of preservation, in the Museum of Natural History in Madrid, it is impossible to avoid being struck with its unusually heavy form, at once awkward as a whole, and ponderous in most of its parts. It is allied to the existing genus of Sloths, which Buffon tells us is "of all the animal creation that which has received the most vicious organisation—a being to which Nature has forbidden all enjoyment; which has only been created for hardships and misery." This notion of the romantic Buffon is, however, altogether incorrect. An attentive examination of the *Animal of Paraguay* [405] shows that its organisation cannot be considered either odd or awkward when viewed in connection with its mode of life and individual habits. The special organisation which renders the movements of the Sloths so sluggish, and apparently so painful on level ground, gives them, on the other hand, marvellous assistance when they live in trees, the leaves of which constitute their exclusive food. In the same manner, if we consider that the *Megatherium* was created to burrow in the earth and feed upon the roots of trees and shrubs, every organ of its heavy frame would appear to be perfectly appropriate to its kind of life, and well adapted to the special purpose which was assigned to it by the Creator. We ought to place the Megatherium between the Sloths and the Anteaters. Like the first, it usually fed on the branches and leaves of trees; like the latter, it burrowed deep in the soil, finding there both food and shelter. It was as large as an Elephant or Rhinoceros of the largest species. Its body measured twelve or thirteen feet in length, and it was between five and six feet high. The engraving on page 403 (Plate XXVII.) will convey, more accurately than any mere verbal description, an idea of the form and proportions of the animal.

The English reader is chiefly indebted to the zeal and energy of Sir Woodbine Parish for the materials from which our naturalists have been enabled to re-construct the history of the Megatherium. The remains collected by him were found in the river Salado, which runs through the flat alluvial plains called Pampas to the south of the city of Buenos Ayres. A succession of three unusually dry seasons had lowered the waters to such a degree as to expose part of the pelvis to view, as the skeleton stood upright in the mud forming the bed of the river. Further inquiries led to the discovery of the remains of two other skeletons near the place where the first had been found; and with them an immense shell or carapace was met with, most of the bones associated with which crumbled to pieces on exposure to the air. The osseous structure of this enormous animal, as furnished by Mr. Clift, an eminent anatomist of the day, and under whose superintendence the skeleton was drawn, must have exceeded fourteen feet in length, and upwards of eight feet in height. The deeply shaded parts of the figure show the portions which are deficient in the Madrid skeleton.

Cuvier pointed out that the skull very much resembled that of the Sloths, but that the rest of the skeleton bore relationship, partly to the Sloths, and partly to the Anteaters.

The large bones, which descend from the zygomatic arch along the cheek-bones, would furnish a powerful means of attaching the motor muscles of the jaws. The anterior part of the muzzle is [406] fully developed, and riddled with holes for the passage of the nerves and vessels which must have been there, not for a trunk, which would have been useless to an animal furnished with a very long neck, but for a snout analogous to that of the Tapir.

The jaw and dental apparatus cannot be exactly stated, because the number of teeth in the lower jaw is not known. The upper jaw, Professor Owen has shown, contained five molars on each side; and from comparison and analogy with the *Scelidotherium* it may be conjectured that the

Megatherium had four on each side of the lower jaw. Being without incisors or canines, the structure of its eighteen molars proves that it was not carnivorous: they each resemble the composite molars of the Elephant.

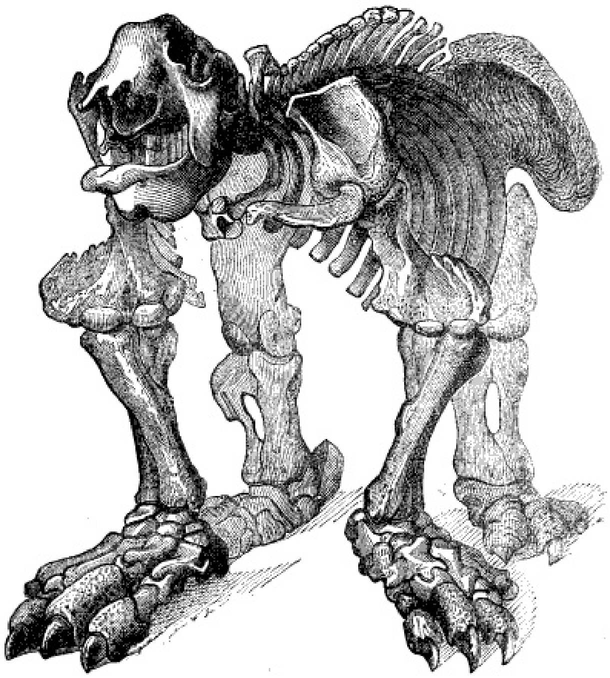


Fig. 186.—Skeleton of Megatherium foreshortened.

The vertebræ of the neck (as exhibited in the foreshortened figure (Fig. 186), taken from the work of Pander and D'Alton, and showing nearly a front view of the head), as well as the anterior and posterior extremities of the Madrid skeleton, although powerful, are not to be compared in dimensions to those of the other extremity of the body; for the head seems to have been relatively light and defenceless. The lumbar vertebræ increase in a degree corresponding to the enormous enlargement of the pelvis and the posterior members. The vertebræ of the tail are enormous, as is seen in Fig. 187, which represents the bones of the pelvis and hind foot, discovered by Sir Woodbine Parish, and now in the Museum of the College of Surgeons. If we add to these osseous organs the muscles, tendons, and integuments which covered them, we must admit that the tail of the *Megatherium* could not be less than two feet in diameter. It is probable that, like the Armadillo, it employed the tail to assist in supporting the enormous weight of its body; it would also be a formidable defensive organ when employed, as is the case with the Pangolins and Crocodiles. The fore-feet would be about three feet long and one foot broad. They would form a powerful implement for excavating the earth, to the greatest depths at which the roots of vegetables penetrate. The fore-feet rested on the ground to their full length. Thus solidly supported by the two hind-feet and the tail, and in advance by one of the fore-feet, the animal could employ the fore-foot left at liberty in clearing away the earth, in digging up the roots of trees, or in tearing down the branches; the toes of the fore-feet were, for this purpose, furnished with large and powerful claws, which lie at an oblique angle relatively to the ground, much like the burrowing talons of the mole.

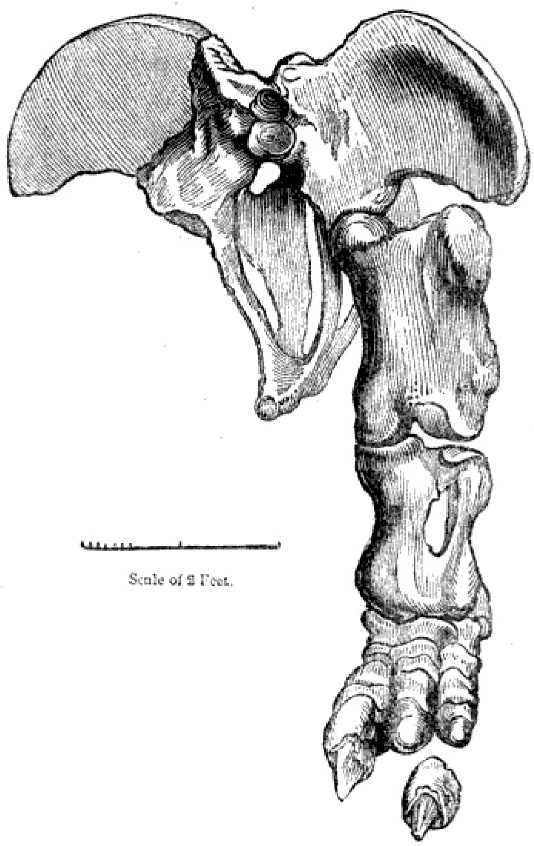


Fig. 187.—Bones of the pelvis of the Megatherium.

The solidity and size of the pelvis must have been enormous; its immense iliac bones are nearly at right angles with the vertebral column; their external edges are distant more than a yard and a half from each other when the animal is standing. The femur is three times the thickness of the thigh-bone of the Elephant, and the many peculiarities of structure in this bone appear to have been intended to give solidity to the whole frame, by means of its short and massive proportions. The two bones of the leg are, like the femur, short, thick, and solid; presenting proportions which we only meet with in the Armadilloes and Anteaters; burrowing animals with which, as we have said, its two extremities seem to connect it.

The anatomical organisation of these members denotes heavy, slow, and powerful locomotion, but solid and admirable combinations for supporting the weight of an enormous sedentary creature; a sort of excavating machine, slow of motion but of incalculable power for its own purposes. In short, the *Megatherium* exceeded in dimensions all existing Edentates. It had the head and shoulders of the Sloth, the feet and legs combined the characteristics of the Anteaters and Sloths, of enormous size, since it was at least twelve feet long when full grown, its feet armed with gigantic claws, and its tail at once a means of supporting its huge body and an instrument of defence. An animal built with such massive proportions could evidently neither creep nor run; its walk would be excessively slow. But what necessity was there for rapid movement in a being only occupied in burrowing under the earth, seeking for roots, and which [409] would consequently rarely change its place? What need had it of agility to fly from its enemies, when it could overthrow the Crocodile with a sweep of its tail? Secure from the attacks of other animals, this robust herbivorous creature, of which Figure 188 is a restoration, must have lived peacefully and respected in the solitary pampas of America.

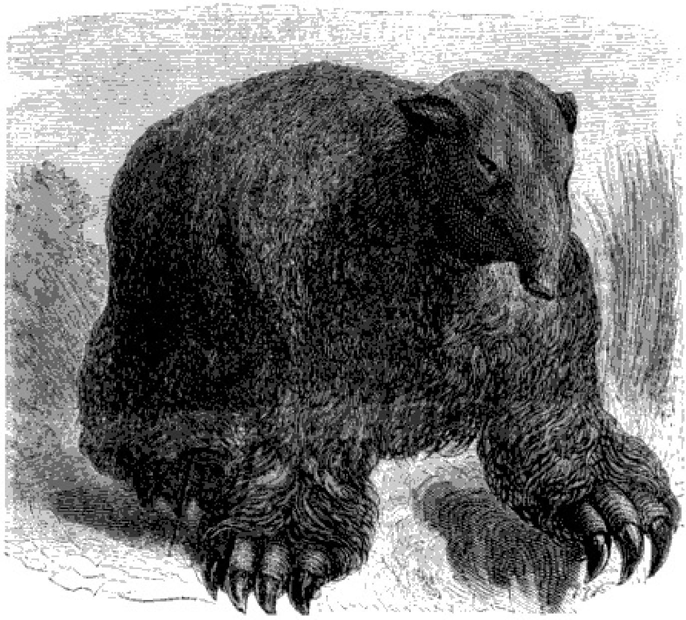


Fig. 188.—Megatherium restored.

The immediate cause of the extinction of the Megatherium is, probably, to be found in causes which are still in operation in South America. The period between the years 1827 and 1830 is called the "gran seco," or the great drought, in South America; and according to Darwin, the loss [410] of cattle in the province of Buenos Ayres alone was calculated at 1,000,000 head. One proprietor at San Pedro, in the middle of the finest pasture-country, had lost 20,000 cattle previously to those years. "I was informed by an eyewitness," he adds, "that the cattle, in herds of thousands, rushed into the Parana, and, being exhausted by hunger, they were unable to crawl up the muddy banks, and thus were drowned. The arm of the river which runs by San Pedro was so full of putrid carcases, that the master of a vessel told me that the smell rendered it quite impassable. All the small rivers became highly saline, and this caused the death of vast numbers in particular spots; for when an animal drinks of such water it does not recover. Azara describes the fury of the wild horses on a similar occasion: rushing into the marshes, those which arrived first being overwhelmed and crushed by those which followed."[100] The upright position in which the various specimens of Megatheria were found indicates some such cause of death; as if the ponderous animal, approaching the banks of the river, when shrunk within its banks, had been bogged in soft mud, sufficiently adhesive to hold it there till it perished.

Like the Megatherium, the *Mylodon* closely resembled the Sloth, and it belonged exclusively to the New World. Smaller than the Megatherium, it differed from it chiefly in the form of the teeth. These organs presented only molars with smooth surfaces, indicating that the animal fed on vegetables, probably the leaves and tender buds of trees. As the Mylodon presents at once hoofs and claws on each foot, it has been thought that it formed the link between the hoofed, or ungulated animals and the Edentates. Three species are known, which lived in the pampas of Buenos Ayres.

In consequence of some hints given by the illustrious Washington, Mr. Jefferson, one of his successors as President of the United States, discovered, in a cavern of Western Virginia, the bones of a species of gigantic Sloth, which he pronounced to be the remains of some carnivorous animal. They consisted of a femur, a humerus, an ulna, and three claws, with half a dozen other bones of the foot. These bones Mr. Jefferson believed to be analogous to those of the lion. Cuvier saw at once the true analogies of the animal. The bones were the remains of a species of gigantic Sloth; the complete skeleton of which was subsequently discovered in the Mississippi, in such a perfect state of preservation that the cartilages, still adhering to the bones, were not [411] decomposed. Jefferson called this species the *Megalonyx*. It resembled in many respects the Sloth. Its size was that of the largest ox; the muzzle was pointed; the jaws were armed with cylindrical teeth; the anterior limbs much longer than the posterior; the articulation of the foot oblique to the leg; two great toes, short, and armed with long and very powerful claws; the index finger more slender, and armed also with a less powerful claw; the tail strong and solid: such were the salient points of the organisation of the *Megalonyx*, whose form was a little slighter than that of the *Megatherium*.

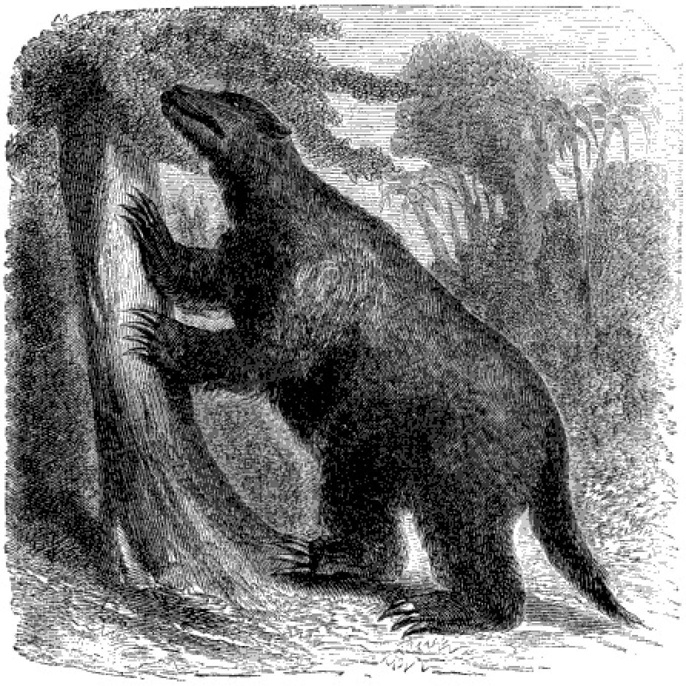


Fig. 189.—Mylodon robustus.

The country in which the Megatherium has been found is described by Mr. Darwin as belonging to the great Pampean formation, which consists partly of a reddish clay and in part of a highly calcareous marly rock. Near the coast there are some plains formed from the wreck of the upper [412] plain, and from mud, gravel, and sand thrown up by the sea during the slow elevation of the land, as shown by the raised beds of recent shells. At Punta Alta there is a highly-interesting section of one of the later-formed little plains, in which many remains of these gigantic land-animals have been found. These were, says Mr. Darwin:—"First, parts of three heads and other bones of the Megatherium, the huge dimensions of which are expressed by its name. Secondly, the *Megalonyx*, a great allied animal. Thirdly, the *Scelidotherium*, also an allied animal, of which I obtained a nearly perfect skeleton: it must have been as large as a rhinoceros; in the structure of its head it comes, according to Professor Owen, nearest to the Cape Anteater, but in some other respects it approaches to the Armadilloes. Fourthly, the *Mylodon Darwinii*, a closely related genus, of little inferior size. Fifthly, another gigantic edental quadruped. Sixthly, a large animal with an osseous coat, in compartments, very like that of an armadillo. Seventhly, an extinct kind of horse. Eighthly, a tooth of a pachydermatous animal, probably the same with the Macrauchenia, a huge beast with a long neck like a camel. Lastly, the Toxodon, perhaps one of the strangest animals ever discovered; in size it equalled an Elephant or Megatherium, but the structure of its teeth, as Professor Owen states, proves indisputably that it was intimately related to the Gnawers, the order which, at the present day, includes most of the smallest quadrupeds; in many details it is allied to the pachydermata; judging from the position of its eyes, ears, and nostrils, it was probably aquatic, like the Dugong and Manatee, to which it is allied. How wonderfully are the different orders—at the present time so well separated—blended together in different points in the structure of the Toxodon!"[101]

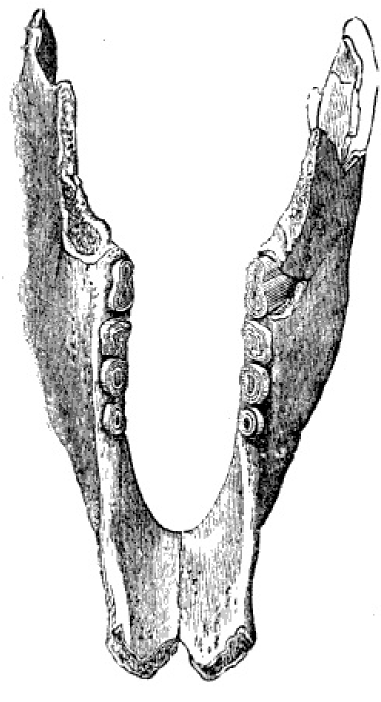


Fig. 190.—Lower jaw of the Mylodon.

The remains on which our knowledge of the *Scelidotherium* is founded include the cranium, which is nearly entire, with the teeth and part of the os hyoides, seven cervical, eight dorsal, and five sacral vertebræ, both the scapulæ, and some other bones. The remains of the cranium indicate that its general form was an elongated slender compressed cone, beginning behind by a flattened vertical base, expanding slightly to the cheek-bone, and thence contracting to the anterior extremity. All these parts were discovered in their natural relative positions, indicating, as Mr. Darwin observes, that the gravelly formation in which they were discovered had not been disturbed since its deposition. [413]

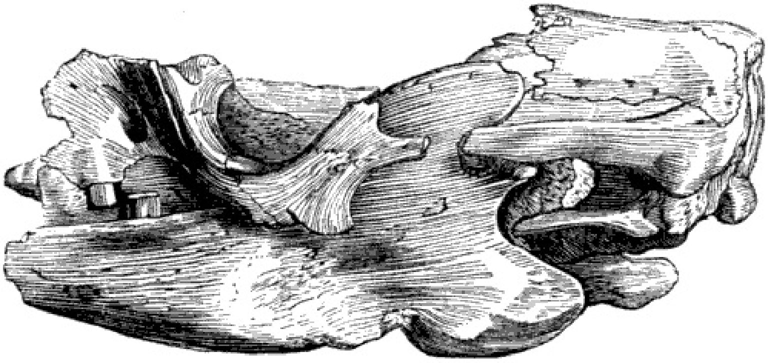
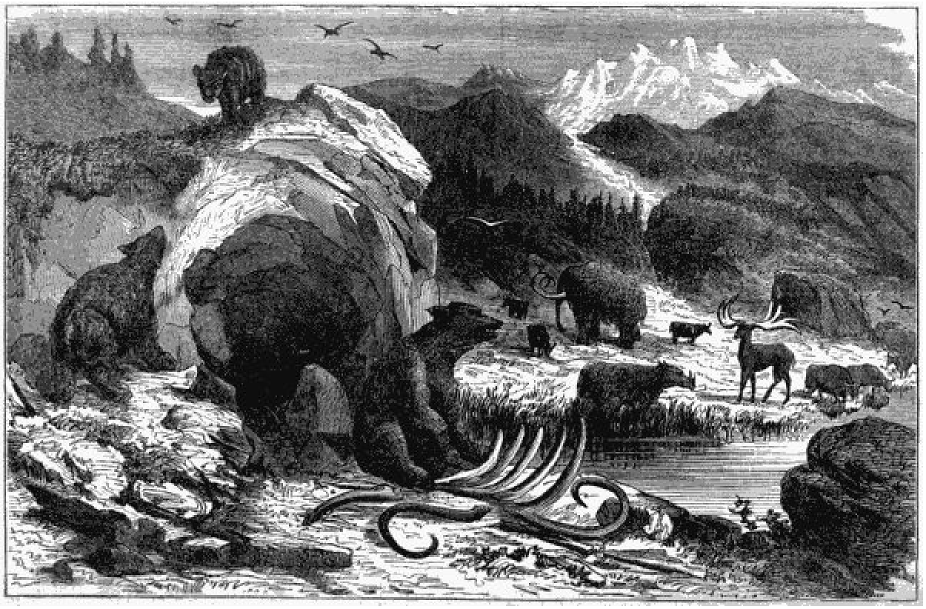


Fig. 191.—Skull of Scelidotherium.

The lower jaw-bone of *Mylodon*, which Mr. Darwin discovered at the base of the cliff called Punta Alta, in Northern Patagonia, had the teeth entire on both sides; they are implanted in deep sockets, and only about one-sixth of the last molar projects above the alveolus, but the proportion of the exposed part increases gradually in the inner teeth (Fig. 191).

“The habits of life of these Megatheroid animals were a complete puzzle to naturalists, until Professor Owen solved the problem with remarkable ingenuity. The teeth indicate, by their simple structure, that these Megatheroid animals lived on vegetable food, and probably on the leaves and small twigs of trees; their ponderous forms and great strong curved claws seem so little adapted for locomotion, that some eminent naturalists have actually believed that, like the Sloths, to which they are intimately related, they subsisted by climbing back downwards, on trees, and feeding on the leaves. It was a bold, not to say preposterous idea to conceive even antediluvian trees with branches strong enough to bear animals as large as elephants. Professor Owen, with far more probability, believes that, instead of climbing on the trees, they pulled the [414] branches down to them, and tore up the smaller ones by the roots, and so fed on the leaves. The colossal breadth and weight of their hinder quarters, which can hardly be imagined without having been seen, become, on this view, of obvious service instead of being an encumbrance; their apparent clumsiness disappears. With their great tails and their huge heels firmly fixed like a tripod in the ground, they could freely exert the full force of their most powerful arms and great claws. The *Mylodon*, moreover, was furnished with a long extensile tongue, like that of the giraffe, which by one of those beautiful provisions of Nature, thus reaches, with the aid of its long [417] neck, its leafy food.”[102]



XXVIII.—Ideal European Landscape in the Quaternary Epoch.

Fig. 192.—Dinornis, and Bos.

Two gigantic birds seem to have lived in New Zealand during the Quaternary epoch. The *Dinornis*, which, if we may judge from the *tibia*, which is upwards of three feet long, and from its eggs, which are much larger than those of the Ostrich, must have been of most extraordinary size for a bird. In Fig. 192 an attempt is made to restore this fearfully great bird, the *Dinornis*. As to the *Epiornis*, its eggs only have been found.

