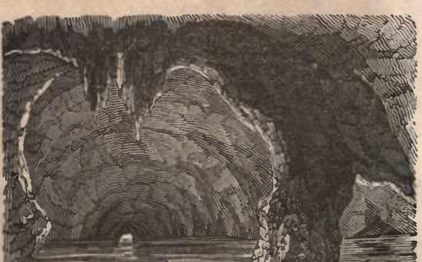

WONDERS OF GEOLOGY.

BOSTON:
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THE WONDERS OF GEOLOGY,

BY THE AUTHOR OF

PETER PARLEY'S TALES.

"Geology is the world's history of itself."
DANIEL WEBSTER.

BOSTON:
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WONDERS OF GEOLOGY.

INTRODUCTION.

HISTORY OF THE SCIENCE.

THE proper object and design of modern Geology are the investigation of the structure of the earth. In former times the science took a wider range, and included the natural history of our globe, — embracing even the entire circuit of the animal, mineral, and vegetable kingdoms.

From the earliest ages, the attention of mankind has been directed to the phenomena displayed by the earth's surface, and innumerable theories have been suggested as well to account for its origin as to point out the process of its formation. Some of

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* We have adopted the title of a work which has recently been published by an eminent geologist of England, Dr. Mantell. Although we have extracted largely from that elegant and scientific author, we have taken important passages and suggestions from Sedgwick, Richardson, Cuvier, Lyell, Hitchcock, and others. To the last named writer, who has furnished the best practical treatise on geology, we are indebted for the general plan of our classification.

these are now known to have contained glimpses of truth, but for the most part they are regarded as vain speculations, and have passed into oblivion or contempt. Yet, as the extravagances of human nature may sometimes furnish instruction as well as amusement, we shall give a few specimens of the strange theories of the earth which have been broached by men of learning and ability.

Passing over earlier writers on this subject, we come to John Kepler, one of the greatest astronomers and mathematicians that ever lived. In a work published in 1619, he seriously attempted to prove by argument, that the earth is an immense animal, and breathes forth winds through the craters or chasms of volcanoes, which serve as a mouth and nostrils. Certain aspects of the planets, he says, occasion winds and tempests, arising from the sympathy which the earth has with the heavens, whereby it instinctively perceives the positions of the stars.

Plato and the Stoics had adopted a similar theory, and Kepler, with them, considered the earth a living creature, which, by the heaving of the huge bellows of its lungs, occasioned the tides. Besides other arguments to prove that the earth is animated, he remarks that in the Scheldt, at Antwerp, the tide rested one whole day, because the earth was in a fainting-fit. Perhaps also, in 1550, it was seized with a cough, when, in the British Ocean, at the mouth of the Thames, the tide ebbed and flowed several times within twenty-four hours!

"Other writers," says Cuvier, "have adopted the ideas of Kepler, and, like that great astronomer, have considered the globe itself as possessed of vital faculties. According to them, a vital fluid circulates in it; a process of assimilation goes on in it, as well as in animated bodies; every particle of it is alive; it possesses instinct and volition, even to the most elementary molecules, which attract and repel each other, according to sympathies and antipathies. Each kind of mineral has the power of converting immense masses into its own nature, as we convert our food into flesh and blood. The mountains are the respiratory organs of the globe, and the schists its organs of secretion; it is by these latter that it decomposes the water of the sea, in order to produce the matters ejected by volcanoes. The veins are carious sores, abscesses of the mineral kingdom; and the metals are products of rottenness and disease, which is the reason that almost all of them have so bad a smell!"

William Whiston, an English divine and mathematician, published a "New Theory of the Earth" in 1708, according to which he deduced the origin of the terrestrial globe from the condensation of the atmosphere of one comet, and the Deluge from the contact of another. Among the daring speculations in which this theorist indulged, there is, however, one, which he advanced on fanciful grounds, but which has derived much probability from the researches of recent inquirers. He imagined the existence in the earth of a central nucleus, which, while it was a cometary body, becoming intensely heated by its near approach to the sun, has preserved ever since a great part of the high temperature which it had acquired. This doctrine of central heat and the gradual cooling of the globe found an able advocate in the late Baron Fourier; and many facts have been brought forward in support of it by other writers. There is nothing extravagant in the length of time during which Whiston supposed the process of cooling to have been going on in the earth; for in 1680 a comet passed so near to the sun, that, from the calculations of astronomers, it must have acquired a temperature two thousand times that of red-hot iron, and would require fifty thousand years in cooling. Hence, if the earth was once a comet, its nucleus would still be burning; since the epoch of its access to the sun is supposed not to have exceeded six thousand years.