On the opposite page (Plate XXVIII.) an attempt is made to represent the appearance of Europe during the epoch we have under consideration. The Bear is seated at the mouth of its den—the cave (thus reminding us of the origin of its name of *Ursus spelæus*), where it gnaws the bones of the Elephant. Above the cavern the *Hyæna spelæa* looks out, with savage eye, for the moment when it will be prudent to dispute possession of these remains with its formidable rival. The great Wood-stag, with other great animals of the epoch, occupies the farthest shore of a small lake, where some small hills rise out of a valley crowned with the trees and shrubs of the period. Mountains, recently upheaved, rise on the distant horizon, covered with a mantle of frozen snow, reminding us that the glacial period is approaching, and has already begun to manifest itself.

All these fossil bones, belonging to the great Mammalia which we have been describing, are found in the Quaternary formation; but the most abundant of all are those of the Elephant and the Horse. The extreme profusion of the bones of the Mammoth, crowded into the more recently formed deposits of the globe, is only surpassed by the prodigious quantity of the bones of the Horse which are buried in the same beds. The singular abundance of the remains of these two animals proves that, during the Quaternary epoch, the earth gave nourishment to immense herds of the Horse and the Elephant. It is probable that from one pole to the other, from the equator to the two extremities of the axis of the globe, the earth must have formed a vast and boundless prairie, while an immense carpet of verdure covered its whole surface; and such abundant pastures would be absolutely necessary to sustain these prodigious numbers of herbivorous animals of great size.

The mind can scarcely realise the immense and verdant plains of this earlier world, animated by the presence of an infinity of such inhabitants. In its burning temperature, Pachyderms of [418] monstrous forms, but of peaceful habits, traversed the tall vegetation, composed of grasses of all sorts. Deer of gigantic size, their heads ornamented with enormous horns, escorted the heavy herds of the Mammoth; while the Horse, small in size and compact of form, galloped and frisked round these magnificent horizons of verdure which no human eye had yet contemplated.

Nevertheless, all was not quiet and tranquil in the landscapes of the ancient world. Voracious and formidable carnivorous animals waged a bloody war on the inoffensive herds. The Tiger, the Lion, and the ferocious Hyæna; the Bear, and the Jackal, there selected their prey. On the opposite page an endeavour is made to represent the great animals among the Edentates which inhabited the American plains during the Quaternary epoch (Plate XXIX). We observe there the Glyptodon, the Megatherium, the Mylodon, and, along with them, the Mastodon. A small Ape (the Orthopithecus), which first appeared in the Miocene period, occupies the branch of a tree in the landscape. The vegetation is that of tropical America at the present time.

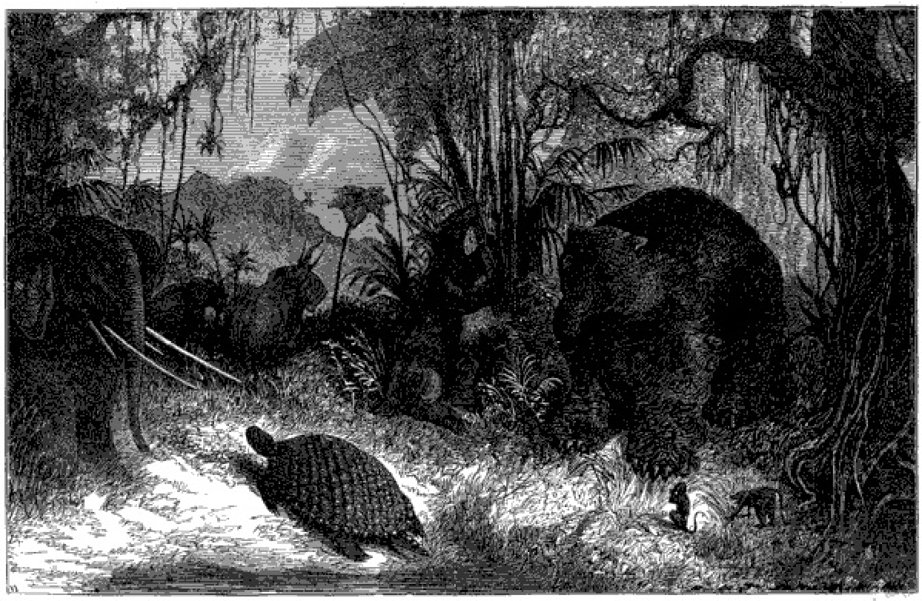
The deposits of this age, which are of later date than the Crag, and of earlier date than the Boulder Clay, with its fragments of rocks frequently transported from great distances, are classed under the term “pre-glacial.”

After the deposition of the Forest Bed, which is seen overlying the Crag for miles between high and low-water mark, on the shore west of Cromer, in Norfolk, there was a general reduction of temperature, and a period of intense cold, known as the “glacial period,” seems to have set in, during which a great part of what is now the British Islands was covered with a thick coating of ice, and probably united with the Continent.

At this time England south of the Bristol Channel (the estuary of the Severn), and the Thames, appears to have been above water. The northern part of the country, and the high-ground generally of Britain and Ireland were covered with gliding glaciers, by whose grinding action the whole surface became moulded and worn into its present shape, while the floating icebergs which broke off at the sea-side from these glaciers, conveyed away and dropped on the bed of the sea those fragments of rocks and the gravel and other earthy materials which are now generally recognised as glacial accumulations.

In all directions, however, proofs are being gradually obtained that, about this period, movements of submersion under the sea were in progress, all north of the Thames.

[419]



XXIX.—Ideal American Landscape in the Quaternary Epoch.

Ramsay points out indications, first of an intensely cold period, when land was much more elevated than it is now; then of submergence beneath the sea; and, lastly, re-elevation attended by glacial action. “When we speak of the vegetation and quadrupeds of Cromer Forest being pre-glacial,” says Lyell, “we merely mean that their formation preceded the era of the general submergence of the British Isles beneath the waters of the glacial sea. The successive deposits seen in direct superposition on the Norfolk coast,” adds Sir Charles, “imply at first the prevalence over a wide area of the Newer Pliocene Sea. Afterwards, the bed of the sea was converted into dry land, and underwent several oscillations of level, so as to be, first, dry land supporting a forest; then an estuary; then again land; and, finally, a sea near the mouth of a river, till the downward movement became so great as to convert the whole area into a sea of considerable depth, in which much floating ice, carrying mud, sand, and boulders melted, letting its burthen fall to the bottom. Finally, over the till with boulders stratified drift was formed; after which, but not until the total subsidence amounted to more than 400 feet, an upward movement began, which re-elevated the whole country, so that the lowest of the terrestrial formations, or the forest bed, was brought up to nearly its pristine level, in such a manner as to be exposed at a low tide. Both the descending and ascending movement seem to have been very gradual.” [421]

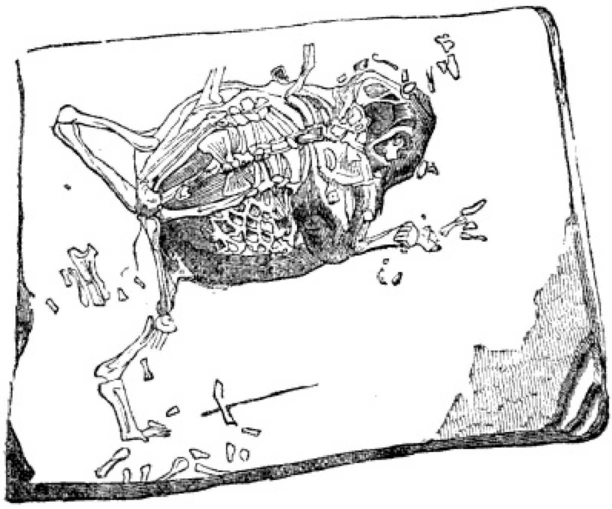


Fig. 193.—Palæophognos Gesneri. Fossil Toad.

EUROPEAN DELUGES. [422]

The Tertiary formations, in many parts of Europe, of more or less extent, are covered by an accumulation of heterogeneous deposits, filling up the valleys, and composed of very various materials, consisting mostly of fragments of the neighbouring rocks. The erosions which we remark at the bottoms of the hills, and which have greatly enlarged already existing valleys; the mounds of gravel accumulated at one point, and which is formed of rolled materials, that is to say, of fragments of rocks worn smooth and round by continual friction during a long period, in which they have been transported from one point to another—all these signs indicate that these denudations of the soil, these displacements and transport of very heavy bodies to great distances, are due to the violent and sudden action of large currents of water. An immense wave has been thrown suddenly on the surface of the earth, making great ravages in its passage, furrowing the earth and driving before it débris of all sorts in its disorderly course. Geologists give the name of *diluvium* to a formation thus removed and scattered, which, from its heterogeneous nature, brings under our eyes, as it were, the rapid passage of an impetuous torrent—a phenomenon which is commonly designated as a *deluge*.

To what cause are we to attribute these sudden and apparently temporary invasions of the earth’s surface by rapid currents of water? In all probability to the upheaval of some vast extent of dry land, to the formation of some mountain or mountain-range in the neighbourhood of the sea, or even in the bed of the sea itself. The land suddenly elevated by an upward movement of the terrestrial crust, or by the formation of ridges and furrows at the surface, has, by its reaction, violently agitated the waters, that is to say, the more mobile portion of the globe. By this new impulse the waters have been thrown with great violence over the earth, inundating the plains and valleys, and for the moment covering the soil with their furious waves, mingled with the earth, sand, and mud, of which the devastated districts have been denuded by their abrupt [423] invasion. The phenomenon has been sudden but brief, like the upheaval of the mountain or chain of mountains, which is presumed to have been the cause of it; but it was often repeated: witness the valleys which occur in every country, especially those in the neighbourhood of Lyons and of the Durance. These strata indicate as many successive deposits. Besides this, the displacement of blocks of minerals from their normal position is proof, now perfectly recognisable, of this great phenomenon.

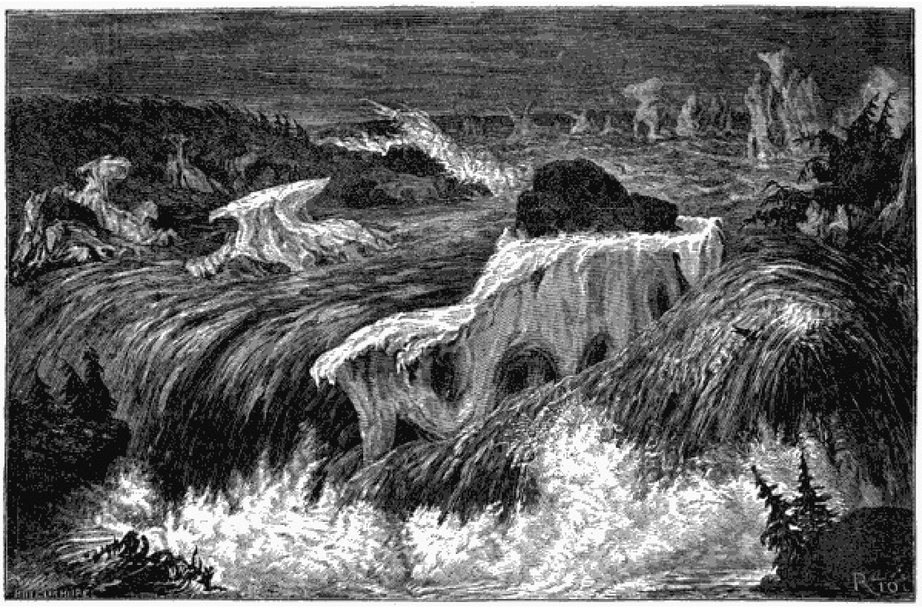
There have been, doubtless, during the epochs anterior to the Quaternary period of which we write, many deluges such as we are considering. Mountains and chains of mountains, through all the ages we have been describing, were formed by upheaval of the crust into ridges, where it was too elastic or too thick to be fractured. Each of these subterranean commotions would be provocative of momentary irruptions of the waves.

But the visible testimony to this phenomenon—the living proofs of this denudation, of this tearing away of the soil, are found nowhere so strikingly as in the beds superimposed, far and near, upon the Tertiary formations, and which bear the geological name of *diluvium*. This term was long employed to designate what is now better known as the “boulder” formation, a glacial deposit which is abundant in Europe north of the 50th, and in America north of the 40th, parallel, and re-appearing again in the southern hemisphere; but altogether absent in tropical regions. It consists of sand and clay, sometimes stratified, mixed with rounded and angular fragments of rock, generally derived from the same district; and their origin has generally been ascribed to a series of diluvial waves raised by hurricanes, earthquakes, or the sudden upheaval of land from the bed of the sea, which had swept over continents, carrying with them vast masses of mud and heavy stones, and forcing these stones over rocky surfaces so as to polish and impress them with furrows and striæ. Other circumstances occurred, however, to establish a connection between this formation and the glacial drift. The size and number of the erratic blocks increase as we travel towards the Arctic regions; some intimate association exists, therefore, between this formation and the accumulations of ice and snow which characterise the approaching glacial period.

As we have already stated at the beginning of this chapter, there is very distinct evidence of two successive deluges in our hemisphere during the Quaternary epoch. The two may be distinguished as the *European Deluge* and the *Asiatic*. The two European deluges occurred prior to the appearance of man; the Asiatic deluge happened after that event; and the human race, [424] then in the early days of its existence, certainly suffered from this cataclysm. In the present chapter we confine ourselves to the two cataclysms which overwhelmed Europe in the Quaternary epoch.

The first occurred in the north of Europe, where it was produced by the upheaval of the mountains of Norway. Commencing in Scandinavia, the wave spread and carried its ravages into those regions which now constitute Sweden, Norway, European Russia, and the north of Germany, sweeping before it all the loose soil on the surface, and covering the whole of Scandinavia—all the plains and valleys of Northern Europe—with a mantle of transported soil. As the regions in the midst of which this great mountainous upheaval occurred—as the seas surrounding these vast spaces were partly frozen and covered with ice, from their elevation and neighbourhood to the pole—the wave which swept these countries carried along with it enormous masses of ice. The shock, produced by the collision of these several solid blocks of frozen water, would only contribute to increase the extent and intensity of the ravages occasioned by this violent cataclysm, which is represented in Plate XXX.

[425]



XXX.—Deluge of the North of Europe.

The physical proof of this *deluge of the north of Europe* exists in the accumulation of unstratified deposits which covers all the plains and low grounds of Northern Europe. On and in this deposit are found numerous blocks which have received the characteristic and significant name of erratic blocks, and which are frequently of considerable size. These become more characteristic as we ascend to higher latitudes, as in Norway, Sweden, and Denmark, the southern borders of the Baltic, and in the British Islands generally, in all of which countries deposits of marine fossil shells occur, which prove the submergence of large areas of Scandinavia, of the British Isles, and other regions during parts of the glacial period. Some of these rocks, characterised as *erratic*, are of very considerable volume; such, for instance, is the granite block which forms the pedestal of the statue of Peter the Great at St. Petersburg. This block was found in the interior of Russia, where the whole formation is *Permian*, and its presence there can only be explained by supposing it to have been transported by some vast iceberg, carried by a diluvial current. This hypothesis alone enables us to account for another block of granite, weighing about 340 tons, which was found on the sandy plains in the north of Prussia, an immense model of which was made for the Berlin Museum. The last of these erratic blocks deposited in Germany covers the grave of King Gustavus Adolphus, of Sweden, killed at the battle of Lutzen, in 1632. He was interred beneath the rock. Another similar block has been raised in Germany into a monument to the geologist [427]
Leopold von Buch.

These erratic blocks which are met with in the plains of Russia, Poland, and Prussia, and in the eastern parts of England, are composed of rocks entirely foreign to the region where they are found. They belong to the primary rocks of Norway; they have been transported to their present sites, protected by a covering of ice, by the waters of the northern deluge. How vast must have been the impulsive force which could carry such enormous masses across the Baltic, and so far inland as the places where they have been deposited for the surprise of the geologist or the contemplation of the thoughtful!

The second European deluge is supposed to have been the result of the formation and upheaval of the Alps. It has filled with débris and transported material the valleys of France, Germany, and Italy over a circumference which has the Alps for its centre. The proofs of a great convulsion at a comparatively recent geological date are numerous. The Alps may be from eighty to 100 miles across, and the probabilities are that their existence is due, as Sir Charles Lyell supposes, to a succession of unequal movements of upheaval and subsidence; that the Alpine region had been exposed for countless ages to the action of rain and rivers, and that the larger valleys were of pre-glacial times, is highly probable. In the eastern part of the chain some of the Primary fossiliferous rocks, as well as Oolitic and Cretaceous rocks, and even Tertiary deposits, are observable; but in the central Alps these disappear, and more recent rocks, in some places even Eocene strata, graduate into metamorphic rocks, in which Oolitic, Cretaceous, and Eocene strata have been altered into granular marble, gneiss, and other metamorphic schists; showing that eruptions continued after the deposit of the Middle Eocene formations. Again, in the Swiss and Savoy Alps, Oolitic and Cretaceous formations have been elevated to the height of 12,000 feet, and Eocene strata 10,000 feet above the level of the sea; while in the Rothal, in the Bernese Alps, occurs a mass of gneiss 1,000 feet thick between two strata containing Oolitic fossils.

Besides these proofs of recent upheaval, we can trace effects of two different kinds, resulting from the powerful action of masses of water violently displaced by this gigantic upheaval. At first broad tracks have been hollowed out by the diluvial waves, which have, at these points, formed deep valleys. Afterwards these valleys have been filled up by materials derived from the mountain and transported into the valley, these materials consisting of rounded pebbles, argillaceous and sandy mud, generally calcareous and ferriferous. This double effect is exhibited, [428] with more or less distinctness, in all the great valleys of the centre and south of France. The valley of the Garonne is, in respect to these phenomena, classic ground, as it were.

As we leave the little city of Muret, three successive levels will be observed on the left bank of the Garonne. The lowest of the three is that of the valley, properly so called; while the loftiest corresponds to the plateau of Saint-Gaudens. These three levels are distinctly marked in the Toulousean country, which illustrates the diluvial phenomena in a remarkable fashion. The city of Toulouse reposes upon a slight eminence of diluvial formation. The flat diluvial plateau contrasts strongly with the rounded hills of Gascony and Languedoc. They are essentially constituted of a bed of gravel, formed of rounded or oval pebbles, and again covered with sandy and earthy deposits. The pebbles are principally quartzose, brown or black externally, mixed with portions of hard "Old Red" and New Red Sandstone. The soft earth which accompanies the pebbles and gravel is a mixture of argillaceous sand of a red or yellow colour, caused by the oxide of iron which enters into its composition. In the valley, properly so called, we find the pebbles again associated with other minerals which are rare at the higher levels. Some teeth of the Mammoth, and *Rhinoceros tichorhinus*, have been found at several points on the borders of this valley.

The small valleys, tributary to the principal valley, would appear to have been excavated secondarily, partly out of diluvial deposits, and their alluvium, essentially earthy, has been formed at the expense of the Tertiary formation, and even of the diluvium itself. Among other celebrated sites, the diluvial formation is largely developed in Sicily. The ancient temple of the Parthenon at Athens is built on an eminence formed of diluvial earth.

In the valley of the Rhine, in Alsace, and in many isolated parts of Europe, a particular sort of *diluvium* forms thick beds; it consists of a yellowish-grey mud, composed of argillaceous matter mixed with carbonate of lime, quartzose and micaceous sand, and oxide of iron. This mud, termed by geologists *loess*, attains in some places considerable thickness. It is recognisable in the neighbourhood of Paris. It rises a little both on the right and left, above the base of the mountains of the Black Forest and of the Vosges; and forms thick beds on the banks of the Rhine.

The fossils contained in diluvial deposits consist, generally, of terrestrial, lacustrine, or fluviatile shells, for the most part belonging to species still living. In parts of the valley of the Rhine, [429] between Bingen and Basle, the fluviatile loam or loess, now under consideration, is seen forming hills several hundred feet thick, and containing, here and there, throughout that thickness, land and fresh-water shells; from which it seems necessary to suppose, according to Lyell, first, a time when the loess was slowly accumulated, then a later period, when large portions of it were removed—and followed by movements of oscillation, consisting, first, of a general depression, and then of a gradual re-elevation of the land.

We have already noticed the caverns in which such extraordinary accumulations of animal remains were discovered: it will not be out of place to give here a résumé of the state of our knowledge concerning *bone-caves* and *bone-breccias*.

The *bone-caves* are not simply cavities hollowed out of the rock; they generally consist of numerous chambers or caverns communicating with each other by narrow passages (often of considerable length) which can only be traversed by creeping. One in Mexico extends several leagues. Perhaps the most remarkable in Europe is that of Gailenreuth in Franconia. The Harz mountains contain many fine caverns; among others, those of Scharrfeld and *Baumann's Hohl*, in which many bones of Hyæna, Bears, and Lions have been found together. The *Kirkdale Cave*, so well known from the description given of it by Dr. Buckland, lying about twenty-five miles north-north-east of York, was the burial-place, as we have stated, of at least 300 Hyænas belonging to individuals of different ages; besides containing some other remains, mostly teeth (those of the Hyæna excepted) belonging to ruminating animals. Buckland states that the bones of all the other animals, those of the Hyænas not excepted, were gnawed. He also noticed a partial polish and wearing away to a considerable depth of one side of many of the best preserved specimens of teeth and bones, which can only be accounted for by referring the partial destruction to the continual treading of the Hyænas, and the rubbing of their skin on the side that lay uppermost at the bottom of the den.

From these facts it would appear probable that the Cave at Kirkdale was, "during a long succession of years, inhabited as a den by Hyænas, and that they dragged into its recesses the other animal bodies, whose remains are found mixed indiscriminately with their own."[103] This conjecture is made almost certain by the discovery made by Dr. Buckland of many coprolites of [430] animals that had fed on bones, as well as traces of the frequent passage of these animals to or from the entrance of the cavern or den. A modern naturalist visiting the Cavern of Adelsberg, in Carniola, traversed a series of chambers extending over three leagues in the same direction, and was only stopped in his subterranean discoveries by coming to a lake which occupied its entire breadth.

The interior walls of the bone-caves are, in general, rounded off, and furrowed, presenting many traces of the erosive action of water, characteristics which frequently escape observation because the walls are covered with the calcareous deposit called *stalactite* or *stalagmite*—that is, with carbonate of lime, resulting from the deposition left by infiltrating water, through the overlying limestone, into the interior of the cavern. The formation of the stalactite, with which many of the bones were incrusted in the Cave of Gailenreuth, is thus described by Liebig. The limestone over the cavern is covered with a rich soil, in which the vegetable matter is continually decaying. This mould, or humus, being acted on by moisture and air, evolves carbonic acid, which is dissolved by rain. The rain-water thus impregnated, permeating the porous limestone, dissolves a portion of it, and afterwards, when the excess of carbonic acid evaporates in the caverns, parts with the calcareous matter, and forms *stalactite*—the stalactites being the pendent masses of carbonate of lime, which hang in picturesque forms either in continuous sheets, giving the cave and its sides the appearance of being hung with drapery, or like icicles suspended from the roof of the cave, through which the water percolates; while those formed on the surface of the floor form *stalagmite*. These calcareous products ornament the walls of these gloomy caverns in a most brilliant and picturesque manner.

Under a covering of stalagmite, the floor of the cave frequently presents deposits of mud and gravel. It is in excavating this soil that the bones of antediluvian animals, mixed with shells, fragments of rocks, and rolled pebbles, are discovered. The distribution of these bones in the middle of the gravelly argillaceous mud is as irregular as possible. The skeletons are rarely entire; the bones do not even occur in their natural positions. The bones of small Rodents are found accumulated in the crania of great Carnivora. The teeth of Bears, Hyænas, and Rhinoceros are cemented with the jaw-bones of Ruminants. The bones are very often polished and rounded, as if they had been transported from great distances; others are fissured; others, nevertheless, are scarcely altered. Their state of preservation varies with their position in the cave.

The bones most frequently found in caves are those of the Carnivora of the Quaternary epoch: [431] the Bear, Hyæna, the Lion, and Tiger. The animals of the plain, and notably the great Pachyderms—the Mammoth and Rhinoceros—are only very rarely met with, and always in small numbers. From the cavern of Gailenreuth more than a thousand skeletons have been taken, of which 800 belonged to the large *Ursus spelæus*, and sixty to the smaller species, with 200 Hyænas, Wolves, Lions, and Gluttons. A jaw of the Glutton has lately been found by Mr. T. McK. Hughes in a cave in the Mountain Limestone at Plas Heaton, associated with Wolf, Bison, Reindeer, Horse, and Cave Bear; proving that the Glutton, which at the present day inhabits Siberia and the inclement northern regions of Europe, inhabited Great Britain during the Pleistocene or Quaternary Period. In the Kirkdale cave the remains, as we have seen, included those of not less than 300 Hyænas of all ages. Dr. Buckland concludes, from these circumstances, that the Hyænas alone made this their den, and that the bones of other animals accumulated there had been carried thither by them as their prey; it is, however, now admitted that this part of the English geologist’s conclusions do not apply to the contents of all bone-caves. In some instances the bones of the Mammals are broken and worn as with a long transport, *rolled*, according to the technical geological expression, and finally cemented in the same mud, together with fragments of the rocks of the neighbourhood. Besides bones of Hyænas, are found not only the bones of inoffensive herbivora, but remains of Lions and Bears.

We ought to note, in order to make this explanation complete, that some geologists consider that these caves served as a refuge for sick and wounded animals. It is certain that we see, in our own days, some animals, when attacked by sickness, seek refuge in the fissures of rocks, or in the hollows of trunks of trees, where they die; to this natural impulse it may, probably, be ascribed that the skeletons of animals are so rarely found in forests or plains. We may conclude, then, that besides the more general mode in which these caverns were filled with bones, the two other causes which we have enumerated may have been in operation; that is to say, they were the habitual sojourn of carnivorous and destructive animals, and they became the retreat of sick animals on some particular occasions.

What was the origin of these caves? How have these immense excavations been produced? Nearly all these caves occur in limestone rocks, particularly in the Jurassic and Carboniferous formations, which present many vast subterranean caverns. At the same time some fine caves [432] exist in the Silurian formation, such as the *Grotto des Demoiselles* (Fig. 194) near Ganges, of Hérault. It should be added, in order to complete the explanation of the cave formations, that the greater part of these vast internal excavations have been chiefly caused by subterranean watercourses, which have eroded and washed away a portion of the walls, and in this manner greatly enlarged their original dimensions.

But there are other modes than the above of accounting, in a more satisfactory manner, for the existence of these caves. According to Sir Charles Lyell, there was a time when (as now) limestone rocks were dissolved, and when the carbonate of lime was carried away gradually by springs from the interior of the earth; that another era occurred, when engulfed rivers or occasional floods swept organic and inorganic débris into the subterranean hollows previously formed; finally, there were changes, in which engulfed rivers were turned into new channels, and springs dried up, after which the cave-mud, breccia, gravel, and fossil bones were left in the position in which they are now discovered. “We know,” says that eminent geologist,[104] “that in every limestone district the rain-water is *soft*, or free from earthy ingredients, when it falls upon the soil, and when it enters the rocks below; whereas it is *hard*, or charged with carbonate of lime, when it issues again to the surface in springs. The rain derives some of its carbonic acid from the air, but more from the decay of vegetable matter in the soil through which it percolates; and by the excess of this acid, limestone is dissolved, and the water becomes charged with carbonate of lime. The mass of solid matter silently and unceasingly subtracted in this way from the rocks in every century is considerable, and must in the course of thousands of years be so vast, that the space it once occupied may well be expressed by a long suite of caverns."

The most celebrated of these bone-caves are those of Gailenreuth, in Franconia; of Nabenstein, and of Brumberg, in the same country; the caves on the banks of the Meuse, near Liège, of which the late Dr. Schmerling examined forty; of Yorkshire, Devonshire, Somersetshire, and Derbyshire, in England; also several in Sicily, at Palermo, and Syracuse; in France at Hérault, in the Cévennes, and Franche Comté; and in the New World, in Kentucky and Virginia.

The *ossiferous breccia* differs from the bone-caves only in form. The most remarkable of them are seen at Cette, Antibes, and Nice, on the shores of Italy; and in the isles of Corsica, Malta, and Sardinia.

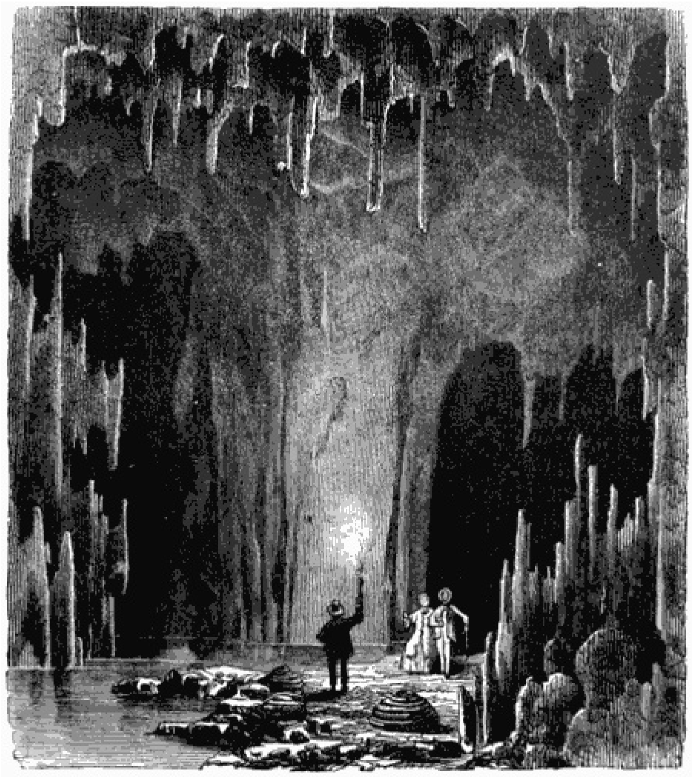


Fig. 194.—Grotto des Demoiselles, Hérault.

Nearly the same bones are found in the *breccia* which we find in the caves; the chief difference being that fossils of the Ruminants are there in greater abundance. The proportions of bones to the fragments of stone and cement vary considerably in different localities. In the *breccia* of Cagliari, where the remains of Ruminants are less abundant than at Gibraltar and Nice, the bones, which are those of the small Rodents, are, so to speak, more abundant than the mud in which they are embedded. We find, there, also, three or four species of Birds which belong to Thrushes and Larks. In the *breccia* at Nice the remains of some great Carnivora are found, among which are recognised two species of Lion and Panther. In the Grotto di San-Ciro, in the Monte Griffone, about six miles from Palermo, in Sicily, Dr. Falconer collected remains of two species of Hippopotamus and bones of *Elephas antiquus*, Bos, Stag, Pig, Bear, Dog, and a large *Felis*, some of which indicated a Pliocene age. Like many others, this cave contains a thick mass of bone-breccia on its floor, the bones of which have long been known, and were formerly supposed to be those of giants; while Prof. Ferrara suggested that the Elephants' bones were due to the Carthaginian elephants imported into Sicily for purposes of sport.[105]

But the *breccia* is not confined to Europe. We meet with it in all parts of the globe; and recent discoveries in Australia indicate a formation corresponding exactly to the *ossiferous breccia* of the Mediterranean, in which an ochreous-reddish cement binds together fragments of rocks and bones, among which we find four species of Kangaroos.

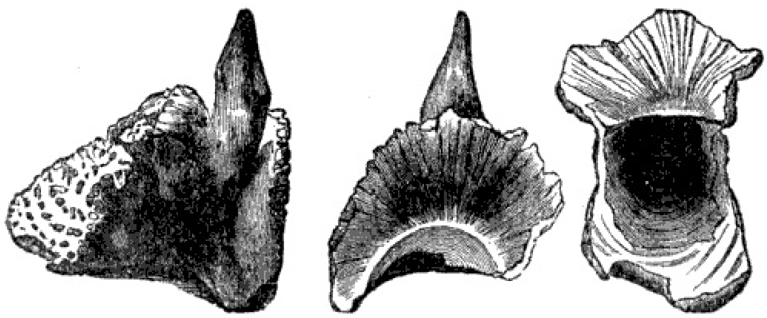


Fig. 195.—Beloptera Sepioidea.

GLACIAL PERIOD.

The two cataclysms, of which we have spoken, surprised Europe at the moment of the development of an important creation. The whole scope of animated Nature, the evolution of animals, was suddenly arrested in that part of our hemisphere over which these gigantic convulsions spread, followed by the brief but sudden submersion of entire continents. Organic life had scarcely recovered from the violent shock, when a second, and perhaps severer blow assailed it. The northern and central parts of Europe, the vast countries which extend from Scandinavia to the Mediterranean and the Danube, were visited by a period of sudden and severe cold: the temperature of the polar regions seized them. The plains of Europe, but now ornamented by the luxurious vegetation developed by the heat of a burning climate, the boundless pastures on which herds of great Elephants, the active Horse, the robust Hippopotamus, and great Carnivorous animals grazed and roamed, became covered with a mantle of ice and snow.

To what cause are we to attribute a phenomenon so unforeseen, and exercising itself with such intensity? In the present state of our knowledge no certain explanation of the event can be given. Did the central planet, the sun, which was long supposed to distribute light and heat to the earth, lose during this period its calorific powers? This explanation is insufficient, since at this period the solar heat is not supposed to have greatly influenced the earth's temperature. Were the marine currents, such as the *Gulf Stream*, which carries the Atlantic Ocean towards the north and west of Europe, warming and raising its temperature, suddenly turned in the contrary direction? No such hypothesis is sufficient to explain either the cataclysms or the glacial phenomena; and we need not hesitate to confess our ignorance of this strange, this mysterious, episode in the history of the globe.

There have been attempts, and very ingenious ones too, to explain these phenomena, of which we shall give a brief summary, without committing ourselves to any further opinion, using for that [436] purpose the information contained in M. Ch. Martins' excellent work. "The most violent convulsions of the solid and liquid elements," says this able writer, "appear to have been themselves only the effects due to a cause much more powerful than the mere expansion of the pyrosphere; and it is necessary to recur, in order to explain them, to some new and bolder hypothesis than has yet been hazarded. Some philosophers have belief in an astronomical revolution which may have overtaken our globe in the first age of its formation, and have modified its position in relation to the sun. They admit that the poles have not always been as they are now, and that some terrible shock displaced them, changing at the same time the inclination of the axis of the rotation of the earth." This hypothesis, which is nearly the same as that propounded by the Danish geologist, Klee, has been ably developed by M. de Boucheporn. According to this writer, many multiplied shocks, caused by the violent contact of the earth with comets, produced the elevation of mountains, the displacement of seas, and perturbations of climate—phenomena which he ascribes to the sudden disturbance of the parallelism of the axis of rotation. The antediluvian equator, according to him, makes a right angle with the existing equator.

"Quite recently," adds M. Martins, "a learned French mathematician, M. J. Adhémar, has taken up the same idea; but, dismissing the more problematical elements of the concussion with comets as untenable, he seeks to explain the deluges by the laws of gravitation and celestial mechanics, and his theory has been supported by very competent writers. It is this: We know that our planet is influenced by two essential movements—one of rotation on its axis, which it accomplishes in twenty-four hours; the other of translation, which it accomplishes in a little more than 365¼ days. But besides these great and perceptible movements, the earth has a third, and even a fourth movement, with one of which we need not occupy ourselves; it is that designated *nutation* by astronomers. It changes periodically, but within very restricted limits, the inclination of the terrestrial axis to the plane of the ecliptic by a slight oscillation, the duration of which is only eighteen hours, and its influence upon the relative length of day and night almost inappreciable. The other movement is that on which M. Adhémar's theory is founded.

"We know that the curve described by the earth in its annual revolution round the sun is not a circle, but an ellipse; that is, a slightly elongated circle, sometimes called a circle of two centres, one of which is occupied by the sun. This curve is called the ecliptic. We know, also, that, in its [437] movement of translation, the earth preserves such a position that its axis of rotation is intercepted, at its centre, by the plane of the ecliptic. But in place of being perpendicular, or at right angles with this plane, it crosses it obliquely in such a manner as to form on one side an angle of one-fourth, and on the other an angle of three-fourths of a right angle. This inclination is only altered in an insignificant degree by the movement of *nutation*. I need scarcely add that the earth, in its annual revolution, occupies periodically four principal positions on the ecliptic, which mark the limits of the four seasons. When its centre is at the extremity most remote from the sun, or *aphelion*, it is the summer solstice for the northern hemisphere. When its centre is at the other extremity, or *perihelion*, the same hemisphere is at the winter solstice. The two intermediate points mark the equinoxes of spring and autumn. The great circle of separation of light and shade passes, then, precisely through the poles, the day and night are equal, and the line of intersection of the plane of the equator and that of the ecliptic make part of the vector ray from the centre of the sun to the centre of the earth—what we call the *equinoctial line*.

“Thus placed, it is evident that if the terrestrial axis remained always parallel to itself, the equinoctial line would always pass through the same point on the surface of the globe. But it is not absolutely thus. The parallelism of the axis of the earth is changed slowly, very slowly, by a movement which Arago ingeniously compares to the varying inclination of a top when about to cease spinning. This movement has the effect of making the equinoctial points on the surface of the earth retrograde towards the east from year to year, in such a manner that at the end of 25,800 years according to some astronomers, but 21,000 years according to Adhémar, the equinoctial point has literally made a circuit of the globe, and has returned to the same position which it occupied at the beginning of this immense period, which has been called the ‘*great year*.’ It is this retrograde evolution, in which the terrestrial axis describes round its own centre that revolution round a double conic surface, which is known as the *precession of the equinoxes*. It was observed 2,000 years ago by Hipparchus; its cause was discovered by Newton; and its complete evolution explained by D’Alembert and Laplace.

“Now, we know that the consequence of the inclination of the terrestrial axis with the plane of the ecliptic is—

“1. That the seasons are inverse to the two hemispheres—that is to say, the northern hemisphere [438] enjoys its spring and summer, while the southern hemisphere passes through autumn and winter.

“2. When the earth approaches nearest to the sun, our hemisphere has its autumn and winter; and the regions near the pole, receiving none of the solar rays, are plunged into darkness, approaching that of night, during six months of the year.

“3. When the earth is most distant from the sun, when much the greater half of the ecliptic intervenes between it and the focus of light and heat, the pole, being then turned towards this focus, constantly receives its rays, and the rest of the northern hemisphere enjoys its long days of spring and summer.

“Bearing in mind that, in going from the equinox of spring to the autumnal equinox of our hemisphere, the earth traverses a much longer curve than it does on its return; bearing in mind, also, the accelerated movement it experiences in its approach to the sun from the attraction, which increases in inverse proportion to the square of its distance, we arrive at the conclusion that our summer should be longer and our winter shorter than the summer and winter of our antipodes; and this is *actually* the case by about eight days.

“I say *actually*, because, if we now look at the effects of the precession of the equinoxes, we shall see that in a time equal to half of the *grand year*, whether it be 12,900 or 10,500 years, the conditions will be reversed; the terrestrial axis, and consequently the poles, will have accomplished the half of their bi-conical revolution round the centre of the earth. It will then be the northern hemisphere which will have the summers shorter and the winters longer, and the southern hemisphere exactly the reverse. In the year 1248 before the Christian era, according to M. Adhémar, the north pole attained its maximum summer duration. Since then—that is to say for the last 3,112 years—it has begun to decrease, and this will continue to the year 7388 of our era before it attains its maximum winter duration.

“But the reader may ask, fatigued perhaps by these abstract considerations, What is there here in common with the deluges?

“The *grand year* is here divided, for each hemisphere, into two great seasons, which De Jouvencel calls the great summer and winter, which will each, according to M. Adhémar, be 10,500 years.

“During the whole of this period one of the poles has constantly had shorter winters and longer summers than the other. It follows that the pole which experiences the long winter undergoes a gradual and continuous cooling, in consequence of which the quantities of ice and snow, which melt during the summer, are more than compensated by those which are again produced in the [439] winter. The ice and snow go on accumulating from year to year, and finish at the end of the period by forming, at the coldest pole, a sort of crust or cap, vast, thick, and heavy enough to modify the spheroidal form of the earth. This modification, as a necessary consequence, produces a notable displacement of the centre of gravity, or—for it amounts to the same thing—of the centre of attraction, round which all the watery masses tend to restore it. The south pole, as we have seen, finished its *great winter* in 1248 B.C. The accumulated ice then added itself to the snow, and the snow to the ice, at the south pole, towards which the watery masses all tended until they covered nearly the whole of the southern hemisphere. But since that date of 1248, our *great winter* has been in progress. Our pole, in its turn, goes on getting cooler continually; ice is being heaped upon snow, and snow upon ice, and in 7,388 years the centre of gravity of the earth will return to its normal position, which is the geometrical centre of the spheroid. Following the immutable laws of central attraction, the southern waters accruing from the melted ice and snow of the south pole will return to invade and overwhelm once more the continents of the northern hemisphere, giving rise to new continents, in all probability, in the southern hemisphere.”

Such is a brief statement of the hypothesis which Adhémar has very ingeniously worked out. How far it explains the mysterious phenomena which we have under consideration we shall not attempt to say, our concern being with the effects. Does the evidence of upward and downward movements of the surface in Tertiary times explain the great change? For if the cooling which preceded and succeeded the two European deluges still remains an unsolved problem, its effects are perfectly appreciable. The intense cold which visited the northern and central parts of Europe resulted in the annihilation of organic life in those countries. All the watercourses, the rivers and streams, the seas and lakes, were frozen. As Agassiz says in his first work on "Glaciers": "A vast mantle of ice and snow covered the plains, the valleys, and the seas. All the springs were dried up; the rivers ceased to flow. To the movements of a numerous and animated creation succeeded the silence of death." Great numbers of animals perished from cold. The Elephant and Rhinoceros perished by thousands in the midst of their grazing grounds, which became transformed into fields of ice and snow. It is then that these two species disappeared, and seem to have been effaced from creation. Other animals were overwhelmed, without their race having been always entirely annihilated. The sun, which lately lighted up the verdant plains, [440] as it dawned upon these frozen steppes, was only saluted by the whistling of the north winds, and the horrible rending of the crevasses, which opened up on all sides under the heat of its rays, acting upon the immense glacier which formed the sepulchre of many animated beings.

How can we accept the idea that the plains, but yesterday smiling and fertile, were formerly covered, and that for a very long period, with an immense sheet of ice and snow? To satisfy the reader that the proof of this can be established on sufficient evidence, it is necessary to direct his attention to certain parts of Europe. It is essential to visit, at least in idea, a country where *glacial phenomena* still exist, and to prove that the phenomena, now confined to those countries, were spread, during geological times, over spaces infinitely vaster. We shall choose for our illustration, and as an example, the glaciers of the Alps. We shall show that the glaciers of Switzerland and Savoy have not always been restricted to their present limits; that they are, so to speak, only miniature resemblances of the gigantic glaciers of times past; and that they formerly extended over all the great plains which extend from the foot of the chain of the Alps.

To establish these proofs we must enter upon some consideration of existing glaciers, upon their mode of formation, and their peculiar phenomena.

The snow which, during the whole year, falls upon the mountains, does not melt, but maintains its solid state, when the elevation exceeds the height of 9,000 feet or thereabouts. Where the snow accumulates to a great thickness, in the valleys, or in the deep fissures in the ground, it hardens under the influence of the pressure resulting from the incumbent weight. But it always happens that a certain quantity of water, resulting from the momentary thawing of the superficial portions, traverses its substance, and this forms a crystalline mass of ice, with a granular structure, which the Swiss naturalists designate *névé*. From the successive melting and freezing caused by the heat by day and the cold by night, and the infiltration of air and water into its interstices, the *névé* is slowly transformed into a homogeneous azure mass of ice, full of an infinite number of little air-bubbles—this was what was formerly called *glace bulleuse* (bubble-ice). Finally, these masses, becoming completely frozen, water replaces the bubbles of air. Then the transformation is complete; the ice is homogeneous, and presents those beautiful azure tints so much admired by the tourist who traverses the magnificent glaciers of Switzerland and Savoy.

Such is the origin of, and such is the mode in which the glaciers of the Alps are formed. An [441] important property of glaciers remains to be pointed out. They have a general movement of translation in the direction of their slope, under the influence of which they make a certain yearly progress downward, according to the angle of the slope. The glacier of the Aar, for example, advances at the rate of about 250 feet each year.

Under the joint influence of the slope, the weight of the frozen mass, and the melting of the parts which touch the earth, the glacier thus always tends downwards; but from the effects of a more genial temperature, the lower extremity melting rapidly, has a tendency to recede. It is the difference between these two actions which constitutes the real progressive movement of the glacier.

The friction exercised by the glacier upon the bottom and sides of the valley, ought necessarily to leave its traces on the rocks with which it may happen to be in contact. Over all the places where a glacier has passed, in fact, we remark that the rocks are polished, levelled, rounded, and, as it is termed, *moutonnées*. These rocks present, besides, striations or scratches, running in the direction of the motion of the glacier, which have been produced by hard and angular fragments of stones imbedded in the ice, and which leave their marks on the hardest rocks under the irresistible pressure of the heavy-descending mass of ice. In a work of great merit, which we have before quoted, M. Charles Martins explains the physical mechanism by which granite rocks borne onwards in the progressive movements of a glacier, have scratched, scored, and rounded the softer rocks which the glacier has encountered in its descent. "The friction," says M. Martins, "which the glacier exercises upon the bottom and upon the walls, is too considerable not to leave its traces upon the rocks with which it may be in contact; but its action varies according to the mineralogical nature of the rocks, and the configuration of the ground they cover. If we penetrate between the soil and the bottom of the glacier, taking advantage of the ice-caverns which sometimes open at its edge or extremity, we creep over a bed of pebbles and fine sand saturated with water. If we remove this bed, we soon perceive that the underlying rock is levelled, polished, ground down by friction, and covered with rectilinear striæ, resembling sometimes small grooves, more frequently perfectly straight scratches, as though they had been produced by means of a graver, or even a very fine needle. The mechanism by which these striæ have been produced is that which industry employs to polish stones and metals. We rub the metallic surface with a fine powder called *emery*, until we give it a brilliancy which proceeds from the reflection of the light from an infinity of minute striæ. The bed of pebbles and mud, interposed between the [442] glacier and the subjacent rock, here represents the emery. The rock is the metallic surface, and the mass of the glacier which presses on and displaces the mud in its descent towards the plain, represents the hand of the polisher. These striæ always follow the direction of the glacier; but as it is sometimes subject to small lateral deviations, the striæ sometimes cross, forming very small angles with one another. If we examine the rocks by the side of a glacier, we find similar striæ engraved on them where they have been in contact with the frozen mass. I have often broken the ice where it thus pressed upon the rock, and have found under it polished surfaces, covered with striations. The pebbles and grains of sand which had engraved them were still encased in the ice, fixed like the diamond of the glazier at the end of the instrument with which he marks his glass.