Benedict de Maillet, who held the office of French Consul in Egypt, and was the author of some philosophical works, was a speculator of a different order from the preceding. About the middle of the last century, appeared one of his productions, containing some geological theories, abundantly absurd and extravagant, but deserving of some notice, as being founded on accurate and extensive observations of existing phenomena. This gentleman, in the course of his travels, remarking the occurrence of sea-shells and other marine remains on the summits of the highest mountains, inferred that the present continents were entirely formed beneath the surface of water, which must have originally covered the whole earth; that, ever since the first appearance of islands in the universal ocean, the waters have been gradually decreasing; in proof of which he instanced the formation of the Delta of Egypt, at the mouth of the Nile, and of similar tracts in other parts of the world, and the alleged extension of the sea-shores in various places. He supposed this gradual decline of the sea to be still in progress; and his opinions so far have been admitted by many other geologists.

But De Maillet not only conceived the whole globe to have been for many thousands of years covered with water, but he further alleged that this water gradually retreated, that all the land animals were originally denizens of the sea, that man himself commenced his career as a fish; supporting his reveries by adverting to stories of sirens, mermaids, tritons, satyrs, and such like monsters; and asserting that even now animals may be found in the ocean, half-human and half-fish, but whose descendants will in time become perfect men and women. Strange and inconsistent as are these speculations, they have been revived and extended by more recent theorists. They suppose that the earth was originally in a fluid state, that the primitive fluid gave existence to animals, which were at first only of the most simple kind, as the *monas*, and other infusory and microscopic species; that in process of time, and by assuming different habitudes, the races of animals became complicated, and at length appeared in that diversity of form and character which we now perceive. By means of those various races of animals, part of the waters of the sea have gradually been converted into calcareous earth; while the vegetables, concerning the origin and metamorphoses of which these writers choose to be quite silent, have, on their part, converted a portion of the same water into clay: these two earths, on being deprived of the characters which vitality had impressed on them, are by an ultimate analysis resolved into silex; and hence the reason that the oldest mountains are more siliceous than the rest. All the solid parts of the earth, therefore, owe their existence to life, and without life the globe would still be entirely liquid.

Other theorists ascribe the origin of the earth to fragments which have fallen successively from the heavens, in the manner of aërolites, or meteoric stones; and thus account for the relics of strange monsters, which they suppose to have been the inhabitants of unknown worlds.

One bold speculator imagines the earth to be hollow, and places within it a magnetic nucleus, which is transported from one pole to the other, by the attraction of comets, carrying with it the centre of gravity, and the mass of waters on the surface, and thus alternately drowning either hemisphere.

A few years ago, an American officer named Symmes asserted that the earth is not only hollow, but also that the interior is habitable, or at least accessible; for he alleged that an opening leading to it exists somewhere in the northern hemisphere, and he actually proposed to explore it.

Leibnitz, in 1680, advanced the bold hypothesis, that the earth was originally a burning luminous mass, the gradual refrigeration of which produced the primitive rocks, forming at first a solid crust; and this being ruptured, owing to irregular contraction, the fragments fell into the universal ocean formed by the condensation of vapors on the surface of the globe. He proceeded to trace the production of inundations, convulsions, and attrition of solid matter, by its subsequent deposition constituting the various kinds of sedimentary or stratified rocks. Hence, he observes, may be conceived a double origin of primitive masses: 1. By cooling, after igneous fusion; 2. By reconcretion from aqueous solution. "Here," says Conybeare, "we have distinctly stated the great basis of every scientific classification of rock formations."