"The sharpness and depth of the striæ or scratches depend on many circumstances: if the rock acted upon is calcareous, and the emery is represented by pebbles and sand derived from harder rocks, such as gneiss, granite, or protogine, the scratches are very marked. This we can verify at the foot of the glaciers of Rosenlaui, and of the Grindenwald in the Canton of Berne. On the contrary, if the rock is gneissic, granitic, or serpentinous, that is to say, very hard, the scratches will be less deep and less marked, as may be seen in the glaciers of the Aar, of Zermatt, and Chamounix. The polish will be the same in both cases, and it is often as perfect as in marble polished for architectural purposes.

"The scratches engraved upon the rocks which confine these glaciers are generally horizontal or parallel to the surface. Sometimes, owing to the contractions of the valley, these striæ are nearly vertical. This, however, need not surprise us. Forced onwards by the superincumbent weight, the glacier squeezes itself through the narrow part, its bulk expanding upwards, in which case the flanks of the mountain which barred its passage are marked vertically. This is admirably seen near the Châlets of Stieregg, a narrow defile which the lower glacier of the Grindenwald has to clear before it discharges itself into the valley of the same name. Upon the right bank of the glacier the scratches are inclined at an angle of 45° to the horizon. Upon the left bank the glacier rises sometimes quite up to the neighbouring forest, carrying with it great clods of earth charged with rhododendrons and clumps of alder, birches, and firs. The more tender or foliated rocks were broken up and demolished by the prodigious force of the glacier; the harder rocks offered more resistance, but their surface is planed down, polished, and striated, testifying to the [443] enormous pressure which they had to undergo. In the same manner the glacier of the Aar, at the foot of the promontory on which M. Agassiz' tent was erected, is polished to a great height, and on the face, turned towards the upper part of the valley, I have observed scratches inclined 64°. The ice, erect against this escarpment, seemed to wish to scale it, but the granite rock held fast, and the glacier was compelled to pass round it slowly.

"In recapitulation, the considerable pressure of a glacier, joined to its movement of progression, acts at once upon the bottom and flanks of the valley which it traverses: it polishes all the rocks which may be too hard to be demolished by it, and frequently impresses upon them a peculiar and characteristic form. In destroying all the asperities and inequalities of these rocks, it levels their surfaces and rounds them on the sides pointing up the stream, whilst in the opposite direction, or down the stream, they sometimes preserve their abrupt, unequal, and rugged surface. We must comprehend, in short, that the force of the glacier acts principally on the side which is towards the circle whence it descends, in the same way that the piles of a bridge are more damaged up-stream, than down, by the icebergs which the river brings down during the winter. Seen from a distance, a group of rocks thus rounded and polished reminds us of the appearance of a flock of sheep: hence the name *roches moutonnées* given them by the Swiss naturalists."

Another phenomenon which plays an important part in existing glaciers, and in those, also, which formerly covered Switzerland, is found in the fragments of rock, often of enormous size, which have been transported and deposited during their movement of progression.

The peaks of the Alps are exposed to continual degradations. Formed of granitic rocks—rocks eminently alterable under the action of air and water, they become disintegrated and often fall in fragments more or less voluminous. "The masses of snow," continues Martins, "which hang upon the Alps during winter, the rain which infiltrates between their beds during summer, the sudden action of torrents of water, and more slowly, but yet more powerfully, the chemical affinities, degrade, disintegrate, and decompose the hardest rocks. The débris thus produced falls from the summits into the circles occupied by the glaciers with a great crash, accompanied by frightful noises and great clouds of dust. Even in the middle of summer I have seen these avalanches of stone precipitated from the highest ridges of the Schreckhorn, forming upon the immaculate snow a long black train, consisting of enormous blocks and an immense number of smaller [444] fragments. In the spring a rapid thawing of the winter snows often causes accidental torrents of extreme violence. If the melting is slow, water insinuates itself into the smallest fissures of the rocks, freezes there, and rends asunder the most refractory masses. The blocks detached from the mountains are sometimes of gigantic dimensions: we have found them sixty feet in length, and those measuring thirty feet each way are by no means rare in the Alps."[106]

Thus, the action of aqueous infiltrations followed by frost, the chemical decomposition which granite undergoes under the influence of a moist atmosphere, degrade and disintegrate the rocks which constitute the mountains enclosing the glacier. Blocks, sometimes of very considerable dimensions, often fall at the foot of these mountains on to the surface of the glacier. Were it immovable the débris would accumulate at its base, and would form there a mass of ruins heaped up without order. But the slow progression, the continuous displacement of the glacier, lead, in the distribution of these blocks, to a certain kind of arrangement: the blocks falling upon its surface participate in its movement, and advance with it. But other downfalls take place daily, and the new débris following the first, the whole form a line along the outer edge of the glacier. These regular trains of rocks bear the name of "*moraines*." When the rocks fall from two mountains, and on each edge of the glacier, and two parallel lines of débris are formed, they are called *lateral moraines*. There are also *median moraines*, which are formed when two glaciers are confluent, in such a manner that the *lateral moraine*, on the right of the one, trends towards the left-hand one of the other. Finally, those moraines are *frontal*, or *terminal*, which repose, not upon the glacier, but at its point of termination in the valleys, and which are due to the accumulation of blocks fallen from the terminal escarpments of glaciers there arrested by some obstacle. In Plate XXXI. we have represented an actual Swiss glacier, in which are united the physical and geological peculiarities belonging to these enormous masses of frozen water: the moraines here are *lateral*, that is to say, formed of a double line of débris.

[445]

XXXI.—Glaciers of Switzerland.

Transported slowly on the surface of the glacier, all the blocks from the mountain preserve their original forms unaltered; the sharpness of their edges is never altered by their gentle transport and almost imperceptible motion. Atmospheric agency only can affect or destroy these rocks when formed of hard resisting material. They then remain nearly of the same form and volume [447] they had when they fell on the surface of the glacier; but it is otherwise with blocks and fragments enclosed between the rock and the glacier, whether it be at the bottom or between the glacier and its lateral walls. Some of these, under the powerful and continuous action of this gigantic grinding process, will be reduced to an impalpable mud, others are worn into facets, while others are rounded, presenting a multitude of scratches crossing each other in all directions. These scratched pebbles are of great importance in studying the extent of ancient glaciers; they testify, on the spot, to the existence of pre-existing glaciers which shaped, ground, and striated the pebbles, which water does not; on the contrary, in the latter, they become polished and rounded, and even natural striations are effaced.

Thus, huge blocks transported to great distances from their true geological beds, that is, *erratic blocks*, to use the proper technical term, rounded (*moutonnées*), polished, and scratched surfaces, *moraines*; finally, pebbles, ground, polished, rounded, or worn into smooth surfaces, are all physical effects of glaciers in motion, and their presence alone affords sufficient proof to the naturalist that a glacier formerly existed in the locality where he finds them. The reader will now comprehend how it is possible to recognise, in our days, the existence of ancient glaciers in different parts of the world. Above all, wherever we may find both *erratic blocks* and *moraines*, and observe, at the same time, indications of rocks having been polished and striated in the same direction, we may pronounce with certainty as to the existence of a glacier during geological times. Let us take some instances.

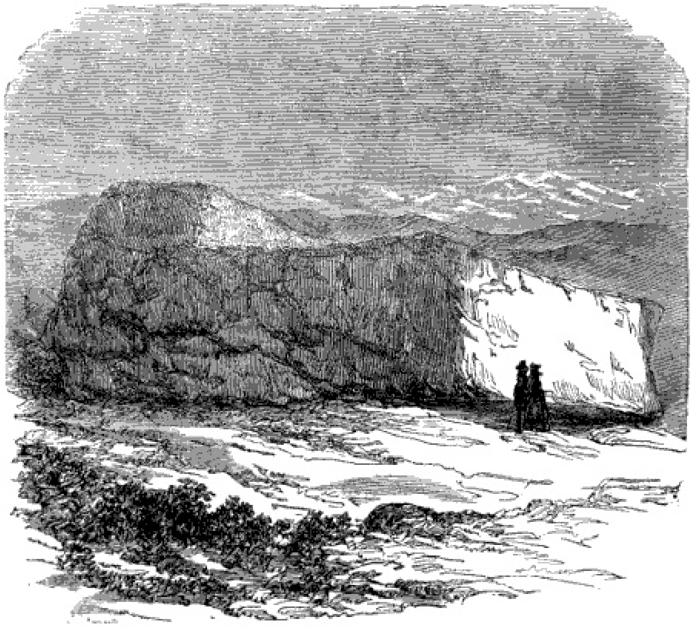


Fig. 196.—Erratic Blocks in the Alps.

At Pravolta, in the Alps, going towards *Monte Santo-Primo*, upon a calcareous rock, we find the mass of granite represented in Fig. 196. This erratic block exists, with thousands of others, on the slopes of the mountain. It is about fifty feet long, nearly forty feet broad, and five-and-twenty in height; and all its edges and angles are perfect. Some parallel striæ occur along the neighbouring rocks. All this clearly demonstrates that a glacier existed, in former times, in this part of the Alps, where none appear at the present time. It is a glacier, then, which has transported and deposited here this enormous block, weighing nearly 2,000 tons.

In the Jura Mountains, on the hill of Fourvières, a limestone eminence at Lyons, blocks of granite are found, evidently derived from the Alps, and transported there by the Swiss glaciers. The particular mode of transport is represented theoretically in Fig. 197. A represents, for example, the summit of the Alps, B the Jura Mountains, or the hill of Fourvières, at Lyons. At the glacial period, the glacier A B C extended from the Alps to the mountain B. The granitic débris, which was detached from the summit of the Alpine mountains, fell on the surface of the glacier. The movement of progression of this glacier transported these blocks as far as the summit B. At a later period the temperature of the globe was raised, and when the ice had melted, the blocks, D E, were quietly deposited on the spots where they are now found, without having sustained the slightest shock or injury in this singular mode of transport. [448]

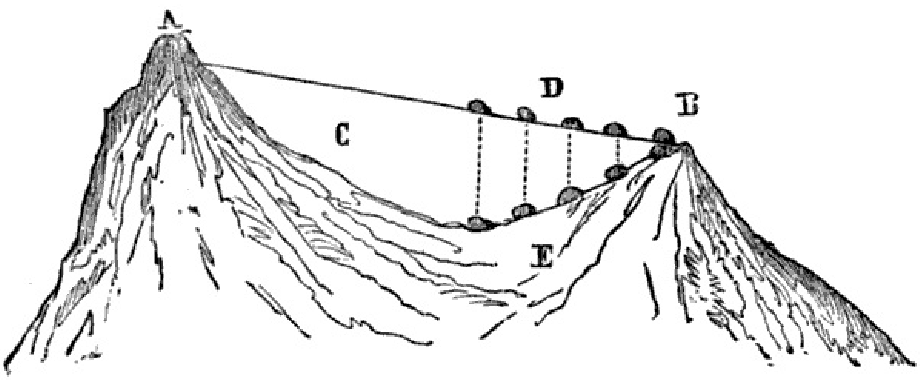


Fig. 197.—Transported blocks.

Every day traces, more or less recognisable, are found on the Alps of ancient glaciers far distant from their existing limits. Heaps of débris, of all sizes, comprehending blocks with sharp-pointed angles, are found in the Swiss plains and valleys. *Blocs perchés* (Perched blocks), as in Pl. XXXI., are often seen perched upon points of the Alps situated far above existing glaciers, or dispersed over the plain which separates the Alps from the Jura, or even preserving an incredible equilibrium, when their great mass is taken into consideration, at considerable heights on the eastern flank of this chain of mountains. It is by the aid of these indications that the geologist has been able to trace to extremely remote distances signs of the former existence of the ancient glaciers of the Alps, to follow them in their course, and fix their point of origin, and where they terminated. Thus the humble Mount Sion, a gently-swelling hill situated to the north of Geneva, was the point at which three great ancient glaciers had their confluence—the glacier of the Rhône, which filled all the basin of Lake Leman, or Lake of Geneva; that of the Isère, which issued from the Annecy and Bourget Lakes; and that of the Arve, which had its source in the valley of Chamounix, all converged at this point. According to M. G. de Mortillet, who has carefully studied this geological question, the extent and situation of these ancient glaciers of the Alps were as follows:—Upon its northern flank the *glacier of the Rhine* occupied all the basin of [449]

Lake Constance, and extended to the borders of Germany; that of the *Linth*, which was arrested at the extremity of the Lake of Zurich—this city is built upon its terminal moraine—that of the *Reus*, which covered the lake of the four cantons with blocks torn from the peaks of Saint-Gothard;—that of the *Aar*, the last moraines of which crown the hills in the environs of Berne;—those of the *Arve* and the *Isère*, which, as we have said, debouched from Lake Annecy and Lake Bourget respectively;—that of the *Rhône*, the most important of all. It is this glacier which has [450] deposited upon the flanks of the Jura, at the height of 3,400 feet above the level of the sea, the great *erratic blocks* already described. This mighty glacier of the Rhône had its origin in all the lateral valleys formed by the two parallel chains of the Valais. It filled all the Valais, and extended into the plain, lying between the Alps and the Jura, from Fort de L'Écluse, near the fall of the Rhône, up to the neighbourhood of Aarau.

The fragments of rocks transported by the ice-sea which occupied all the Swiss plain follow, in northerly direction, the course of the valley of the Rhine. On the other hand, the glacier of the Rhône, after reaching the plain of Switzerland, turned off obliquely towards the south, received the glacier of the Arve, then that of the Isère, passed between the Jura and the mountains of the Grande-Chartreuse, spread over La Bresse, then nearly all Dauphiny, and terminated in the neighbourhood of Lyons.

Upon the southern flank of the Alps, the ancient glaciers, according to M. de Mortillet's map, occupied all the great valleys from that of the Dora, on the west, to that of the Tagliamento, on the east. "The glacier of the *Dora*" says de Mortillet, whose text we greatly abridge, "debouched into the valley of the Po, close to Turin. That of the *Dora-Baltéa* entered the plain of Ivréa, where it has left a magnificent semicircle of hills, which formed its terminal moraine. That of the *Toce* discharged itself into Lake Maggiore, against the glacier of the Tessin, and then threw itself into the valley of Lake Orta, at the southern extremity of which its terminal moraines were situated. That of the Tessin filled the basin of Lake Maggiore, and established itself between Lugano and Varèse. That of the *Adda* filled the basin of Lake Como, and established itself between Mendrizio and Lecco, thus describing a vast semicircle. That of the *Oglio* terminated a little beyond Lake Iseo. That of the *Adige*, finding no passage through the narrow valley of Roveredo, where the valley became very narrow, took another course, and filled the immense valley of the Lake of Garda. At Novi it has left a magnificent moraine, of which Dante speaks in his 'Inferno.' That of the *Brenta* extended over the plain of that commune. The *Drave* and the *Tagliamento* had also their glaciers. Finally, glaciers occupied all the valleys of the Austrian and Bavarian Alps."[107]

Similar traces of the existence of ancient glaciers occur in many other European countries. In the Pyrenees, in Corsica, the Vosges, the Jura, &c., extensive ranges of country have been covered, in [451] geological times, by these vast plains of ice. The glacier of the Moselle was the most considerable of the glaciers of the Vosges, receiving numerous affluents; its lowest frontal moraine, which is situated below Remiremont, could not be less than a mile and a quarter in length.

But the phenomenon of the glacial extension which we have examined in the Alps was not confined to Central Europe. The same traces of their ancient existence are observed in all the north of Europe, in Russia, Iceland, Norway, Prussia, the British Islands, part of Germany, in the north, and even in some parts of the south, of Spain. In England, *erratic* blocks of granite are found which were derived from the mountains of Norway. It is evident that these blocks were borne by a glacier which extended from the north pole to England. In this manner they crossed the Baltic and the North Seas. In Prussia similar traces are observable.

Thus, during the Quaternary epoch, glaciers which are now limited to the Polar regions, or to mountainous countries of considerable altitude, extended very far beyond their present known limits; and, taken in connection with the deluge of the north, and the vast amount of organic life which they destroyed, they form, perhaps, the most striking and mysterious of all geological phenomena.

M. Edouard Collomb, to whom we owe much of our knowledge of ancient glaciers, furnishes the following note explanatory of a map of Ancient Glaciers which he has prepared:—

"The area occupied by the ancient Quaternary glaciers may be divided into two orographical regions:—1. The region of the north, from lat. 52° or 55° up to the North Pole. 2. The region of Central Europe and part of the south.

"The region of the north which has been covered by the ancient glaciers comprehends all the Scandinavian peninsula, Sweden, Norway, and a part of Western Russia, extending from the Niemen on the north in a curve which passed near the sources of the Dnieper and the Volga, and thence took a direction towards the shores of the glacial ocean. This region comprehends Iceland, Scotland, Ireland, the isles dependent on them, and, finally, a great part of England.

"This region is bounded, on all its sides, by a wide zone from 2° to 5° in breadth, over which is recognised the existence of erratic blocks of the north: it includes the middle region of Russia in Europe, Poland, a part of Prussia, and Denmark; losing itself in Holland on the Zuider Zee, it cut into the northern part of England, and we find a shred of it in France, upon the borders of the Cotentin.

"The ancient glaciers of Central Europe consisted, first, of the grand masses of the Alps. [452] Stretching to the west and to the north, they extended to the valley of the Rhône as far as Lyons, then crossing the summit-level of the Jura, they passed near Basle, covering Lake Constance, and stretching beyond into Bavaria and Austria. Upon the southern slopes of the Alps, they turned round the summit of the Adriatic, passed near to Udinet, covered Peschiera, Solferino, Como, Varèse, and Ivréa, extended to near Turin, and terminated in the valley of the Stura, near the Col de Tenda.

“In the Pyrenees, the ancient glaciers have occupied all the principal valleys of this chain, both on the French and Spanish sides, especially the valleys of the centre, which comprehend those of Luchon, Aude, Baréges, Cauterets, and Ossun. In the Cantabrian chain, an extension of the Pyrenees, the existence of ancient glaciers has also been recognised.

“In the Vosges and the Black Forest they covered all the southern parts of these mountains. In the Vosges, the principal traces are found in the valleys of Saint-Amarin, Giromagny, Munster, the Moselle, &c.

“In the Carpathians and the Caucasus the existence of ancient glaciers of great extent has also been observed.

“In the Sierra Nevada, in the south of Spain, mountains upwards of 11,000 feet high, the valleys which descend from the Picacho de Veleta and Mulhacen have been covered with ancient glaciers during the Quaternary epoch.”

There is no reason to doubt that at this epoch all the British islands, at least all north of the Thames, were covered by glaciers in their higher parts. “Those,” says Professor Ramsay, “who know the Highlands of Scotland, will remember that, though the weather has had a powerful influence upon them, rendering them in places rugged, jagged, and cliffy, yet, notwithstanding, their general outlines are often remarkably rounded and flowing; and when the valleys are examined in detail, you find in their bottoms and on the sides of the hills that the mammillated structure prevails. This rounded form is known, by those who study glaciers, by the name of *roches moutonnées*, given to them by the Swiss writers. These mammillated forms are exceedingly common in many British valleys, and not only so, but the very same kind of grooving and striation, so characteristic of the rocks in the Swiss valleys, also marks those of the Highlands of Scotland, of Cumberland, and Wales. Considering all these things, geologists, led by Agassiz some five or six and twenty years ago, have by degrees come to the conclusion, that a very large part of our island was, during the glacial period, covered, or nearly covered, with a thick coating of ice in the same way that the north of Greenland is at present; and that by the [453]
long-continued grinding power of a great glacier, or set of glaciers nearly universal over the northern half of our country, and the high ground of Wales, the whole surface became moulded by ice.”

Whoever traverses England, observing its features with attention, will remark in certain places traces of the action of ice in this era. Some of the mountains present on one side a naked rock, and on the other a gentle slope, smiling and verdant, giving a character more or less abrupt, bold, and striking, to the landscape. Considerable portions of dry land were formerly covered by a bluish clay, which contained many fragments of rock or “boulders” torn from the old Cumbrian mountains; from the Pennine chain; from the moraines of the north of England; and from the Chalk hills—hence called “boulder” clay—present themselves here and there, broken, worn, and ground up by the action of water and ice. These erratic blocks or “boulders” have clearly been detached from the parent rock by violence, and often transported to considerable distances. They have been carried, not only across plains, but over the tops of mountains; some of them being found 130 miles from the parent rocks. We even find, as already hinted, some rocks of which no prototypes have been found nearer than Norway. There is, then, little room for doubting the fact of an extensive system of glaciers having covered the land, although the proofs have only been gathered laboriously and by slow degrees in a long series of years. In 1840 Agassiz visited Scotland, and his eye, accustomed to glaciers in his native mountains, speedily detected their signs. Dr. Buckland became a zealous advocate of the same views. North Wales was soon recognised as an independent centre of a system which radiated from lofty Snowdon, through seven valleys, carrying with them large stones and grooving the rocks in their passage. In the pass of Llanberis there are all the common proofs of the valley having been filled with glacier ice. “When the country was under water,” says Professor Ramsay, “the drift was deposited which more or less filled up many of the Welsh valleys. When the land had risen again to a considerable height, the glaciers increased in size: although they never reached the immense magnitude which they attained in the earlier portion of the icy epoch. Still they became so large that such a valley as the Pass of Llanberis was a second time occupied by ice, which ploughed out the drift that more or less covered the valley. By degrees, however, as we approach nearer our own days, the climate slowly ameliorated, and the glaciers began to decline, till, growing less and less, they crept up and up; and here and there, as they died away, they left their terminal and lateral [454]
moraines still as well defined in some cases as moraines in lands where glaciers now exist. Frequently, too, masses of stone, that floated on the surface of the ice, were left perched upon the rounded *roches moutonnées*, in a manner somewhat puzzling to those who are not geologists.

“In short, they were let down upon the surface of these rocks so quietly and so softly, that there they will lie, until an earthquake shakes them down, or until the wasting of the rock on which they rest precipitates them to a lower level.”

It was the opinion of Agassiz, after visiting Scotland, that the Grampians had been covered by a vast thickness of ice, whence erratic blocks had been dispersed in all directions as from a centre; other geologists after a time adopted the opinion—Mr. Robert Chambers going so far as to maintain, in 1848, that Scotland had been at one time moulded by ice. Mr. T. F. Jamieson followed in the same track, adducing many new facts to prove that the Grampians once sent down glaciers in all directions towards the sea. “The glacial grooves,” he says, “radiate outward from the central heights towards all points of the compass, although they do not strictly conform to the actual shape and contour of the minor valleys and ridges.” But the most interesting part of Mr. Jamieson’s investigations is undoubtedly the ingenious manner in which he has worked out Agassiz’ assertion that Glenroy, whose remarkable “*Parallel Roads*” have puzzled so many investigators, was once the basin of a frozen lake.

Glenroy is one of the many romantic glens of Lochaber, at the head of the Spey, near to the Great Glen, or the valley of the Caledonian Canal, which stretches obliquely across the country in a northwesterly direction from Loch Linnhè to Loch Ness, leaving Loch Arkaig, Loch Aich, Glen Garry, and many a highland loch besides, on the left, and Glen Spean, in which Loch Treig, running due north and south, has its mouth, on the south. Glenroy opens into it from the north, while Glen Gluoy opens into the Great Glen opposite Loch Arkaig. Mr. Jamieson commenced his investigations at the mouth of Loch Arkaig, which is about a mile from the lake itself. Here he found the gneiss ground down as if by ice coming from the east. On the hill, north of the lake, the gneiss, though much worn and weathered, still exhibited well-marked striæ, directed up and down the valley. Other markings showed that the Glen Arkaig glacier not only blocked up Glen Gluoy, but the mouth of Glen Spean, which lies two miles or so north of it on the opposite side.

At Brackletter, on the south side of Glen Spean, near its junction with Glen Lochy, glacial scores [455]
pointing more nearly due west, but slightly inclining to the north, were observed, as if caused by the pressure of ice from Glen Lui. The south side of Glen Spean, from its mouth to Loch Treig, is bounded by lofty hills—an extension of Ben Nevis, the highest of these peaks exceeding 3,000 feet. Numerous gullies intersect their flanks, and the largest of these, Corry N’Eoin, presents a series of rocky amphitheatres, or rather large caldrons, whose walls have been ground down by long-continued glacial action: the quartz-veins are all shorn down to the level of the gneiss, and streaked with fine scratches, pointing down the hollows and far up the rocks on either side. During all these operations the great valley was probably filled up with ice, which would close Glen Gluoy and Glen Spean, and might also close the lowest of the lines in Glenroy. But how about the middle and upper lines?

A glacier crossing from Loch Treig, and protruding across Glen Spean, would cut off Glens Glaibu and Makoul, when the water in Glenroy could only escape over the Col into Strathspey, when the first level would be marked.

Now let the Glen Treig glacier shrink a little, so as to let out water to the level of the second line by the outline at Makoul, and the theory is complete. When the first and greatest glacier gave way, Glenroy would be nearly in its present state.

The glacier, on issuing from the gorge at the end of Loch Treig, would dilate immensely, the right flank spreading over a rough expanse of syenite, the neighbouring hills being mica-schists, with veins of porphyry. Now the syenite breaks into large cuboidal blocks of immense size. These have been swept before the advancing glacier along with other débris, and deposited in a semicircle of mounds having a sweep of several miles, forming circular bands which mark the edges of the glacier as it shrunk from time to time under the influence of a milder climate.

This moraine, which was all that was wanting to complete the theory laid down by Agassiz, is found on the pony-road leading from the mouth of Loch Treig towards Badenoch. A mile or so brings the traveller to the summit-level of the road, and beyond the hill a low moor stretches away to the bottom of the plain. Here, slanting across the slope of the hill towards Loch Treig, two lines of moraine stretch across the road. At first they consist of mica-schists and bits of porphyry, but blocks of syenite soon become intermingled. Outside these are older hillocks, rising in some places sixty and seventy feet high, forming narrow steep-sided mounds, with blocks
fourteen feet in length sticking out of the surface, mixed with fragments of mica-schist and [456]
gneiss. The inner moraine consists, almost wholly, of large blocks of syenite, five, ten, fifteen, and five-and-twenty feet long.

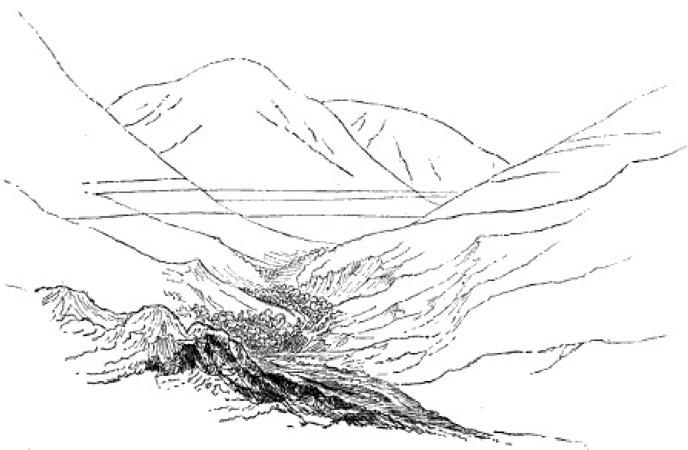


Fig. 198.—Parallel roads of Glenroy; from a sketch by Professor J. Phillips.

The present aspect of Glenroy is that of an upper and lower glen opening up from the larger Glen

Spean. The head-waters of Lochaber gather in a wild mountain tract, near the source of the Spey. The upper glen is an oval valley, four miles long, by about one broad, bounded on each side by high mountains, which throw off two streams dividing the mica-schist from the gneissic systems; the former predominating on the west side, and the latter on the east. The united streams flow to the south-west for two miles, when the valley contracts to a rocky gorge which separates the upper from the lower glen. Passing from the upper to the lower glen, a line is observed to pass from near the junction of the two streams, on a level with a flat rock at the gorge, and also with the uppermost of the three lines of terraces in the lower glen. This line girdles the sides of the hills right and left, with a seemingly higher sweep, and is followed by two other perfectly parallel and continuous lines till Glenroy expands into Glen Spean, which crosses its mouth and enters the great glen a little south of Loch Lochy. At the point, however, where Glenroy enters Glen Spean, the two upper terraces cease, while the lower of the three appears on the north and south side of Glen Spean, as far as the pass of Glen Muckal, and southward a little way up the Gubban river and round the head of Loch Treig. [457]

In Scotland, and in Northern England and Wales, there is distinct evidence that the Glacial Epoch commenced with an era of continental ice, the land being but slightly lower than at present, and possibly at the same level, during which period the Scottish hills received their rounded outlines, and scratched and smoothed rock-surfaces; and the plains and valleys became filled with the stiff clay, with angular scratched stones, known as the "Till," which deposit is believed by Messrs. Geikie, Jamieson, and Croll to be a *moraine profonde*, the product of a vast ice-sheet.

In Wales, Professor Ramsay has described the whole of the valleys of the Snowdonian range as filled with enormous glaciers, the level of the surface of the ice filling the Pass of Llanberis, rising 500 feet above the present watershed at Gorphwysfa. In the Lake District of Cumberland and Westmorland, Mr. De Rance has shown that a vast series of glaciers, or small ice-sheets, filled all the valleys, radiating out in all directions from the larger mountains, which formed centres of dispersion, the ice actually pushing over many of the lesser watersheds, and scooping out the great rock-basins in which lie the lakes Windermere, Ullswater, Thirlmere, Coniston Water, and Wastwater, the bottoms of which are nearly all below the sea-level. The whole of this district, he has shown, experienced a second glaciation, after the period of great submergence, in which valley-glaciers scooped out the marine drift, and left their *moraines* in the Liza, Langdale, and [458] other valleys, and high up in the hills, as at Harrison's Stickle, where a tarn has been formed by a little *moraine*, acting as a dam, as shown by Professor Hull.

In Wales, also, valley-glaciers existed after the submergence beneath the Glacial sea. Thus in Cwm-llafar, under the brow of Carnedd Dafydd, and Carnedd Llewelyn, Professor Ramsay has shown that a narrow glacier, about two miles in length, has ploughed out a long narrow hollow in the drift (which "forms a succession of terraces, the result of marine denudation, during pauses in the re-elevation of its submersion) to a depth of more than 2,000 feet."[108]

The proofs of this great submergence, succeeding the era of "land-ice," are constantly accumulating. Since 1863, when Professor Hull first divided the thick glacial deposits of Eastern Lancashire and Cheshire into an Upper Boulder Clay, and Lower Boulder Clay divided by a Middle Sand and Gravel, the whole of which are of marine origin, these subdivisions have been found to hold good, by himself and Mr. A. H. Green, over 600 square miles of country around Manchester, Bolton, and Congleton; by Mr. De Rance over another 600 square miles, around Liverpool, Preston, Blackpool, Blackburn, and Lancaster, and also in the low country lying between the Cumberland and Welsh mountains and the sea.

In Ireland, also, the same triplex arrangement appears to exist. Professors Harkness and Hull have identified the "Limestone and Manure Gravels" of the central plain, as referable to the "Middle Sand and Gravel," and the "Lower Boulder Clay" rests on a glaciated rock-surface along the coasts of Antrim and Down, and is overlain by sand, which, in 1832, was discovered by Dr. Scouler to be shell-bearing. At Kingstown the three deposits are seen resting on a moutonnéed surface of granite, scored from the N.N.W.

In Lancashire and on the coast of North Wales, between Llandudno and Rhyl, Mr. De Rance has shown that these deposits often lie upon the denuded and eroded surface of another clay, of older date, which he believes to be the product of land-ice, the remnant of the *moraine profonde*, and the equivalent of the Scotch "Till." He also shows that the Lower Boulder Clay never rises above an elevation of fifty or eighty feet above the sea-level; and that the Middle Sand and Shingle rests directly upon the rock, or on the surface of this old Till.

Near Manchester the Lower Boulder Clay occasionally rests upon an old bed of sand and gravel. It is extremely local, but its presence has been recorded in several sections by Mr. Edward Binney, who was the first to show, in 1842,[109] that the Lancashire Boulder Clays were formed in [459] the sea, and that the erratic pebbles and boulders, mainly derived from the Cumberland Lake Districts, were brought south by means of floating ice.

Most of the erratic pebbles and boulders in the Lancashire clays are more or less scratched and scored, many of them (though quite rounded) in so many directions that Mr. De Rance believes the Cumberland and Westmoreland hills to have been surrounded by an ice-belt, which, occasionally thawing during summer or warm episodes, admitted "breaker action" on the gradually subsiding coast, wearing the fragments of rocks brought down by rivers or by glaciers into pebbles that, with the return of the cold, became covered with the "ice-belt," which, lifted by the tides, rolled and dinted the pebbles one against another, and gradually allowed them to be impressed into its mass, with which they eventually floated away.

The Middle Sands and Shingles in England have also afforded a great number of shells of mollusca. At Macclesfield they have been described by Messrs. Prestwich and Darbishire as occurring at an elevation of 1,100 to 1,200 feet above the level of the sea.[110]

Among other proofs of glacial action and submersion in Wales may be mentioned the case of Moel Tryfaen, a hill 1,400 feet high, lying to the westward of Caernarvon Bay, and six or seven miles from Caernarvon. Mr. Joshua Trimmer had observed stratified drift near the summit of this mountain, from which he obtained some marine shells; but doubts were entertained as to their age until 1863, when a deep and extensive cutting was made in search of slates. In this cutting a stratified mass of loose sand and gravel was laid open near the summit, thirty-five feet thick, containing shells, some entire, but mostly in fragments. Sir Charles Lyell examined the cutting, and obtained twenty species of shells, and in the lower beds of the drift, "large heavy boulders of far-transported rocks, glacially polished and scratched on more than one side:" underneath the whole, the edges of vertical slates were exposed to view, exhibiting "unequivocal marks of prolonged glaciation." The shells belonged to species still living in British or more northern seas.

From the gravels of the Severn Valley, described by Mr. Maw, thirty-five forms of mollusca have been identified by Mr. Gwyn Jeffreys. In the Shingle beds of Leyland, Euxton, Chorley, Preston, [460] Lancaster, and Blackpool,[111] Mr. De Rance has obtained nearly thirty species.

In Eastern Yorkshire, Mr. Searles V. Wood, Jun., has divided the glacial deposits into "Purple Clay without Chalk," "Purple Clay with Chalk," and "Chalky Clay," the whole being later than his "Middle Glacial Sands and Gravel," which, in East Anglia, are overlain by the "Chalky Clay," and rest unconformably upon the "Contorted Drift" of Norfolk, the Cromer Till, and the Forest Bed. His three Yorkshire clays are, however, considered by most northern geologists to be the representatives of the "Upper Boulder Clay" west of the Pennine Chain, the "Chalky Clay" having been formed before the country had sufficiently subsided to allow the sandstones and marls, furnishing the red colouring matter, to have suffered denudation; while the "Purple Clay without Chalk, and with Shap Granite," was deposited when all the chalk was mainly beneath the sea, and the granite from Shap Fell, which had been broken up by breaker-action during the Middle Sand era, was floated across the passes of the Pennine Chain and southwards and northwards. A solitary pebble of Shap granite has been found by Mr. De Rance at Hoylake, in Cheshire; and many of Criffel Granite, in that county, and on the coast of North Wales, by Mr. Mackintosh, who has also traced the flow of this granite in the low country lying north and south of the Cumberland mountains.

At Bridlington, in Yorkshire, occurs a deposit at the base of the "Purple Clay," with a truly Arctic fauna. Out of seventy forms of mollusca recorded by Mr. S. V. Wood, Jun., nineteen are unknown to the Crag—of these thirteen are purely arctic, and two not known as living.

Shells have been found in the Upper Boulder Clay of Lancashire, at Hollingworth Reservoir, near Mottram, by Messrs. Binney, Bateman, and Prestwich, at an elevation of 568 feet above the sea, consisting of *Fusus Bamffius*, *Purpura lapillus*, *Turritilla terebra*, and *Cardium edule*. The clay is described by Mr. Binney as sandy, and brown-coloured, with pebbles of granite and greenstone, some rounded and some angular. All the above shells, as well as *Tellina Balthica*, have been found in the Upper Clay of Preston, Garstang, Blackpool, and Llandudno, by Mr. De Rance, who has also found all the above species (with the exception of *Fusus*), as well as *Psammobia ferroensis*, and the siliceous spiculæ of marine sponges, in the Lower Boulder Clay of West Lancashire. He has described the ordinary red Boulder Clay of Lancashire as extending continuously through Cheshire and Staffordshire into Warwickshire, gradually becoming less red [461] and more chalky, everywhere overlying intermittent sheets of "sands and shingle-beds," one of which is particularly well seen at Leamington and Warwick, where it contains Pectens from the Crag, *Gryphæa* from the Lias, and chalk fossils and flints. The latter have also been found by Mr. Lucy in the neighbourhood of Mount Sorrel, associated with bits of the Coral Rag of Yorkshire. The gravels of Leicester, Market Harborough, and Lutterworth were long ago described by the Rev. W. D. Conybeare as affording "specimens of the organic remains of most of the Secondary Strata in England."

The Rev. O. Fisher, F.G.S., has paid much attention to the superficial covering usually described as "heading," or "drift," as well as to the contour of the surface, in districts composed of the softer strata, and has published his views in various papers in the *Journal of the Geological Society* and in the *Geological Magazine*. He thinks that the contour of the surface cannot be ascribed entirely to the action of rain and rivers, but that the changes in the ancient contour since produced by those changes can be easily distinguished. He finds the covering beds to consist of two members—a lower one, entirely destitute of organic remains, and generally unstratified, which has often been forcibly indented into the bed beneath it, sometimes exhibiting slickenside at the junction.

There is evidence of this lower member having been pushed or dragged over the surface, from higher to lower levels, in a plastic condition; on which account he has named it "The Trail."

The upper member of the covering beds consists of soil derived from the lower one, by weathering. It contains, here and there, the remains of the land-shells which lived in the locality at a period antecedent to cultivation. It is "The Warp" of Mr. Trimmer.

Neither of these accumulations occur on low flats, where the surface has been modified since the recent period. They both alike pass below high-water mark, and have been noticed beneath estuarine deposits.

Mr. Fisher is of opinion that land-ice has been instrumental in forming the contour of the surface, and that the trail is the remnant of its *moraine profonde*. And he has given reasons[112] for believing that the climate of those latitudes may have been sufficiently rigorous for that result about 100,000 years ago. He attributes the formation of the superficial covering of Warp to a period of much rainfall and severe winter-frosts, after the ice-sheet had disappeared.

The phenomena which so powerfully affected our hemisphere present themselves, in a much grander manner, in the New World. The glacier-system appears to have taken in America the [462] same gigantic proportions which other objects assume there. Nor is it necessary, in order to explain the permanent existence of this icy mantle in temperate climates, to infer the prevalence of any very extraordinary degree of cold. On this subject M. Ch. Martins thus expresses himself: "The mean temperature of Geneva is 9° 5 Cent. Upon the surrounding mountains the limit of perpetual snow is found at 8,800 feet above the level of the sea. The great glaciers of the valley of Chamounix descend 5,000 feet below this line. Thus situated, let us suppose that the mean temperature of Geneva was lowered only 4°, and the average became 5° 5; the decrease of temperature with the height being 1° c. for every 600 feet, the limit of perpetual snow would be lowered by 2,437 feet, and would be 6,363 feet above the level of the sea. We can readily admit that the glaciers of Chamounix would descend below this new limit, to an extent at least equal to that which exists between their present limit and their lower extremity. Now, in reality, the foot of these glaciers is 5,000 feet above the ocean; with a climate 4° colder, it would be 2,437 feet lower; that is to say, at the level of the Swiss plain. Thus, the lowering of the line of perpetual snow to this extent would suffice to bring the glacier of the Arve to the environs of Geneva.... Of the climate which has favoured the prodigious development of glaciers we have a pretty correct idea; it is that of Upsala, Stockholm, Christiana, and part of North America, in the State of New York.... To diminish by four degrees the mean temperature of a country in order to explain one of the grandest revolutions of the globe, is to venture on an hypothesis not bolder than geology has sometimes permitted to itself."[113]

In proving that glaciers covered part of Europe during a certain period, that they extended from the North Pole to Northern Italy and the Danube, we have sufficiently established the reality of this *glacial period*, which we must consider as a curious episode, as well as certain, in the history of the earth. Such masses of ice could only have covered the earth when the temperature of the air was lowered at least some degrees below zero. But organic life is incompatible with such a temperature; and to this cause must we attribute the disappearance of certain species of animals and plants—in particular, the Rhinoceros and the Elephant—which, before this sudden and extraordinary cooling of the globe, appear to have limited themselves, in immense herds, to Northern Europe, and chiefly to Siberia, where their remains have been found in such prodigious quantities. Cuvier says, speaking of the bodies of the quadrupeds which the ice had seized, and in [463] which they have been preserved, with their hair, flesh, and skin, up to our own times: "If they had not been frozen as soon as killed, putrefaction would have decomposed them; and, on the other hand, this eternal frost could not have previously prevailed in the place where they died; for they could not have lived in such a temperature. It was, therefore, at the same instant when these animals perished that the country they inhabited was rendered glacial. These events must have been sudden, instantaneous, and without any gradation."[114]

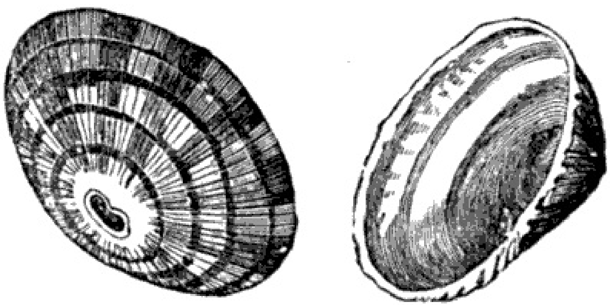


Fig. 199.—Fissurella nembosa.
(Living shell.)

How can we explain the *glacial period*? We have explained M. Adhémar's hypothesis, to which it may be objected that the cold of the glacial period was so general throughout the Polar and temperate regions on both sides of the equator, that mere local changes in the external configuration of our planet and displacement of the centre of gravity scarcely afford adequate causes for so great a revolution in temperature. Sir Charles Lyell, speculating upon the suggestion of Ritter and the discovery of marine shells spread far and wide over the Sahara Desert by Messrs. Escher von der Linth, Desor, and Martins—which seem to prove that the African Desert has been under water at a very recent period—infers that the Desert of Sahara constituted formerly a wide marine area, stretching several hundred miles north and south, and east and west. "From this area," he adds, "the south wind must formerly have absorbed moisture, and must have been still further cooled and saturated with aqueous vapour as it passed over the Mediterranean. When at length it reached the Alps, and, striking them, was driven into the higher and more rarefied regions of the atmosphere, it would part with its watery burthen in the form of snow; so that the same aërial current which, under the name of the Föhn, or Sirocco, now plays a leading part with its hot and dry breath, sometimes, even in the depth of winter, in melting the snow and checking the growth of glaciers, must, at the period alluded to, have been the principal feeder of Alpine snow and ice."[115] Nevertheless, we repeat, no explanation presents itself which can be considered conclusive; and in science we should never be afraid to say, *I do not know*.

CREATION OF MAN AND THE ASIATIC DELUGE. [464]

It was only after the glacial period, when the earth had resumed its normal temperature, that man was created. Whence came he?

He came from whence originated the first blade of grass which grew upon the burning rocks of the Silurian seas; from whence proceeded the different races of animals which have successively replaced each other upon the globe, gradually, but unceasingly, rising in the scale of perfection. He emanated from the supreme will of the Author of the worlds which constitute the universe.

The earth has passed through many phases since the time when—in the words of the Sacred Record—"the earth was without form and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters." We have considered all these phases; we have seen the globe floating in space in a state of gaseous nebulosity, condensing into liquidity, and beginning to solidify at the surface. We have pictured the internal agitations, the disturbances, the partial dislocations to which the earth has been subjected, almost without interruption, while it could not, as yet, resist the force of the waves of the fiery sea imprisoned within its fragile crust. We have seen this envelope acquiring solidity, and the geological cataclysms losing their intensity and frequency in proportion as this solid crust increased in thickness. We have looked on, so to speak, while the work of organic creation was proceeding. We have seen life making its appearance upon the globe; and the first plants and animals springing into existence. We have seen this organic creation multiplying, becoming more complex, and constantly made more perfect with each advance in the progressive phases of the history of the earth. We now arrive at the greatest event of this history, at the crowning of the edifice, *si parva licet componere magnis*.

At the close of the Tertiary epoch, the continents and seas assumed the respective limits which they now present. The disturbances of the ground, the fractures of the earth's crust, and the volcanic eruptions which are the consequence of them, only occurred at rare intervals, [465] occasioning only local and restricted disasters. The rivers and their affluents flowed between tranquil banks. Animated Nature is that of our own days. An abundant vegetation, diversified by the existence of a climate which has now been acquired, embellishes the earth. A multitude of animals inhabit the waters, the dry land, and the air. Nevertheless, creation has not yet achieved its greatest work—a being capable of comprehending these marvels and of admiring the sublime work—a soul is wanting to adore and give thanks to the Creator.

God created man.

What is man?

We might say that man is an intelligent and moral being; but this would give a very imperfect idea of his nature. Franklin says that man is one that can make tools! This is to reproduce a portion of the first proposition, while depreciating it. Aristotle calls man the "wise being," ζωον πολιτικον. Linnæus, in his "System of Nature," after having applied to man the epithet of wise (*homo sapiens*) writes after this generic title these profound words: *Nosce te ipsum*. The French naturalist and philosopher, Isidore Geoffroy Saint-Hilaire, says, "The plant *lives*, the animal *lives and feels*, man *lives, feels, and thinks*"—a sentiment which Voltaire had already expressed. "The Eternal Maker," says the philosopher of Ferney, "has given to man organisation, sentiment, and intelligence; to the animals sentiment, and what we call instinct; to vegetables organisation alone. His power then acts continually upon these three kingdoms." It is probably the animal which is here depreciated. The animal on many occasions undoubtedly thinks, reasons, deliberates with itself, and acts in virtue of a decision maturely weighed; it is not then reduced to mere sensation.