Many writers now successively appeared, who advantageously directed their attention to the investigation of particular topics connected with this subject; as, the causes and phenomena of earthquakes and volcanoes, the formation of *deltas*, or low tracts at the mouths of rivers, the actual structure and position of mineral strata, and the description of fossil remains of animal or vegetable origin. Among those who rendered important services to the cause of science by advancing general views of the theory of the earth, were Dr. James Hutton, of Edinburgh, and Professor Werner, of Freiberg, in Saxony. These celebrated philosophers produced systems in one respect diametrically opposite to each other; for, while Hutton attributed the formation of the older rocks entirely to the agency of fire, Werner insisted that they originated from solution in a liquid. The German geologist, however, deserves the credit of having directed the attention of his pupils to the constant relations of mineral groups, and their regular order of superposition; distinguishing the classes of primary rocks, or those destitute of organic remains, as granite and gneiss; transition or secondary rocks, formed from the disintegration of the preceding, and occasionally ex hibiting traces of organic remains, as grauwacke, a mechanical compound of agglutinated fragments; floetz, or tertiary rocks, including the coal strata, chalk, and freestone, some of which abound in organic relics; and, besides these, alluvial strata and volcanic rocks, the latter of which he seems to have regarded as of little importance, for he asserted that in the primeval ages of the world there were no volcanoes.

The great merit of Hutton consists in his having demonstrated the igneous origin of basalt, and other trap rocks; the high probability that granite is derived from the same source, and that the other primary non-fossiliferous rocks have been more or less subjected to the agency of fire. "The ruins of an older world," said Hutton, "are visible in the present structure of our planet; and the strata which now compose our continents have been once beneath the sea, and were formed out of the waste of preëxisting continents. The same forces are still destroying, by chemical decomposition or mechanical violence, even the hardest rocks, and transporting the materials to the sea, where they are spread out, and form strata analogous to those of more ancient date. Although loosely deposited along the bottom of the ocean, they become afterwards altered and consolidated by volcanic heat, and then heaved up, fractured and contorted."

The theory of Hutton was admirably illustrated and ably supported by Professor Playfair, of Edinburgh, while it was assailed by Murray, Kirwan, Deluc, and others; a violent controversy being maintained between the partisans of Werner, who were called Neptunists, as ascribing the formation of all rocks to water, — and those of Hutton, styled Vulcanists, because they attributed the original formation of rocks to fire. The Neptunists, for a time, constituted by much the more numerons party; but in the course of these discussions, it was at length perceived that speculation had, on both sides, been carried further than was warranted by the extent of existing information; and that, while neither the theory of Werner nor that of Hutton could be considered as affording an explanation of all the phenomena, or making near approaches to perfection, there were many points with respect to which the researches and observations of both these philosophers contributed to the extension of our knowledge and the improvement of the science.

"A new school," says Lyell, "at last arose, who professed the strictest neutrality, and the utmost indifference to the systems of Werner and Hutton, and who were resolved diligently to devote their labors to observation. The reaction, provoked by the intemperance of the contending parties, now produced a tendency to extreme caution. Speculative views were discountenanced; and, through fear of exposing themselves to the suspicion of a bias towards the dogmas of a party, some geologists became anxious to entertain no opinion whatever on the causes of phenomena, and were inclined to skepticism, even where the conclusions deducible from observed facts scarcely admitted of reasonable doubt.

"But, although the reluctance to theorize was carried somewhat to excess, no measure could be more salutary, at such a moment, than a suspension of all attempts to form what were termed *theories of the* *earth.* A great body of new data was required, and the Geological Society of London, founded in 1807, conduced greatly to the attainment of this desirable end. To multiply and record observations, and patiently to await the result at some future period, was the object proposed by them; and it was their favorite maxim, that the time was not yet come for a general system of geology, but that all must be content, for many years, to be exclusively engaged in furnishing materials for future generalizations. By acting up to these principles with consistency, they in a few years disarmed all prejudice, and rescued the science from the imputation of being a dangerous, or at best but a visionary pursuit."

One train of research which was now pursued with great ardor, and which contributed much to the improvement of science, was respecting the nature of the organic remains which were found imbedded in various strata in differents parts of the world. Cuvier, the celebrated anatomist and zoölogist, Professor of Natural History at Paris, acquired great distinction by the number, accuracy, and importance of the discoveries which he made relative to the generic and specific characters of the animals, fragments of whose bones, and other constituent parts, came under notice in the course of his long and laborious investigations. He ascertained, that numerous living beings, of different classes, which have no existing analogues, once inhabited the surface of the globe; and that the relative priority of the several strata might, to a certain extent, be inferred from the characters of the organic remains included in them.

The results of the researches of eminent men relative to these subjects, and those of other geologists concerning the mineralogical structure and position of rocks and mountains, and the modifying influence of existing causes on the surface of the earth, have greatly contributed to the augmentation of our knowledge of the nature and arrangement of the superficial strata of the planet on which we dwell, which must be regarded as the only sure foundation of a true system of geognosy, that may verify or overturn the conjectural speculations of those philosophers who wrote during the infancy of the science.