To define exactly the human being, we believe that it is necessary to characterise the nature and extent of his intelligence. In certain cases the intelligence of the animal approaches nearly to that of man, but the latter is endowed with a certain faculty which belongs to him exclusively; in creating him, God has added an entirely new step in the ascending scale of animated beings. This faculty, peculiar to the human race, is *abstraction*. We will say, then, that man is an *intelligent* being, gifted with the faculty of comprehending the *abstract*.

It is by this faculty that man is raised to a pre-eminent degree of material and moral power. By it he has subdued the earth to his empire, and by it also his mind rises to the most sublime contemplations. Thanks to this faculty, man has conceived the ideal, and realised poesy. He has conceived the infinite, and created mathematics. Such is the distinction which separates the [466] human race so widely from the animals—which makes him a creation apart and absolutely new upon the globe. A being capable of comprehending the ideal and the infinite, of creating poetry and algebra, such is man! To invent and understand this formula—

$$(a + b)^2 = a^2 + 2ab + b^2,$$

or the algebraic idea of negative quantities, this belongs to man. It is the greatest privilege of the human being to express and comprehend thoughts like the following:

J'étais seul près des flots, par une nuit d'étoiles,
Pas un nuage aux cieux, sur les mers pas de voiles,
Mes yeux plongeaient plus loin que le monde réel,
Et les vents et les mers, et toute la nature
Semblaient interroger dans un confus murmure,
Les flots des mers, les feux du ciel.

Et les étoiles d'or, légions infinies,
À voix haute, à voix basse, avec mille harmonies
Disaient, en inclinant leur couronne de feu;
Et les flots bleus, que rien ne gouverne et n'arrête:
Disaient, en recourbant l'écume de leur crête:
"C'est le Seigneur, le Seigneur Dieu!"*

Victor Hugo, *les Orientales*.

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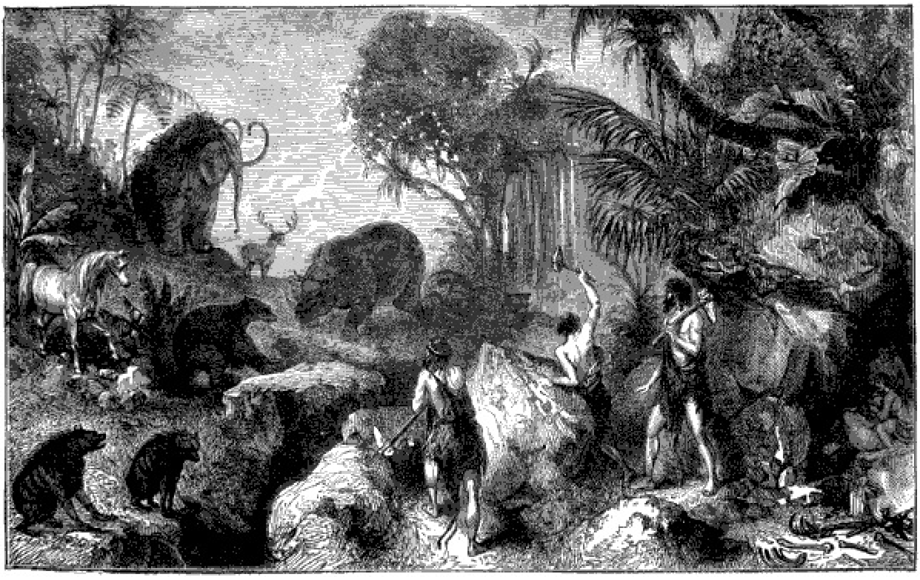
* Alone with the waves, on a starry night,
My thoughts far away in the infinite;
On the sea not a sail, not a cloud in the sky,
And the wind and the waves with sweet lullaby
Seem to question in murmurs of mystery,
The fires of heaven, the waves of the sea.

And the golden stars of the heavens rose higher,
Harmoniously blending their crowns of fire,
And the waves which no ruling hand may know,
'Midst a thousand murmurs, now high, now low,
Sing, while curving their foaming crests to the sea,
"It is the Lord God! It is He."

The "Mécanique Céleste" of Laplace, the "Principia" of Newton, Milton's "Paradise Lost," the "Orientales" by Victor Hugo—are the fruits of the *faculty of abstraction*.

[468]



XXXII.—Appearance of Man.

In the year 1800, a being, half savage, who lived in the woods, clambered up the trees, slept upon dried leaves, and fled on the approach of men, was brought to a physician named Pinel. [469] Some sportsmen had found him; he had no voice, and was devoid of intelligence; he was known as the little savage of Aveyron. The Parisian *savants* for a long time disputed over this strange individual. Was it an ape?—was it a wild man?

The learned Dr. Itard has published an interesting history of the savage of Aveyron. "He would sometimes descend," he writes, "into the garden of the deaf and dumb, and seat himself upon the edge of the fountain, preserving his balance by rocking himself to and fro; after a time his body became quite still, and his face assumed an expression of profound melancholy. He would remain thus for hours—regarding attentively the surface of the water—upon which he would, from time to time, throw blades of grass and dried leaves. At night, when the clear moonlight penetrated into the chamber he occupied, he rarely failed to rise and place himself at the window, where he would remain part of the night, erect, motionless, his neck stretched out, his eyes fixed upon the landscape lit up by the moon, lost in a sort of ecstasy of contemplation." This being was, undoubtedly, a man. No ape ever exhibited such signs of intelligence, such dreamy manifestations, vague conceptions of the ideal—in other words, that faculty of *abstraction* which belongs to humanity alone. In order worthily to introduce the new inhabitant who comes to fill the earth with his presence—who brings with him intelligence to comprehend, to admire, to subdue, and to rule the creation (Pl. XXXII.), we require nothing more than the grand and simple language of Moses, whom Bossuet calls "the most ancient of historians, the most sublime of philosophers, the wisest of legislators." Let us listen to the words of the inspired writer: "And God said, Let us make man in our image, after our likeness: and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth. So God created man in his *own* image, in the image of God created he him; male and female created he them."

"And God saw everything that he had made, and, behold, *it was* very good."

Volumes have been written upon the question of the unity of the human race; that is, whether there were many centres of the creation of man, or whether our race is derived solely from the Adam of Scripture. We think, with many naturalists, that the stock of humanity is unique, and that the different human races, the negroes, and the yellow race, are only the result of the influence of climate upon organisation. We consider the human race as having appeared for the [470] first time (the mode of his creation being veiled in Divine mystery, eternally impenetrable to us) in the rich plains of Asia, on the smiling banks of the Euphrates, as the traditions of the most ancient races teach us. It is there, where Nature is so rich and vigorous, in the brilliant climate and under the radiant sky of Asia, in the shade of its luxuriant masses of verdure and its mild and perfumed atmosphere, that man loves to represent to himself the father of his race as issuing from the hand of his Creator.

We are, it will be seen, far from sharing the opinion of those naturalists who represent man, at the beginning of the existence of his species, as a sort of ape, of hideous face, degraded mien, and covered with hair, inhabiting caves like the bears and lions, and participating in the brutal instincts of those savage animals.[116] There is no doubt that early man passed through a period in which he had to contend for his existence with ferocious beasts, and to live in a primitive state in the woods or savannahs, where Providence had placed him. But this period of probation came to an end, and man, an eminently social being, by combining in groups, animated by the same interests and the same desires, soon found means to intimidate the animals, to triumph over the elements, to protect himself from the innumerable perils which surrounded him, and to subdue to his rule the other inhabitants of the earth. "The first men," says Buffon, "witnesses of the convulsive movements of the earth, still recent and frequent, having only the mountains for refuge from the inundations; and often driven from this asylum by volcanoes and earthquakes, which trembled under their feet; uneducated, naked, and exposed to the elements, victims to the fury of ferocious animals, whose prey they were certain to become; impressed also with a common sentiment of gloomy terror, and urged by necessity, would they not unite, first, to defend themselves by numbers, and then to assist each other by working in concert, to make habitations and arms? They began by shaping into the forms of hatchets these hard flints, the Jade, and other stones, which were supposed to have been formed by thunder and fallen from the [471] clouds, but which are, nevertheless, only the first examples of man's art in a pure state of Nature. He will soon draw fire from these same flints, by striking them against each other; he will seize the flames of the burning volcano, or profit by the fire of the red-hot lava to light his fire of brushwood in the forest; and by the help of this powerful element he cleanses, purifies, and renders wholesome the place he selects for his habitation. With his hatchet of stone he chops wood, fells trees, shapes timber, and puts it together, fashions instruments of warfare and the most necessary tools and implements; and after having furnished themselves with clubs and other weighty and defensive arms, did not these first men find means to make lighter weapons to reach the swift-footed stag from afar? A tendon of an animal, a fibre of the aloe-leaf, or the supple bark of some ligneous plant, would serve as a cord to bring together the two extremities of an elastic branch of yew, forming a bow; and small flints, shaped to a point, arm the arrow. They will soon have snares, rafts, and canoes; they will form themselves into communities composed of a few families, or rather of relations sprung from the same family, as is still the case with some savage tribes, who have their game, fish, and fruits in common. But in all those countries whose area is limited by water, or surrounded by high mountains, these small nations, becoming too numerous, have been in time forced to parcel out the land between them; and from that moment the earth has become the domain of man; he has taken possession of it by his labour, he has cultivated it, and attachment to the soil follows the very first act of possession; the private interest makes part of the national interest; order, civilisation, and laws succeed, and society acquires force and consistency."[117] We love to quote the sentiments of a great writer—but how much more eloquent would the words of the naturalist have been, if he had added to his own grand eloquence of language, the knowledge which science has placed within reach of the writers of the present time—- if he could have painted man in the early days of his creation, in presence of the immense animal population which then occupied the earth, and fighting with the wild beasts which filled the forests of the ancient world! Man, comparatively very weak in organisation, destitute of natural weapons of attack or defence, incapable of rising into the air like the birds, or living under water like the fishes and some reptiles, might seem doomed to speedy destruction. But he was marked on the forehead with the Divine seal. Thanks to the superior gift of an exceptional intelligence, this being, in appearance so helpless, has by degrees [472] swept the most ferocious of its occupants from the earth, leaving those only who cater to his wants or desires, or by whose aid he changes the primitive aspects of whole continents.

The antiquity of man is a question which has largely engaged the attention of geologists, and many ingenious arguments have been hazarded, tending to prove that the human race and the great extinct Mammalia were contemporaneous. The circumstances bearing on the question are usually ranged under three series of facts: 1. The Cave-deposits; 2. Peat and shell mounds; 3. Lacustrine habitations, or Lake dwellings.

We have already briefly touched upon the Cave-deposits. In the Kirkdale Cave no remains or other traces of man's presence seem to have been discovered. But in Kent's Hole, an unequal deposit of loam and clay, along with broken bones much gnawed, and the teeth of both extinct and living Mammals, implements evidently fashioned by the human hand were found in the following order: in the upper part of the clay, artificially-shaped flints; on the clay rested a layer of stalagmite, in which streaks of burnt charcoal occurred, and charred bones of existing species of animals. Above the stalagmite a stone hatchet, or celt, made of syenite, of more finished appearance, was met with, with articles of bone, round pieces of blue slate and sandstone-grit, pieces of pottery, a number of shells of the mussel, limpet, and oyster, and other remains, Celtic, British, and Roman, of very early date; the lower deposits are those with which we are here more particularly concerned. The Rev. J. MacEnery, the gentleman who explored and described them, ascertained that the flint-instruments occupied a uniform situation intermediate between the stalagmite and the upper surface of the loam, forming a connecting link between both; and his opinion was that the epoch of the introduction of the knives must be dated antecedently to the formation of the stalagmite, from the era of the quiescent settlement of the mud. From this view it would follow that the cave was visited posteriorly to the introduction and subsidence of the loam, and before the formation of the new super-stratum of stalagmite, by men who entered the cave and disturbed the original deposit. Although flints have been found in the loam underlying the regular crust of stalagmite, mingled confusedly with the bones, and unconnected with the evidence of the visits of man—such as the excavation of ovens or pits—Dr. Buckland refused his belief to the statement that the flint-implements were found beneath the stalagmite, and always contended that they were the work of men of a more recent period, who had broken up the [473] sparry floor. The doctor supposed that the ancient Britons had scooped out ovens in the stalagmite, and that through them the knives got admission to the underlying loam, and that in this confused state the several materials were cemented together.

In 1858 Dr. Falconer heard of the newly-discovered cave at Brixham, on the opposite side of the bay to Torquay, and he took steps to prevent any doubts being entertained with regard to its contents. This cave was composed of several passages, with four entrances, formerly blocked up with breccia and earthy matter; the main opening being ascertained by Mr. Bristow to be seventy-eight feet above the valley, and ninety-five feet above the sea, the cave itself being in some places eight feet wide. The contents of the cave were covered with a layer of stalagmite, from one to fifteen inches thick, on the top of which were found the horns of a Reindeer; under the stalagmite came reddish loam or cave-earth, with pebbles and some angular stones, from two to thirteen feet thick, containing the bones of Elephants, Rhinoceros, Bears, Hyænas, Felis, Reindeer, Horses, Oxen, and several Rodents; and, lastly, a layer of gravel, and rounded pebbles without fossils, underlaid the cave-earth and formed the lowest deposit.

In these beds no human bones were found, but in almost every part of the bone-bed were flint-knives, one of the most perfect being found thirteen feet down in the bone-bed, at its lowest part. The most remarkable fact in connection with this cave was the discovery of an entire left hind-leg of the Cave-bear lying in close proximity to this knife; "not washed in a fossil state out of an older alluvium, and swept afterwards into this cave, so as to be mingled with the flint implements, but having been introduced when clothed in its flesh." The implement and the Bear's leg were evidently deposited about the same time, and it only required some approximative estimate of the date of this deposit, to settle the question of the antiquity of man, at least in an affirmative sense.

Mr. H. W. Bristow, who was sent by the Committee of the Royal Society to make a plan and drawings of the Brixham Cave, found that its entrance was situated at a height of ninety-five feet above the present level of the sea. In his Report made to the Royal Society, in explanation of the plan and sections, Mr. Bristow stated that, in all probability, at the time the cave was formed, the land was at a lower level to the extent of the observed distance of ninety-five feet, and that its mouth was then situated at or near the level of the sea.

The cave consisted of wide galleries or passages running in a north and south direction, with [474] minor lateral passages branching off nearly at right angles to the main openings—- the whole cave being formed in the joints, or natural divisional planes, of the rock.

The mouth or entrance to the cave originated, in the first instance, in an open joint or fissure in the Devonian limestone, which became widened by water flowing backwards and forwards, and was partly enlarged by the atmospheric water, which percolated through the cracks, fissures, and open joints in the overlying rock. The pebbles, forming the lowest deposit in the cave, were ordinary shingle or beach-gravel, washed in by the waves and tides. The cave-earth was the residual part of the limestone rock, after the calcareous portion had been dissolved and carried away in solution; and the stalactite and stalagmite were derived from the lime deposited from the percolating water.

With regard to bone-caves generally, it would seem that, like other such openings, they are most common in limestone rocks, where they have been formed by water, which has dissolved and carried away the calcareous ingredient of the rock. In the case of the Brixham cave, the mode of action of the water could be clearly traced in two ways: first, in widening out the principal passages by the rush of water backwards and forwards from the sea; and, secondly, by the infiltration and percolation of atmospheric water through the overlying rock. In both cases the active agents in producing the cave had taken advantage of a pre-existing fissure or crack, or an open joint, which they gradually enlarged and widened out, until the opening received its final proportions.

The cave presented no appearance of ever having been inhabited by man; or of having been the den of Hyænas or other animals, like Wookey Hole in the Mendips, and some other bone-caves. The most probable supposition is, that the hind quarter of the Bear and other bones which were found in the cave-earth, had been washed into the cave by the sea, in which they were floating about.

We draw some inferences of the greatest interest and significance from the Brixham cave and its contents.

We learn that this country was, at one time, inhabited by animals which are now extinct, and of whose existence we have not even a tradition; that man, then ignorant of the use of metal, and little better than the brutes, was the contemporary of the animals whose remains were found in the cave, together with a rude flint-implement—the only kind of weapon with which our savage ancestor defended himself against animals scarcely wilder than himself.

We also learn that after the cave had been formed and sealed up again, as it were, together with all its contents, by the deposition of a solid crust of stalagmite—an operation requiring a very great length of time to effect—the Reindeer (*Cervus Tarandus*) was indigenous to this country, as is proved by the occurrence of an antler of that animal which was found lying upon, and partly imbedded in, the stalagmite forming the roof or uppermost, that is, the latest formed, of the cave-deposits. [475]

Lastly, we learn that, at the time the cave was formed, and while the land was inhabited by man, that part of the country was lower by ninety-five feet than it is now; and that this elevation has probably been produced so slowly and so gradually, as to have been imperceptible during the time it was taking place, which extended over a vast interval of time, perhaps over thousands of years.

Perhaps it may not be out of place here to describe the mode of formation of bone-caves generally, and the causes which have produced the appearances these now present.

Caves in limestone rocks have two principal phases—one of formation, and one of filling up. So long as the water which enters the cavities in the course of formation, and carries off some of the calcareous matter in solution, can find an easy exit, the cavity is continually enlarged; but when, from various causes, the water only enters in small quantities, and does not escape, or only finds its way out slowly, and with difficulty, the lime, instead of being removed, is re-deposited on the walls, roof, sides, and floor of the cavity, in the form of stalactites and stalagmite, and the work of re-filling with solid carbonate of lime then takes place.

Encouraged by the Brixham discoveries, a congress of French and English geologists met at Amiens, in order to consider certain evidence, on which it was sought to establish as a fact that man and the Mammoth were formerly contemporaries.

The valley of the Somme, between Abbeville and Amiens, is occupied by beds of peat, some twenty or thirty feet deep, resting on a thin bed of clay which covers other beds, of sand and gravel, and itself rests on white Chalk with flints. Bordering the valley, some hills rise with a gentle slope to a height of 200 or 300 feet, and here and there, on their summits, are patches of Tertiary sand and clay, with fossils, and again more extensive layers of loam. The inference from this geological structure is that the river, originally flowing through the Tertiary formation, gradually cut its way through the various strata down to its present level. From the depth of the peat, its lower part lies below the sea-level, and it is supposed that a depression of the region has occurred at some period: again, in land lying quite low on the Abbeville side of the valley, but [476] above the tidal level, marine shells occur, which indicate an elevation of the region; again, about 100 feet above the valley, on the right bank of the river, and on a sloping surface, is the Moulin-Quignon, where shallow pits exhibit a floor of chalk covered by gravel and sand, accompanied by gravel and marly chalk and flints more or less worn, well-rounded Tertiary flints and pebbles, and fragments of Tertiary sandstone. Such is the general description of a locality which has acquired considerable celebrity in connection with the question of the antiquity of man.

The Quaternary deposits of Moulin-Quignon and the peat-beds of the Somme formerly furnished Cuvier with some of the fossils he described, and in later times chipped flint-implements from the quarries and bogs came into the possession of M. Boucher de Perthes; the statements were received at first not without suspicion—especially on the part of English geologists who were familiar with similar attempts on their own credulity—that some at least of these were manufactured by the workmen of the district. At length, the discovery of a human jaw and tooth in the gravel-pits of St. Acheul, near Amiens, produced a rigorous investigation into the facts, and it seems to have been established to the satisfaction of Mr. Prestwich and his colleagues, that flint-implements and the bones of extinct Mammalia are met with in the same beds, and in situations indicating very great antiquity. In the sloping and irregular deposits overlooking the Somme, the bones of Elephants, Rhinoceros, with land and fresh-water shells of existing species, are found mingled with flint-implements. Shells like those now found in the neighbouring streams and hedge-rows, with the bones of existing quadrupeds, have been obtained from the peat, with flint-tools of more than usual finish, and together with them a few fragments of human bones. Of these reliquiæ, the Celtic memorials lie below the Gallo-Roman; above them, oaks, alders, and walnut trees occur, sometimes rooted, but no succession of a new growth of trees appear.

The theory of the St. Acheul beds is this: they were deposited by fluviatile action, and are probably amongst the oldest deposits in which human remains occur, older than the peat-beds of the Somme—but what is their *real* age? Before submitting to the reader the very imperfect answer this question admits of, a glance at the previous discoveries, which tended to give confirmation to the observations just narrated, may be useful.

Implements of stone and flint have been continually turning up during the last century and a half in all parts of the world. In the neighbourhood of Gray's Inn Lane, in 1715, a flint spear-head was [477] picked up, and near it some Elephants' bones. In the alluvium of the Wey, near Guildford, a wedge-shaped flint-tool was found in the gravel and sand, in which Elephants' tusks were also found. Under the cliffs at Whitstable an oval-shaped flint-tool was found in what had probably been a fresh-water deposit, and in which bones of the Bear and Elephant were also discovered. Between Herne Bay and Reculver five other flint-tools have been found, and three more near the top of the cliff, all in fresh-water gravel. In the valley of the Ouse, at Beddenham, in Bedfordshire, flint-implements, like those of St. Acheul, mixed with the bones of Elephant, Rhinoceros, and Hippopotamus, have been found, and near them an oval and a spear-shaped implement. In the peat of Ireland great numbers of such implements have been met with. But nowhere have they been so systematically sought for and classified as in the Scandinavian countries.

The peat-deposits of those countries—of Denmark especially—are formed in hollows and depressions, in the northern drift and Boulder clay, from ten to thirty feet deep. The lower stratum, of two or three feet in thickness, consists of *sphagnum*, over which lies another growth of peat formed of aquatic and marsh plants. On the edge of the bogs trunks of Scotch firs of large size are found—a tree which has not grown in the Danish islands within historic times, and does not now thrive when planted, although it was evidently indigenous within the human period, since Steenstrup took with his own hands a flint-implement from beneath the trunk of one. The sessile variety of the oak would appear to have succeeded the fir, and is found at a higher level in the peat. Higher up still, the common oak, *Quercus robur*, is found along with the birch, hazel, and alder. The oak has in its turn been succeeded by the beech.

Another source from which numerous relics of early humanity have been taken is the midden-heaps (Kjökken-mödden) found along the Scandinavian coast. These heaps consist of castaway shells mixed with bones of quadrupeds, birds, and fishes, which reveal in some respects the habits of the early races which inhabited the coast. Scattered through these mounds are flint-knives, pieces of pottery, and ashes, but neither bronze nor iron. The knives and hatchets are said to be a degree less rude than those of older date found in the peat. Mounds corresponding to these, Sir Charles Lyell tells us, occur along the American coast, from Massachusetts and Georgia. The bones of the quadrupeds found in these mounds correspond with those of existing species, or species which have existed in historic times.

By collecting, arranging, and comparing the flint and stone implements, the Scandinavian [478] naturalists have succeeded in establishing a chronological succession of periods, which they designate—1. The Age of Stone; 2. The Age of Bronze; 3. The Age of Iron. The first, or Stone period, in Denmark, corresponded with the age of the Scotch fir, and, in part, of the sessile oak. A considerable portion of the oak period corresponded, however, with the age of *bronze*, swords made of that metal having been found in the peat on the same level with the oak. The *iron* age coincides with the beech. Analogous instances, confirmatory of these statements, occur in Yorkshire, and in the fens of Lincolnshire.

The traces left indicate that the aborigines went to sea in canoes scooped out of a single tree, bringing back deep-sea fishes. Skulls obtained from the peat and from tumuli, and believed to be contemporaneous with the mounds, are small and round, with prominent supra-orbital ridges, somewhat resembling the skulls of Laplanders.

The third series of facts (*Lake-dwellings*, or *lacustrine habitations*) consisted of the buildings on piles, in lakes, and once common in Asia and Europe. They are first mentioned by Herodotus as being used among the Thracians of Pæonia, in the mountain-lake Prasias, where the natives lived in dwellings built on piles, and connected with the shore by a narrow causeway, by which means they escaped the assaults of Xerxes. Buildings of the same description occupied the Swiss lakes, in the mud of which hundreds of implements, like those found in Denmark, have been dredged up. In Zurich, Moosseedorf near Berne, and Lake Constance, axes, celts, pottery, and canoes made out of single trees, have been found; but of the human frame scarcely a trace has been discovered. One skull dredged up at Meilen, in the Lake of Zurich, was intermediate between the Lapp-like skull of the Danish tumuli and the more recent European type.

The age of the different formations in which these records of the human race are found will probably ever remain a mystery. The evidence which would make the implements formed by man contemporaneous with the Mammoth and other great Mammalia would go a great way to prove that man was also pre-glacial. Let us see how that argument stands.

At the period when the upper Norwich Crag was deposited, the general level of the British Isles is supposed to have been about 600 feet above its present level, and so connected with the

European continent as to have received the elements of its fauna and flora from thence.

By some great change, a period of depression occurred, in which all the country north of the mouth of the Thames and the Bristol Channel was placed much below the present level. Moel Tryfaen experienced a submergence of at least 1,400 feet, during which it received the erratic blocks and other marks, indicative of floating icebergs, which have been described in a former chapter. The country was raised again to something like its original level, and again occupied by plants, Molluscs, Fishes and Reptiles, Birds, and Mammifera. Again subsidence takes place, and, after several oscillations, the level remains as we now find it. The estimated time required for these various changes is something enormous, and might have extended the term to double the number of years. The unit of the calculation is the upward rate of movement observed on the Scandinavian coast; applied to the oscillation of the ancient coast of Snowdonia, the figures represent 224,000 years for the several oscillations of the glacial period. Adding the pre-glacial period, the computation gives an additional 48,000 years. But, let us repeat, the figures and data are somewhat hypothetical. [479]

With regard to the St. Acheul beds—said to be the most ancient formation in which the productions of human hands have been found—they are confessedly older than the peat-beds, and the time required for the production of other peat-beds of equal thickness has been estimated at 7,000 years. The antiquity of the gravel-beds of St. Acheul may be estimated on two grounds:—1. General elevation above the level of the valley. 2. By estimating the animal-remains found in the gravel-beds, and not in the peat. The first question implies the denudation of the valley below the level of the gravel, or the elevation of the whole plateau. Each of these operations would involve an incalculable time, for want of data. In the second case, judging from the slow rate at which quadrupeds have disappeared in historic times, the extinct Mammoth and other great animals must have occupied many centuries in dying out, for the notion that they died out suddenly from sharp and sudden refrigeration, is not generally admitted.

With regard to the three ages of stone, bronze, and iron, M. Morlot has based some calculations upon the condition of the delta of Tinière, near Villeneuve, which lead him to assign to the oldest, or stone period, an age of 5,000 to 7,000 years, and to the bronze period from 3,000 to 4,000. We may, then, take leave of this subject with the avowal that, while admitting the probability that an immense lapse of time would be required for the operations described, we are, in a great measure, without reliable data for estimating its actual extent.

The opinion which places the creation of man on the banks of the Euphrates in Central Asia is confirmed by an event of the highest importance in the history of humanity, and by a crowd of concordant traditions, preserved by different races of men, all tending to confirm it. We speak of the Asiatic deluge. [480]

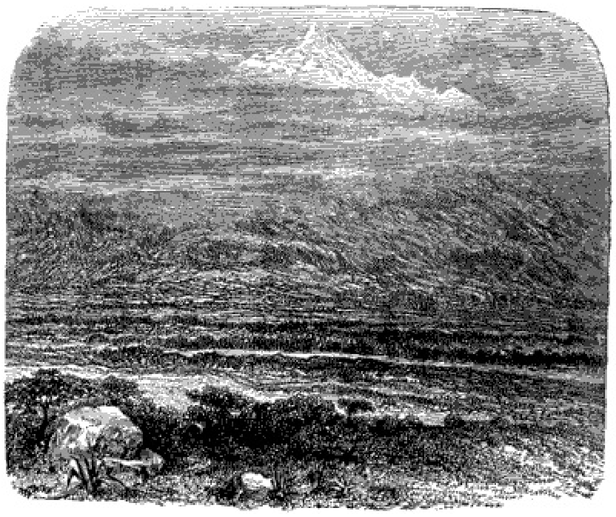


Fig. 200.—Mount Ararat.

The Asiatic deluge—of which sacred history has transmitted to us the few particulars we know—was the result of the upheaval of a part of the long chain of mountains which are a prolongation of the Caucasus. The earth opening by one of the fissures made in its crust in course of cooling, an eruption of volcanic matter escaped through the enormous crater so produced. Volumes of watery vapour or steam accompanied the lava discharged from the interior of the globe, which, being first dissipated in clouds and afterwards condensing, descended, in torrents of rain, and [481] the plains were drowned with the volcanic mud. The inundation of the plains over an extensive radius was the immediate effect of this upheaval, and the formation of the volcanic cone of Mount Ararat, with the vast plateau on which it rests, altogether 17,323 feet above the sea, the permanent result. The event is graphically detailed in the seventh chapter of Genesis.

11. "In the six hundredth year of Noah's life, in the second month, the seventeenth day of the month, the same day were all the fountains of the great deep broken up, and the windows of heaven were opened.

12. "And the rain was upon the earth forty days and forty nights."

17. “And the flood was forty days upon the earth; and the waters increased, and bare up the ark, and it was lift up above the earth.

18. “And the waters prevailed, and were increased greatly upon the earth; and the ark went upon the face of the waters.

19. “And the waters prevailed exceedingly upon the earth; and all the high hills, that *were* under the whole heaven, were covered.

20. “Fifteen cubits upward did the waters prevail; and the mountains were covered.

21. “And all flesh died that moved upon the earth, both of fowl, and of cattle, and of beast, and of every creeping thing that creepeth upon the earth, and every man:

22. “All in whose nostrils *was* the breath of life, of all that *was* in the dry land, died.

23. “And every living substance was destroyed which was upon the face of the ground, both man, and cattle, and the creeping things, and the fowl of the heaven; and they were destroyed from the earth: and Noah only remained *alive*, and they that *were* with him in the ark.

24. “And the waters prevailed upon the earth an hundred and fifty days.”

All the particulars of the Biblical narrative here recited are only to be explained by the volcanic and muddy eruption which preceded the formation of mount Ararat. The waters which produced the inundation of these countries proceeded from a volcanic eruption accompanied by enormous volumes of vapour, which in due course became condensed and descended on the earth, inundating the extensive plains which now stretch away from the foot of Ararat. The expression, [482]
“the earth,” or “all the earth” as it is translated in the Vulgate, which might be implied to mean the entire globe, is explained by Marcel de Serres, in a learned book entitled “La Cosmogonie de Moïse,” and other philologists, as being an inaccurate translation. He has proved that the Hebrew word *haarets*, incorrectly translated “all the earth,” is often used in the sense of *region* or *country*, and that, in this instance, Moses used it to express only the part of the globe which was then peopled, and not its entire surface. In the same manner “*the mountains*” (rendered “*all the mountains*” in the Vulgate), only implies all the mountains known to Moses. Similarly, M. Glaire, in the “Christomathie Hébraïque,” which he has placed at the end of his Grammar, quotes the passage in this sense: “The waters were so prodigiously increased, that the highest mountains of the vast horizon were covered by them;” thus restricting the mountains covered by the inundation to those bounded by the horizon.

Nothing occurs, therefore, in the description given by Moses, to hinder us from seeing in the Asiatic deluge a means made use of by God to chastise and punish the human race, then in the infancy of its existence, and which had strayed from the path which he had marked out for it. It seems to establish the countries lying at the foot of the Caucasus as the cradle of the human race; and it seems to establish also the upheaval of a chain of mountains, preceded by an eruption of volcanic mud, which drowned vast territories entirely composed, in these regions, of plains of great extent. Of this deluge many races besides the Jews have preserved a tradition. Moses dates it from 1,500 to 1,800 years before the epoch in which he wrote. Berosus, the Chaldean historian, who wrote at Babylon in the time of Alexander, speaks of a universal deluge, the date of which he places immediately before the reign of Belus, the father of Ninus.

The *Vedas*, or sacred books of the Hindus, supposed to have been composed about the same time as Genesis, that is, about 3,300 years ago, make out that the deluge occurred 1,500 years before their time. The *Guebers* speak of the same event as having occurred about the same date.

[483]

XXXIII.—The Asiatic Deluge.

Confucius, the celebrated Chinese philosopher and lawgiver, born towards the year 551 before Christ, begins his history of China by speaking of the Emperor named Jas, whom he represents as making the waters flow back, which, *being raised to the heavens*, washed the feet of the highest mountains, covered the less elevated hills, and inundated the plains. Thus the Biblical deluge (Plate XXXIII.) is confirmed in many respects; but it was local, like all phenomena of the kind, and [485] was the result of the upheaval of the mountains of western Asia.

A deluge, quite of modern date, conveys a tolerably exact idea of this kind of phenomena. We recall the circumstances the better to comprehend the true nature of the ravages the deluge inflicted upon some Asiatic countries in the Quaternary period. At six days' journey from the city of Mexico there existed, in 1759, a fertile and well-cultivated district, where grew abundance of rice, maize, and bananas. In the month of June frightful earthquakes shook the ground, and were continued unceasingly for two whole months. On the night of the 28th September the earth was violently convulsed, and a region of many leagues in extent was slowly raised until it attained a height of about 500 feet over a surface of many square leagues. The earth undulated like the waves of the sea in a tempest; thousands of small hills alternately rose and fell, and, finally, an immense gulf opened, from which smoke, fire, red-hot stones and ashes were violently discharged, and darted to prodigious heights. Six mountains emerged from this gaping gulf; among which the volcanic mountain Jorullo rises 2,890 feet above the ancient plain, to the height of 4,265 feet above the sea.

At the moment when the earthquake commenced the two rivers *Cuitimba* and *San Pedro* flowed backwards, inundating all the plain now occupied by Jorullo; but in the regions which continually rose, a gulf opened and swallowed up the rivers. They reappeared to the west, but at a point very distant from their former beds.

This inundation reminds us on a small scale of the phenomena which attended the deluge of Noah.

Besides the deposits resulting from the partial deluges which we have described as occurring in Europe and Asia during the Quaternary epoch there were produced in the same period many new formations resulting from the deposition of *alluvia* thrown down by seas and rivers. These deposits are always few in number, and widely disseminated. Their stratification is as regular as that of any which belong to preceding periods; they are distinguished from those of the Tertiary epoch, with which they are most likely to be confounded, by their situation, which is very frequently upon the shores of the sea, and by the predominance of shells of a species identical with those now living in the adjacent seas.

A marine formation of this kind, which, after constituting the coast of Sicily, principally on the side of Girgenti, Syracuse, Catania, and Palermo, occupies the centre of the island, where it rises to the height of 3,000 feet, is amongst the most remarkable of the great Quaternary European [486] productions. It is chiefly formed of two great beds; the lower a bluish argillaceous marl, the other a coarse but very compact limestone, both containing shells analogous to those of the present Mediterranean coast. The same formation is found in the neighbouring islands, especially in Sardinia and Malta. The great sandy deserts of Africa, as well as the argillo-arenaceous formation of the steppes of Eastern Russia, and the fertile Tchornozem, or "*black earth*" of its southern plains, have the same geological origin; so have the Travertines of Tuscany, Naples, and Rome, and the Tufas, which are an essential constituent of the Neapolitan soil.

The pampas of South America—which consist of an argillaceous soil of a deep reddish-brown colour, with horizontal beds of marly clay and calcareous tufa, containing shells either actually living now in the Atlantic, or identical with fresh-water shells of the country—ought surely to be considered as a Quaternary deposit, of even greater extent than the preceding.

We are now approaching so near to our own age, that we can, as it were, trace the hand of Nature in her works. Professor Ramsay shows, in the Memoirs of the Government Geological Survey, that beds nearly a mile in thickness have been removed by denudation from the summit of the Mendip Hills, and that broad areas in South Wales and the neighbouring counties have been denuded of their higher beds, the materials being transported elsewhere to form newer strata. Now, no combination of causes has been imagined which has not involved submersion during long periods, and subsequent elevation for periods of longer or shorter duration.

We can hardly walk any great distance along the coast, either of England or Scotland, without remarking some flat terrace of unequal breadth, and backed by a more or less steep escarpment—upon such a terrace many of the towns along the coast are built. No geologist now doubts that this fine platform, at the base of which is a deposit of loam or sandy gravel, with marine shells, had been, at some period, the line of coast against which the waves of the ocean once broke at high water. At that period the sea rose twenty, and thirty, and some places a hundred feet higher than it does now. The ancient sea-beaches in some places formed terraces of sand and gravel, with littoral shells, some broken, others entire, and corresponding with species in the seas below; in others they form bold projecting promontories or deep bays. In an historical point of view, this coast-line should be very ancient, though it may be only of yesterday in a geological sense—its origin ascending far beyond written tradition. The wall of Antoninus, raised by the Romans as a [487] protection from the attacks of the Caledonians, was built, in the opinion of the best authorities, not in connection with the old, but with the new coast-line. We may, then, conclude that in A.D.

140, when the greater part of this wall was constructed, the zone of the ancient coast-line had attained its present elevation above the actual level of the sea.

The same proofs of a general and gradual elevation of the country are observable almost everywhere: in the estuary of the Clyde, canoes and other works of art have been exhumed, and assigned to a recent period. Near St. Austell, and at Carnon, in Cornwall, human skulls and other relics have been met with beneath marine strata, in which the bones of whales and still-existing species of land-quadrupeds were imbedded. But in the countries where hard limestone rocks prevail, in the ancient Peloponnesus, along the coast of Argolis and Arcadia, three and even four ranges of ancient sea-cliffs are well preserved, which Messrs. Boblaye and Verlet describe as rising one above the other, at different distances from the present coast, sometimes to the height of 1,000 feet, as if the upheaving force had been suspended for a time, leaving the waves and currents to throw down and shape the successive ranges of lofty cliffs. On the other hand, some well-known historical sites may be adduced as affording evidence of the subsidence of the coast-line of the Mediterranean in times comparatively modern. In the Bay of Baiæ, the celebrated temple of Serapis, at Puzzuoli, near Naples, which was originally built about 100 feet from the sea, and at or near its present level, exhibits proofs of having gradually sunk nineteen feet, and of a subsequent elevation of the ground on which the temple stands of nearly the same amount.

So, also, about half a mile along the sea-shore, and standing at some distance from it, in the sea, there are the remains of buildings and columns which bear the name of the Temples of the Nymphs and of Neptune. The tops of these broken columns are now nearly on a level with the surface of the water, which is about five feet deep.

With respect to the littoral deposits of the Quaternary period, they are of very limited extent, except in a few localities. They are found on the western coast of Norway, and on the coasts of England. In France, an extensive bed of Quaternary formation is seen on the shores of the ancient Guienne, and on other parts of the coast, where it is sometimes concealed by trees and shrubs, or by blown sand, as at Dax in the Landes, where a steep bank may be traced about [488] twelve miles inland, and parallel with the present coast, which falls suddenly about fifty feet from a higher platform of the land, to a lower one extending to the sea. In making some excavations for the foundations of a building at Abesse, in 1830, it was discovered that this fall consisted of drift-sand, filling up a steep perpendicular cliff about fifty feet high, consisting of a bed of Tertiary clay extending to the sea, a bed of limestone with Tertiary shells and corals, and, at the summit, the Tertiary sand of the Landes. The marine beds, together with the alluvium of the rivers, have given rise to those deposits which occur more especially near the mouths of rivers and watercourses.

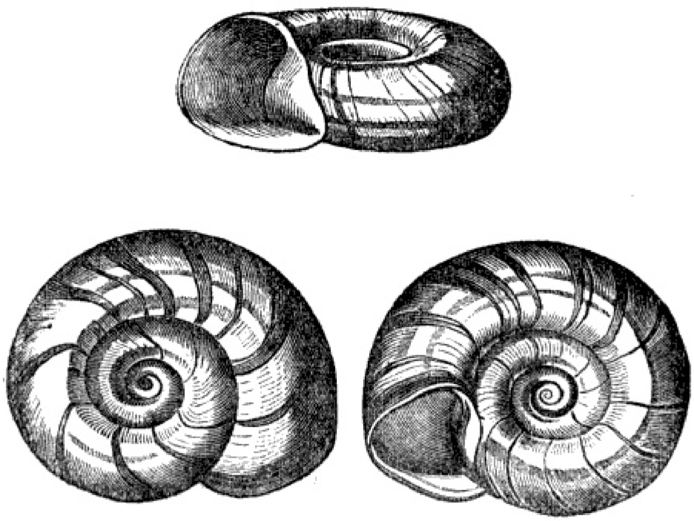


Fig. 201.—Shell of Planorbis corneus.

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[98] H. Woodward, *Geological Magazine*, vol. viii., p. 193.

[99] “Darwin’s Journal,” p. 130.

[100] “Journal of Researches,” &c., 2nd ed., p. 133. Charles Darwin.

[101] “Journal of Researches,” &c., by Charles Darwin, p. 81.

[102] “Journal of Researches,” &c., by Charles Darwin, 2nd ed., p. 81.

[103] “Reliquiæ Diluvianæ,” by the Rev. W. Buckland, 1823, p. 19.

[104] “Elements of Geology,” p. 122.

[105] *Quart. Jour. Geol. Soc.*, 1859.

[106] *Revue des Deux Mondes*, p. 925; March 1, 1847.

[107] “Carte des Anciens Glaciers des Alpes,” pp. 8-10. (1860.)

[108] Professor Ramsay, “The Old Glaciers of North Wales.” Longman, 1860.

[109] In 1840 Dr. Buckland described the occurrence of boulders of Criffel Granite between Shalbeck and Carlisle, and attributed their position to the agency of ice floating across the Solway Firth.

[110] Mr. Darbishire records seventy species from Macclesfield and Moel Tryfaen, taken together, of which 6 are Arctic, and 18 are not known in the Upper Crag.

[111] The typical species in West Lancashire are *Tellina Balthica*, *Cardium edule*, *C. aculeatum*, *C. rusticum*, *Psammobia ferroensis*, *Turritella terebra*.

[112] *Geological Magazine*, vol. iii., p. 483.

[113] *Revue des Deux Mondes.*

[114] “Ossements fossiles. Discours sur les Révolutions du Globe.”

[115] Lyell’s “Elements of Geology,” p. 175.

[116] It is told of a former distinguished and witty member of the Geological Society that, having obtained possession of the rooms on a certain day, when there was to be a general meeting, he decorated its walls with a series of cartoons, in which the parts of the members were strangely reversed. In one cartoon Ichthyosauri and Plesiosauri were occupied with the skeleton of Homo sapiens; in another, a party of Crustaceans were occupied with a cranium suspiciously like the same species; while in a third, a party of Pterichthys were about to dine on a biped with a suspicious resemblance to a certain well-conditioned F.G.S. of the day.

[117] “Époques de la Nature,” vol. xii., pp. 322-325. 18mo. Paris, 1778.

EPILOGUE. [489]

Having considered the past history of the globe, we may now be permitted to bestow a glance upon the future which awaits it.

Can the actual state of the earth be considered as definitive? The revolutions which have fashioned its surface, and produced the Alps in Europe, Mount Ararat in Asia, the Cordilleras in the New World—are they to be the last? In a word, will the terrestrial sphere for ever preserve the form under which we know it—as it has been, so to speak, impressed on our memories by the maps of the geographers?

It is difficult to reply with any confidence to this question; nevertheless, our readers will not object to accompany us a step further, while we express an opinion, founded on analogy and scientific induction.

What are the causes which have produced the present inequalities of the globe—the mountain-ranges, continents, and waters? The primordial cause is, as we have had frequent occasion to repeat, the cooling of the earth, and the progressive solidification of the external crust, the nucleus of which still remains in a fluid or viscous state. These have produced the contortions, furrows, and fractures which have led to the elevation of the great mountain-ranges and the depression of the great valleys—which have caused some continents to emerge from the bed of ocean and have submerged others. The secondary causes which have contributed to the formation of a vast extent of dry land are due to the sedimentary deposits, which have resulted in the creation of new continents by filling up the basins of the ancient seas.

Now these two causes, although in a minor degree, continue in operation to the present day. The thickness of the terrestrial crust is only a small fraction compared to that of the internal liquid mass. The principal cause, then, of the great dislocations of the earth’s crust is, so to speak, at our gates; it threatens us unceasingly. Of this the earthquakes and volcanic eruptions, which are still frequent in our day, give us disastrous and incontestable proofs. On the other hand, our seas [490] are continually forming new land: the bed of the Baltic Sea, for instance, is gradually rising, in consequence of the deposits which will obviously fill up its area entirely in an interval of time which it might not be impossible to calculate.

It is, then, probable that the actual condition of the surface and the respective limits of seas and continents have nothing fixed or definite in them—that they are, on the contrary, open to great modifications in the future.

There is another problem much more difficult of solution than the preceding, but for which neither induction nor analogy furnish us with any certain data—viz., the perpetuity of our species. Is man doomed to disappear from the earth some day, like all the races of animals which preceded him, and prepared the way for his advent? Will a new *glacial period*, analogous to that which, during the Quaternary period, was felt so rigorously, again come round to put an end to his existence? Like the Trilobites of the Silurian period, the great Reptiles of the Lias, the Mastodons of the Tertiary, and the Megatheriums of the Quaternary epoch, is the human species to be annihilated—to perish from the globe by a simple natural extinction? Or must we believe that man, gifted with the attribute of reason, marked, so to say, with the Divine seal, is to be the ultimate and supreme term of creation?

Science cannot pronounce upon these grave questions, which exceed the competence, and extend beyond the circle of human reasoning. It is not impossible that man should be only a step in the ascending and progressive scale of animated beings. The Divine Power which has lavished upon the earth life, sentiment, and thought; which has given organisation to plants; to animals, motion, sensation, and intelligence; to man, in addition to these multiple gifts, the faculty of reason, doubled in value by the ideal—reserves to Himself perhaps in His wisdom the privilege of creating alongside of man, or after him, a being still more perfect. This new being, religion and modern poesy would present in the ethereal and radiant type of the Christian angel, with moral qualities whose nature and essence would escape our perceptions—of which we could no more form a notion than one born blind could conceive of colour, or the deaf and dumb of sound. *Erunt æquales angelis Dei.* “They will be as the angels of God,” says Holy Scripture, speaking of man raised to the life eternal.

During the Metamorphic epoch the *mineral kingdom* existed alone; the rocks, silent and solitary, were all that was yet formed of the burning earth. [491] During the Primary epoch, the vegetable kingdom, newly created, extended itself over the whole globe, which it soon covered from pole to pole with an uninterrupted mass of verdure. During the Secondary and Tertiary epochs, the vegetable and animal kingdoms divided the earth between them. In the Quaternary epoch the *human kingdom* appeared. Is it in the future destinies of our planet to receive yet another lord? And after the four kingdoms which now occupy it, is there to be a *new kingdom* created, the attributes of which can never be anything but an impenetrable mystery, and which will differ from man in as great a degree as man differs from the other animals, and plants from rocks?