The highly interesting nature and relative importance of the discoveries of modern geologists have been most eloquently unfolded by two distinguished writers, who have themselves contributed in no small degree to extend the boundaries of knowledge.

"When we compare the result of observations in the last thirty years," says the author last quoted, "with those of the three preceding centuries, we cannot but look forward with the most sanguine expectations to the degree of excellence to which geology may be carried, even by the labors of the present generation. Never, perhaps, did any science, with the exception of astronomy, unfold, in an equally brief period, so many novel and unexpected truths, and overturn so many preconceived opinions. The senses had for ages declared the earth to be at rest, until the astronomer taught that it was carried through space with inconceivable rapidity. In like manner was the surface of this planet regarded as having remained unaltered since its creation, until the geologist proved that it had been the theatre of reiterated change, and was still the subject of slow but never ending fluctuations. The discovery of other systems in the boundless regions of space was the triumph of astronomy; to trace the same system through various transformations, — to behold it at successive eras adorned with different hills and valleys, lakes and seas, and peopled with new inhabitants, was the delightful meed of geological research. By the geometer, were measured the regions of space, and the relative distances of the heavenly bodies; by the geologist, myriads of ages were reckoned, not by arithmetical computation, but by a train of physical events, — a succession of phenomena in the animate and inanimate worlds, — signs which convey to our minds more definite ideas than figures can do of the immensity of time."

"By the discoveries of a new science, — the very name of which has been but a few years ingrafted on our language, — we learn that the manifestations of God's power on earth have not been limited to the few thousand years of man's existence. The geologist tells us, by the clearest interpretation of the phenomena which his labors have brought to light, that our globe has been subject to vast physical revolutions. He counts his time, not by celestial cycles, but by an index which he has found in the solid framework of the globe itself. He sees a long succession of monuments, each of which may have required a thousand ages for its elaboration. He arranges them in chronological order, observes on them the marks of skill and wisdom, and finds within them *the* *tombs of the ancient inhabitants of the earth.* He finds strange and unlooked-for changes in the forms and fashions of organic life during each of the long periods he thus contemplates. He traces these changes backwards through each successive era, till he reaches a time when the monuments lose all symmetry, and the types of organic life are no longer seen. He has then entered on the dark age of nature's history; and he closes the old chapter of her records. This account has so much of what is exactly true, that it hardly deserves the name of figurative description." *

USES OF GEOLOGY.

As already remarked, geology has been considered as a science comprising an inquiry into universal nature, and embracing in its scope all time present, past, and to come. But in its more restricted acceptation, and as taking cognizance only of the origin and structure of the earth, it takes a wide range of investigation, and leads to many useful practical results.

Whatever definition we adopt, geology is by no means to be regarded as a mere single or isolated department of knowledge; but the pursuits which pass under this general denomination are, in fact, a combination of all the physical sciences, of all those

* Discourse on the Studies of the University, by Adam Sedgwick, M. A., F. R. S.

studies which have the harmonies and beauties of nature as their object, and the perfections of her Divine Author as their ultimate end. From the magnitude and importance of the objects which it contemplates, geology may be considered as vying with the most exalted of the natural sciences in grandeur and extent; while, in the varied and attractive character of its investigations, it will be found to surpass them all. So diversified and so universal, indeed, is the sphere of its inquiries, as to afford themes for contemplation, fitted for every order of mind; and, while it often, in the same object, calls attention to facts which the infant understanding may comprehend, it offers problems for solution, which the loftiest intellect is unable to determine. The shell imbedded in limestone, or the vegetable converted into coal, the child may perceive to be, the one a marine, the other a terrestrial production; but the process of the conversion of that shell into limestone, while the animal matter is often replaced by flint, — or the agency by which the plant has been transmuted into a mineral substance, while the woody structure is still retained, — each involves questions which the most advanced state of our knowledge is scarcely sufficient to determine.

In addition to other advantages which might be adduced, it must not be forgotten, that geology, notwithstanding the important advances which it has recently made, is still a youthful and a progressive study; all whose investigations possess the charm of novelty; all whose discoveries bear the gloss of freshness to recommend them. When Columbus revealed a new hemisphere to mankind, the old world was eager and anxious to precipitate itself upon the new; and, when science discloses a fresh world beneath our feet, we cannot be surprised that all are eager and anxious to explore it.

Yet even the variety, extent, and novelty of geological investigation would never have procured for it so high a degree of popularity and favor as it has now attained; nor have enrolled among its students men of all ranks, from the scholar and the philosopher, to the laborer in the quarry, and the workman in the mine; were it not recommended by the more valuable advantages of practical utility, and application to many of the most essential wants of mankind.

Before the benefits of philosophic research and discovery were rendered so palpable as they have now become, it was the fate of this, like some other scientific studies, to be regarded as a merely speculative and visionary pursuit, which, however well adapted to interest the philosopher in his closet, was utterly useless and uninteresting to the great mass of mankind. This prejudice, though now, in a great measure, dispelled, is still firmly implanted in the minds of many, who have paid little attention to the subject.

Among those economical advantages which the science of geology is calculated to confer, its assistance to the miner may be first adduced. It is at once the object and the boast of geology, to redeem the search after metallic ores from the mere blind chance, or still more benighted superstition, by which it has frequently been governed; and by showing that mineral substances have not been distributed at random, but that each is referable to some peculiar geological deposit, to direct the search for them on fixed and enlightened principles, and in conformity with those laws of nature which regulate their occurrence.

The metals are found to occur in a great variety of situations. In one country they are connected with certain formations, and in another with those of a different character. They are also often distributed, under these diversified circumstances, in districts differing in character; thus rendering their discovery a matter of mere accident, unless the light which geology furnishes be brought to aid the search after them.

But there is a mineral substance more precious than silver, more valuable than gold, the occurrence and profitable discovery of which geology alone is able to determine, and that substance is coal. It is obvious, that, if the mines of the precious metals — unphilosophically so termed — were closed to-morrow, and gold and silver no longer raised for the use of man, society, with some very considerable revolution and difficulty in the mode of adopting other imaginary representatives of value, would go on nearly as before; but deprive civilized communities of their coal, and how fatal would be such a catastrophe to the welfare and happiness of the great family of mankind!

In illustration of the enormous expense which might have been saved by an acquaintance with the principles of geology, in the search after coal, Richardson gives us the following facts. "Some few years only have elapsed since the deceptive appearance of lignite, or imperfect coal, in strata appertaining to the Wealden formation, at Bexhill, in Sussex, on some land belonging to the duchess of Dorset, induced certain parties, imperfectly acquainted with geological science, to prevail on her Grace to institute a search for coal; and it was not till after works of the most extensive and costly nature had been constructed, and an outlay of £10,000 incurred, that an enterprise, hopeless from the first, was at length abandoned.

"Many attempts of a like abortive kind have been made, from the county of Somerset to Wales; and Mr. Murchison, in his admirable work on the Silurian System, mentions numerous enterprises all similarly unsuccessful. One of the most recent and the most ill-judged of these consisted in an endeavour made, a short time since, at the Kingsthorpe pits, within a mile of Northampton. The author was, at that time, lecturing in the neighbourhood, and his opinion was requested as to the probable success of the undertaking. The geological site of the locality, which is about the middle of the Oolite formation, was decisive of the futility of the enterprise, and he therefore denounced it as mistaken, and strongly protested against its farther prosecution. His remonstrances, as is usually the case on these occasions, were disregarded, as those of a mere theorist; it appeared that a person employed to sink a well near the spot, having bored through a bed of clay, which bore some slight resemblance to the *clunch* or clay which frequently overlies the coal, had advised the undertaking; and thus, on a fact of the most common geological occurrence, — the similarity of one bed of clay to another, — the speculation was set on foot; a joint-stock company was organized; a large amount of capital subscribed by parties, many of them little able to sustain even a slight pecuniary loss; steam-engines were erected; shafts were sunk; and an enormous outlay was incurred.

"This was the situation of affairs, during the visit of the author in 1839. The result may easily be anticipated; the works, after being extensively prosecuted, were finally closed, and the enterprise abandoned for want of funds, after an expenditure of £20,000! Such was the termination of an enterprise which an acquaintance with the simplest principles of geology would have decided, from the first, to be altogether fruitless. It will thus be seen, that the power, which the skilful geologist possesses, to determine on the existence or non-existence of coal in any given locality, may be regarded as one of the most striking proofs of the importance and usefulness of the science."