We must be contented with suggesting, without hoping to solve, this formidable problem. It is a great mystery, which, according to the fine expression of Pliny, “lies hidden in the majesty of Nature,” *latet in majestate naturæ*; or (to speak more in the spirit of Christian philosophy) it is known only to the Almighty Creator of the Universe.

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TABLE
OF
BRITISH SEDIMENTARY AND FOSSILIFEROUS STRATA.

By H. W. BRISTOW.

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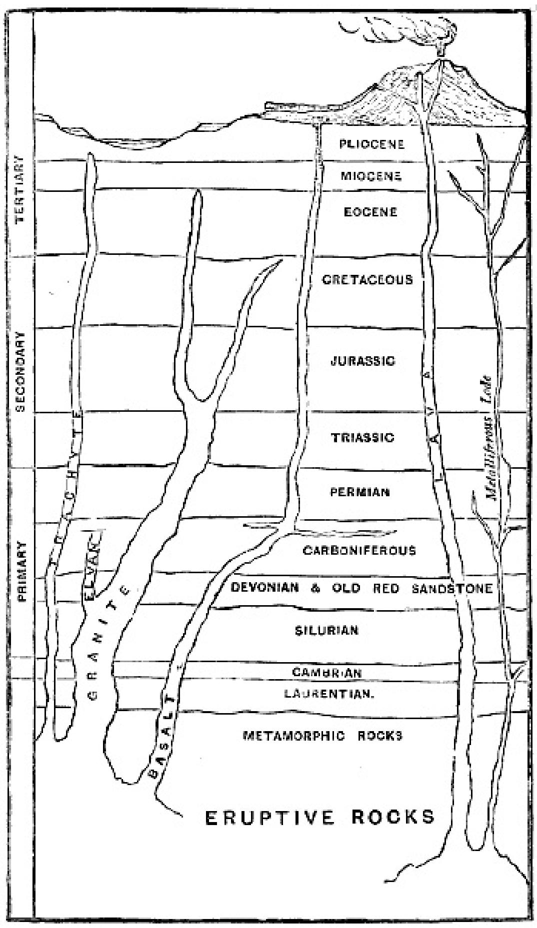

[495]

	Subdivisions.	Foreign Equivalents.	Origin.	Commercial Products.
	Blown Sand.			

Post Pliocene.	Raised Beaches. Alluvium. Brick Earth. River Gravel. Cave Deposits. Glacial Deposits.	Mud of the Nile. Loess of the Rhine.	Various.	Peat. Amber. Gold, Diamonds, and other Gems derived from the older deposits.
Pliocene.	Crags.	Sub-Apennine Strata.	Marine	Phosphatic Nodules.
Miocene.	Leaf Beds and Lignite.	Molasse. Faluns of Touraine.	and	Pipeclay.
Eocene.	Upper Eocene. Bagshot Beds. London Clay. Reading Beds, &c.	Calcaire Grossier. Nummulitic Limestones (European and Asiatic).	Freshwater. Estuarine and Marine.	Sand, Brown Coal, Pipeclay, Cement Stone, Bricks, and Pottery.
Upper Cretaceous. Lower Cretaceous.	White and Grey Chalk. Upper Greensand. Gault. Lower Greensand. Wealden Beds, &c.	Maestricht Beds. Senonien Turonien. Albien. Aptien. Neocomian.	Marine and Freshwater (Wealden).	Flints from Up. Chalk. Phosphate of Lime. Iron Pyrites. Sandy Ironstones. Building Stone.
Upper Oolitic. Middle Oolitic. Lower Oolitic.	Purbeck. Portland and Kimeridge. Coral Rag & Oxford Clay. Cornbrash. Forest Marble and Great Oolite. Stonesfield Slate. Inferior Oolite. Lias.	Jura Formation.	Estuarine and Marine. Marine.	Coal, Jet, Iron Ores, Roofing Slates, Building Stones, and Flags. Alum Shales. Hydraulic Limestones.
Keuper. Bunter.	Rhætic. New Red Marl, Sandstone, and Conglomerate. Sandstone & Pebble Beds.	Muschelkalk absent in British Isles.	Inland Seas. Salt Lakes.	Gypsum. Rock Salt. Building Stones.
Magnesian Limestone. Lower Permian.	Red Marls and Magnesian Limestone. Red Marl, Sandstone, and Conglomerate.	Zechstein. Kupferschiefer. Rothliegende.	Marine.	Building Stones.
Carboniferous.	Coal Measures. Millstone Grit. Yoredale Rocks. Mountain Limestone.	Carboniferien.	Terrestrial and Marine.	Coal, Anthracite. Iron and Lead Ores. Bldng. Stone,Marble. Oil Springs.
Devonian and Old Red Sandstone.	Devonian Slates and Limestones. Old Red Sandstone, &c.	Eifel Limestone.	Marine and Freshwater.	Ornamental Marbles. Serpentine & Slates. Tin, Copper, Lead, Silver Ores, &c.
Upper Silurian. Lower Silurian.	Ludlow. Wenlock. Upper Llandovery. Lower Llandovery. Bala and Caradoc. Llandeilo. Lingula Flags.	Primordial Zone.	Marine.	Roofing Slates. Building Stones. Gold & other Metals.
Cambrian.	Harlech Grits. Llanberis Slates.	Huronian of America.	Marine.	Roofing Slates. Gold & other Metals.
Laurentian.	Gneiss of the Outer Hebrides, and N.W. Coast of Scotland.	Labradorite Series in Canada.	Marine.	Serpentine. Graphite.

Metamorphic Rocks (*of all ages*):—
Gneiss, Mica-schist, Quartzite, Talcose-schist, &c. (Serpentine probably?)

Intrusive Rocks (*of all ages*):—
Lavas, Basalt, Trachyte, Pitchstone, &c.
Granite, Syenite, Greenstone, Felstone, Porphyrites, Melaphyres, Mica-Traps, &c. &c.

EXTENSION OF THE PREVIOUS TABLE.

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		Recent and Pre-	Blown Sand and Shingle. Alluvium and River Deltas. Burtle Beds of Somerset. Clay, with Scrobicularia of Pagham, Morecombe,

- AGE OF MAMMALS.
  - POST TERTIARY.
    - PLEISTOCENE, or Quaternary.
      - Historic.
        - &c.
        - Submerged Forests of Bristol Channel, &c.
        - Peat Bogs of Ireland and Peat Beds of England.
      - Post Glacial
        - Raised Beaches.
        - Cave Deposits
          - Cave Earth and Loam.
          - Stalagmite and Bone-breccia.
        - River Gravels, Brick Earths, and Freshwater Clays, with Mammalian Remains.
        - Gravels of Bedford Levels, Salisbury, and other Old Valley Gravels and Alluvia.
        - Tufa and Shell-marl.
      - Glacial
        - Kaimes or Kames of Scotland.
        - Eskers or Escars of Ireland.
        - Drift (Upper Boulder Clay or Till, Marine Gravels, Lower Till and Moraines), Scotch and Welsh, Loess of the Rhine, &c.
      - Pre-glacial
        - Forest Bed of Norfolk Shore.
  - KAINOZOIC, OR TERTIARY.
    - PLIOCENE.
      - Crag
        - Mammaliferous Crag, Red Crag — *Norwich and Chillesford Crag* (Newer Pliocene).
        - Coralline Crag (*Suffolk Crag*) (Older Pliocene).
    - MIOCENE.
      - Leaf Bed of Mull.
      - Lignite of Antrim.
      - Bovey Beds, with Lignite.
    - EOCENE.
      - Upper Eocene.
        - Hempstead Beds
          - Corbula Beds.
          - Upper, Middle, Lower — Freshwater and Estuary Marls.
        - Bembridge Beds
          - Bembridge Marls.
          - „ Limestone.
      - Middle Eocene.
        - Osborne Beds
          - St. Helen's Sands.
          - Nettlestone Grits.
        - Headon Beds
          - Upper, Middle, Lower — Headon Beds.
        - (Hempstead, Bembridge, Osborne and Headon Beds — Fluvio-Marine Series.)
        - Bagshot Beds
          - Upper Bagshot Sand.
          - Middle „
            - Barton Clay.
            - Bracklesham Beds.
          - Lower „ Sand and Pipeclay, with Plants.
      - Lower Eocene.
        - London Tertiaries
          - London Clay and Bognor Beds (Upper London Tertiaries).
          - Oldhaven Beds, Woolwich and Reading Beds (Plastic Clay), Thanet Beds — Lower do.

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- CRETACEOUS.
  - Upper Cretaceous.
    - Chalk
      - Upper Chalk, with Layers of Flint (Maestricht and Faxoe Beds).
      - Lower Chalk, without Flints.
      - Chalk Marl.
      - Chloritic Marl.
    - Upper Greensand (Fire-stone of Surrey, Malm-rock), &c.
    - Gault.
  - Lower Greensand
    - Folkestone Beds (Sand).
    - Sandgate Beds (with Fullers' Earth).
    - Hythe Beds (with Kentish Rag and Bargate Stone).
    - Atherfield Clay.
  - Weald Clay (with Sussex or Bethersden Marble and

- MESO-ZOIC, OR SECON-DARY. —
  - Lower Cretaceous, or Neo-comian. —
    - Weal-den. —
      - Neo-co-mian. —
        - Horsham Stone).
        - Has-tings Sands —
          - Tunbridge Wells Beds. —
            - Upper Tunbridge Wells Sand
            - Grinstead Clay
            - Lower Tunbridge Wells Sand
          - Wadhurst Clay (with Iron Ore).
          - Ashdown Sands.
          - Ashburnham Beds.
      - Pur-beck —
        - Purbeck Beds. —
          - Upper (with Purbeck Marble)
          - Middle
          - Lower (with Dirt Beds)
  - JURAS-SIC SERIES. —
    - OO-LITIC SERIES. —
      - Upper Oolite. —
        - (Wealden — Purbeck, as above)
        - Portland —
          - Portland Stone.
          - Portland Sand.
          - Kimeridge Clay (with Bituminous Shale).
      - Middle Oolite. —
        - Coralline Oolite —
          - Upper Calcareous Grit.
          - Coral Rag (with Iron Ore).
          - Lower Calcareous Grit.
        - Oxford Clay —
          - Oxford Clay and
          - Kellaways Rock.
      - Lower Oolite. —
        - Forest Marble —
          - Cornbrash.
          - —
            - Forest Marble and
            - Bradford Clay (with Encrinites)
        - Great Oolite —
          - Great or Bath Oolite (with "Fullers' Earth" at base, in S. of England).
          - Stonesfield Slate, near the base, in part of S. of England.
        - Fullers' Earth —
          - Upper Fullers' Earth (Clay).
          - Fullers' Earth Rock (Limestone).
          - Lower Fullers' Earth (Clay).
        - Inferior Oolite —
          - Northampton Sand (with Iron Ore, in N. Oxfordshire and S. Northamptonshire).
          - Ragstone and Clypeus Bed.
          - Cheltenham Sections. —
            - Upper Freestone.
            - Oolite Marl.
            - Lower Freestone.
            - Pea Grit.
          - (Colleyweston Slate, at the base of the Limestone, in Lincolnshire).
          - Sands.
    - Age of Reptiles, or Saurozoic Epoch.
      - Lias. —
        - Upper Lias — Clay and Shale.
        - Middle Lias, or Marlstone (Rock Bed, with Iron Ore, Sand, &c.).
        - Lower Lias — Clay, Shale, and Limestone.
  - Upper
    - Rhætic, or Penarth Beds. —
      - "White Lias," Avicula contorta Beds, with Koessen Beds.
      - Bone Beds of Aust, &c.
      - *St. Cassian and Hallstadt Beds.* [498]

- POIKILITIC SERIES.
  - TRIAS, OR NEW RED SANDSTONE.
    - TRIAS. — Keuper
      - Red variegated Marl and Upper Keuper Sandstone (with Gypsum and Rock Salt).
      - Lower Keuper Sandstone and Marl (Waterstones).
      - Dolomitic Conglomerate (of Keuper Age, Somerset, Gloucester, and S. Wales).
    - MIDDLE TRIAS. — *Muschelkalk, absent in Britain.*
    - LOWER TRIAS. — Bunter
      - Upper Red and Mottled Sandstone.
      - Pebble Beds, Calcareous Conglomerate, and Breccia.
      - Lower Red and Mottled Sandstone.

- PALÆOZOIC, OR PRIMARY.
  - UPPER PALÆOZOIC. AGE OF FISHES, OR ICHTHYOZOIC EPOCH.
    - PERMIAN.
      - Upper, or Magnesian Limestone Series. (GERMANY.)
        - Upper Red Marl and Sandstone
        - Upper Magnesian Limestone
        - Lower Red Marl and Sandstone
        - Lower Magnesian Limestone
        - — Zechstein.
      - Lower, or Rothliegende.
        - Red Marl, Sandstone, Breccia, Rötheliegende, and Conglomerate.
    - CARBONIFEROUS SERIES. AGE OF PLANTS, OR PHYTOZOIC EPOCH.

	ENGLAND.	SCOTLAND.
Coal Measures	Upper Coal Measures; Middle Coal Measures, Pennant Grit; Lower Coal Measures; Gannister Beds	Upper Coal Measures.
	Millstone Grit or Farewell Rock	Moor Rock.
Carboniferous, or Mountain Limestone.	Upper Limestone Shale (Yoredale Rocks); Carboniferous Limestone	Upper Limestones. Edge Coals Series. Lower Limestones.
	Lower Limestone Shale	Sandstones, Shales, and Burdie House Limestone.

- OLD RED SANDSTONE AND DEVONIAN.
  - Old Red Sandstone, or Devonian Beds.
    - Upper Devonian or Barnstaple and Marwood Beds, with Petherwin Limestone, in N.E. Cornwall.
    - Middle Devonian or Ilfracombe Beds, with Fossiliferous Limestones and Cornstones.
    - Lower Devonian, or Lynton Beds.

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	WALES AND CENTRAL ENGLAND.	LAKE DISTRICT.
Ludlow Beds	Tilestones (Passage Beds); Upper Ludlow Beds (with Bone Bed)	Kirkby Moor Flags.
	Aymestry Limestone; Lower Ludlow Beds	Bannisdale Beds.

LOWER PALÆOZOIC. Age of Crustaceans ond Molluscs, or Malacozoic Epoch.	Silurian.	Upper Silurian.	Wenlock Beds	Wenlock Limestone Wenlock Shale, Sandstone, and Flags	
				Woolhope Limestone and Shale Denbighshire Grits, Shales, Slates, and Flags	Coniston Grits and Flags. Stockdale Slates.
				Tarannon Shale (Pale Slates).	
			Llandovery Beds	Upper Llandovery Rocks. (May Hill Sandstone). (Pentamerus Beds). Lower Llandovery Rocks.	
		Lower Silurian.	Caradoc, or Bala Beds.	Caradoc and Bala Beds. (Sandstones often shelly, with Bala Limestone, Shale, and Slate)	Coniston Limestone, Bala (Limestone and Shale) Skiddaw Slates.
			Llandeilo	Llandeilo Flags and Limestone, &c. Tremadoc Slates.	
			Lingula Beds	Lingula Flags. (Primordial Zone of Barrande).	
EOZOIC.	Cambrian.		Cambrian	Harlech Grits, &c. Purple Slates and Grits (St. David's). Llanberis Grits and Slates. Longmynd Rocks. Red Sandstone and Conglomerate (Scotland).	
	Laurentian			Fundamental Gneiss of the Outer Hebrides and of the N.W. coast of Scotland, &c., containing the oldest known fossil, *Eozoon Canadense*.	

INDEX.

*** ITALICS ARE WOODCUT ILLUSTRATIONS.

THE END.

CASSELL, PETTER, AND GALPIN, BELLE SAUVAGE WORKS, LONDON, E.C.
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TRANSCRIBER'S NOTES:

The original text has been maintained, including inconsistencies in spelling, hyphenation, lay-out, formatting, etc. and in the use of capitals, diacriticals and accents, except as described below under Changes Made. Important inconsistencies include: Saarbruck/Saarbrück, Coalbrookdale/Coalbrook Dale, Roth-liegende/Rothliegende/Röthe-liegende, Westmorland/Westmoreland, blow-pipe/blowpipe, cuttle-fish/cuttlefish, frame-work/framework, fresh-water/freshwater, Kupfer-schiefer/Kupferschiefer, rain-drops/raindrops, re-construct/reconstruct (and related words), Roth-todt-liegende/Rothe-todte-liegende, sub-divide/subdivide (and related words), tile-stones/tilestones, under-clay/underclay, water-stones/waterstones, aërial/aerial, Baikal/Baïkal, Ceteosaurus/Cetiosaurus, Colley Weston/Colleyweston, Cupanioides/Cupanioïdes, Hoffman/Hoffmann (this is apparently the same person, it is not clear what the correct spelling should be); Kjökken-Mödden/Kjökken Mödden/Kjökken-mödden, Mæstricht/Maestricht, Néocomian/Neocomian, predaceous/predacious, proboscideans/proboscidians, and

Tunguragua/Tunguraqua.

There are slight differences in wording between the Table of Contents, the Index and the text. Since the meaning is not affected, this has not been standardised.

Depending on the software used and its settings, some symbols may not display properly, or not at all.

Textual remarks:

- Page 109 (table): *12,060* should possibly be *12,000*;
- Page 196 (table): *Red and variegated sandstone (Collyhurst)* ...: there is a line missing in the original work that is not present in other editions either. This line has been replaced by [...];
- Page 212: *The Lias, in England, is generally in three groups*: possibly there is a word (divided or similar) missing;
- Page 301: *The invertebrate animals which characterise the Cretaceous age are among*: possibly there is a word missing at the end of the sentence (others);
- Page 339: *not one-fifth the size of Switzerland* should possibly be *not one-fifth the size of Great Britain*;
- Index: contrary to the remark at the top of the index, not all italic entries refer to illustrations.

Changes made to original text:

- Multi-page tables have been combined into single tables.
- Footnotes have been moved to the end of each chapter.
- Some obvious typographical errors (including punctuation) have been corrected silently.
- Table of Contents: entries Eruptive Rocks and The Beginning have been indented one level less as in the text; entry Metamorphic Rocks has been indented one level less, in line with the other headings printed in small capitals.
- Page 11: *Ancylyceras* changed to *Ancyloceras*;
- Page 34: *has disappeared* changed to *have disappeared*; *Strasburg* changed to *Strasbourg* as elsewhere;
- Page 36: *Cevennes* changed to *Cévennes* as elsewhere;
- Page 37: *bigarrè* changed to *bigarré*; *gres* changed to *grès* as elsewhere; *porpyhries* changed to *porphyries*;
- Page 57: *diameter)* changed to *diameter* (bracket removed);
- Page 152: *on page 155* changed to *on page 157*;
- Page 167: *Liége* changed to *Liège*;
- Page 184: *Cevennes* changed to *Cévennes* as elsewhere; *Rhone* changed to *Rhône* as elsewhere;
- Page 194: *Nilsonia* changed to *Nilssonia* as elsewhere;
- Page 206: *Cevennes* changed to *Cévennes* as elsewhere;
- Page 213: *Pentatrinus* changed to *Pentacrinus*;
- Page 225: *Ichythyosaurus* changed to *Ichthyosaurus*;
- Page 239: *Nilsonia* changed to *Nilssonia* as elsewhere;
- Page 240: *Nilsonia* changed to *Nilssonia* as elsewhere;
- Page 247, caption fig 115: *Polyzoa.* changed to *Polyzoa.)* (bracket added);
- Page 248: *O. cuneatea* changed to *O. cuneata*;
- Page 250: first footnote anchor missing, inserted in most likely place;
- Page 269: *Gryphea* changed to *Gryphæa* as elsewhere;
- Page 305: *represented in Fig. 146* changed to *represented in Fig. 145*;
- Page 316: *Nymphæea* changed to *Nymphæa*;
- Page 319: *πσχυς* changed to *παχυς*; *inférièure/inférièurs* changed to *inférieure/inférieurs*;
- Page 329: *Nymphæeas* changed to *Nymphæas*;
- Page 338: *—astodon* changed to *Mastodon*;
- Page 341: *Fig. 161* changed to *Fig. 160*;
- Page 348: *Rhone* changed to *Rhône* as elsewhere;
- Page 401: *chaneled* changed to *channelled* as elsewhere; *Fig 186* changed to *Fig. 185*;
- Page 413: *antedulivian* changed to *antediluvian*;
- Page 429: *Bauman's* changed to *Baumann's*;
- Page 430: *Gailenruth* changed to *Gailenreuth* as elsehwere;
- Page 452: *Varese* changed to *Varèse*;

- Page 462: *Upsal* changed to *Upsala*;
- Page 470, footnote 117: *Epoques* changed to *Époques* as elsewhere;
- Page 479: *Tiniêre* changed to *Tinière*;
- Page 502: *Archeopterix* changed to *Archeopteryx* as in text; *Bathonean* changed to *Bathonian* as in text; *cervicornus* changed to *cervicornis* as in text;
- Page 503: second entry *Carboniferous Flora* aligned with *Flora*, ditto marks added;
- Page 504: ditto mark added under *Man* in *Creation of Man* for clarity; Cerithium plicatum *250* changed to *350*; Coccosteus *141* changed to *142*; Coupe d'Ayzac *45, 47* changed to *46, 47*;
- Page 505: *Danien* changed to *Danian* as in text; *Duvalii* changed to *Duvallii* as in text (the modern spelling is *Duvalii*, Lyell used *Duvallii*);
- Page 508: *tichorhynus* changed to *tichorhinus* as in text;
- Page 509: *Igneous*, *Iguana* and *Iguanodon* moved to proper place in alphabetical order; *Kellaway's* changed to Kellaways as in text; *Lachow* changed to *Lächow* as in text; *lacumosus* changed to *lacunosus* as in text; *Leptœna* changed to *Leptæna* as in text;
- Page 510: *Limnea* changed to *Limnæa* as in text; *Lithostrotion cornu-arietis* changed to *Lituites cornu-arietis*;
- Page 511: page numbers added after *Mortillet on Glaciers* and *Mosaic Account of Creation*; page reference *737* changed to *73*;
- Page 512: *Osmeroïdes* changed to *Osmeroides* as in text;
- Page 513: *Pecopteris*, page numbers placed in numerical order; *Fustembergii* changed to *Furstembergii* as in text; second reference to *Otopteris acuminata* removed; *Pecten obicularis* changed to *Pecten orbicularis* as in text;
- Page 514: *Podophtalmus* changed to *Podophthalmus* as in text; Purbeck Beds: *27* changed to *279*;
- Page 515: *Reptiles, Prevalence of*: two entries combined into one; *St. Cassian Beds* moved to proper alphabetical order; tichorhynus changed to tichorhinus as in text; entries on Sheppey Isle moved to proper alphabetical order;
- Page 516: *Sphærodus* changed to *Sphœrodus* and moved to proper alphabetic place; *Sun-Appenine* changed to *Sub-Apennine*; *Terebellaria* moved to proper place in alphabetical order.

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