The cultivator of the soil is, in like manner, benefited by that insight into the structure of the earth, which geology is enabled to supply; for, as the superficial soil is usually derived from the disintegration of the rocks beneath, an acquaintance with the nature and chemical composition of those rocks cannot but prove of indispensable utility in pointing out the most successful mode of cultivation. Those lands are most productive and least liable to exhaustion, which contain a due admixture of the three earths, clay, flint, and lime; but, as the instances are comparatively few in which nature has bestowed the three substances in unison, it is the study of the scientific agriculturist to supply the deficient material, by the introduction of a counteracting substance; to correct, for instance, the moisture of clay soils by the application of lime; and to remedy the dryness of sandy deposits by a judicious tempering of clay. And lastly, by consulting a good geological map, and ascertaining those districts, the deposits of which are analogous to those of his own neighbourhood, and learning the mode of cultivation most successfully pursued in that locality, he may ascertain the kind of tillage best adapted to his own.

The inestimable benefit of water is another boon, which, under peculiar conditions of the district, geology enables the scientific agriculturist to obtain. The Artesian wells, so called from their being conceived to have been first introduced in the province of Artois, in France, have been frequently brought before the notice of the public. The chief advantage of this invention consists in the circumstance, that we are by this means enabled to procure copious supplies of water, from depths, and under conditions, which would either preclude our sinking a well altogether, or without such an expense as would impose a prohibition on the enterprise. The plan has been adopted with eminent success, in the vicinity of London, and other places; but the most important enterprise of this kind is that which has recently been brought to a most successful termination in the Plaine de Grenelle, near Paris, where, after boring to an immense depth, sufficient water is ejected in a few days, to supply all Paris for twelve months.

Nor is the knowledge of this science scarcely less essential to the architect and the student of the arts; since an acquaintance with its principles affords a sure guide in the important object of selecting a good and durable quality of stone, and avoiding a perishable and unworthy material. Many of the public edifices of England, both in the capital and the provinces, are fast hastening to decay; several of the buildings of the universities have required to be nearly rebuilt; and many of the newly erected churches are in course of premature dilapidation, owing to the fragile and decomposing nature of the stone. The Capitol at Washington, in our own country, the finest senate-house at present in existence, is in a like state of disfigurement from the same cause.

The sculptor is no less indebted to geology, and its associate science, mineralogy, in the choice of a material for the exercise of his art. Some of the best productions of the artist's skill, owing to the choice of an unworthy material, have become chipped or decomposed, and have thus lost the finest lineaments of the features and the most delicate graces of expression; or the stain occasioned by metallic admixture, or the impure character of the limestone, has veined or disfigured the most perfect examples of art. Even where these actual defects have not existed, the beauty and effect of a statue are known to be dependent on the more or less crystalline character of the stone, and the efforts of the Greek artist have been largely assisted by the quality of the substance on which he was employed. We have only to place a cast in plaster beside the antique statue from which it has been modelled, to perceive in how important a degree the expression of sculpture is enhanced by the purity of the material of which it is composed.

The connection of geology with letters is evident from the distinguished merit of the works of its most eminent professors. The publications of Buckland, Lyell, Mantell, Murchison, Phillips, Sedgwick, Silliman, and others, are as much an honor to letters as they are to science; and the study unquestionably owes much of its popularity and favor, among the most intellectual classes of society, to the genius and the gifts of those who have made it so peculiarly their study. There is nothing in history — nay, even in poetry or romance — so startling and so wonderful, as the incontestible facts disclosed by geology; and these have found fitting delineators in the authors we have named. After noticing the observation of Lord Byron,

"The dust we tread upon was once alive,"

Mr. Lyell remarks, that the philosopher transcends the poet; for, while the one only utters the vague exclamation, that inanimate matter was once animate, it is the triumph of the other not only to describe the form it assumed, but to present it to the imagination endowed with all the faculties of actual existence.

ASTRONOMICAL VIEW OF THE EARTH.

The solar system consists of the sun, — whose mass is made up of solid matter, which is surrounded by a luminous atmosphere, or nebulosity, — and of eleven small planets, which revolve around it in various periods; the earth being the third in distance from the sun, and in bulk, as compared with that body, of the size of a pea to that of a globe two feet in diameter; and having a satellite, the moon, revolving round it.

Upon examining the moon with powerful telescopes, we perceive that its surface is diversified by hills and valleys; that it is a congeries of mountains, many of which are manifestly volcanic, the lava currents being distinctly visible. We see, in fact, a torn, crateriform, and disturbed surface, like that which we may conceive would be presented by our earth, were the bristling pinnacles of the granite mountains unreduced, and the valleys neither smoothed, nor filled up by sedimentary deposits. In Venus and Mercury the mountains appear to be enormous; while in Jupiter and Saturn there are but slight traces of any considerable elevations.

Astronomy instructs us, that, in the original condition of the solar system, the sun was the nucleus of a nebulosity, or luminous mass, which revolved on its axis, and extended far beyond the orbits of all the planets; the planets as yet having no existence. Its temperature gradually diminished, and becoming contracted by cooling, the rotation increased in rapidity, and zones of nebulosity were successively thrown off, in consequence of the centrifugal force overpowering the central attraction; the condensation of these separated masses constituted the planets and satellites.

But this view of the conversion of gaseous matter into planetary bodies is not limited to our own system; it extends to the formation of the innumerable suns and worlds which are distributed throughout the universe. The sublime discoveries of modern astronomers have shown that every part of the realms of space abounds in large expansions of attenuated matter, termed *nebulæ*, which are reflective of light, of various figures, and in different states of condensation,—from that of a diffused luminous mass, to suns and planets like our own.

It must be admitted that this assertion appears astounding,—and that it may fairly be asked, if man, the ephemeron of the material world, can measure the vast epochs which mark the progressive development of suns and systems. The genius of Herschel has effected this wonderful achievement, and explained the successive changes by which suns and worlds are formed, through the agency of the eternal and unerring laws of the Almighty. As the naturalist in the midst of a forest is unable by a glance to discover that the trees around him are in a state of progressive change; yet, perceiving that there are plants in different stages of growth, from the acorn just bursting from the soil, to the lofty oak that stands the monarch of the woods, can readily, from the succession of changes thus at once presented to his view, ascertain the progression of vegetable life, although extending over a period far beyond his own brief existence;—in like manner, the astronomer, by surveying the varied condition of the heavenly bodies around him, can, by careful induction, determine the nature of those changes, which, as regards a single nebula, the human mind might otherwise be unable to ascertain. Thus, Herschel has traced, from nebular masses of absolute vagueness, to others which present form and structure, the effects of the mysterious law which governs the stupendous stellular phenomena that are constantly taking place.*

The doctrine of modern astronomers is, that the Milky Way is a shoal of stars or worlds, constituting one of the many systems of worlds which the telescope reveals to the eye. In this system, the sun is a planetary orb with a luminous atmosphere, the central nucleus of a once extensive nebulosity. During the condensation of this nebula, the planets were successively thrown off; the most distant, as Herschel, being the first or most ancient, followed by Saturn, Jupiter, the four asteroids, Mars, the Earth, Venus, and Mercury; the satellites, as distinct worlds, being the most recent of the whole. It is inferred, that, in any given state of the rotating solar mass, the outer portion or ring might have its centrifugal force exactly balanced by gravity; but increased rotation would throw off that ring, which might sometimes retain its figure, of which we have a beautiful example in Saturn.

In addition to the appearances, presented by the nebulæ, of various states of attenuation and of solidity, we have in the orbs of our own system evidence of corresponding gradations of density. The planets near to the sun are denser than those which are more distant; thus, Mercury, which is the nearest, is the heaviest, being almost thrice as dense as the earth; while the density of Jupiter, which is far removed, is not more than one third that of our planet; and Saturn,

* For a fuller view of this subject, see "Glance at the Sciences"; article, *Astronomy*.

which, with the exception of Herschel, is the remotest is but little more than one eighth as dense, and is supposed to be as light as cork.

Though an unscientific inquirer may find it difficult to comprehend that our planet once existed in a gaseous state, this difficulty will vanish upon considering the nature of the changes that all the materials of which the earth is composed must constantly undergo. Water offers a familiar example of a substance existing on the surface of the globe, in the separate states of rock, fluid, and vapor; for water consolidated into ice is as much a rock as granite or the adamant, and, as is well known, has the power of preserving, for an indefinite period, the animals and vegetables that may be therein imbedded. Yet, upon an increase of temperature, the glaciers of the Alps, and the icy pinnacles of the Arctic circles, disappear; and, by a degree of heat still higher, would be resolved into vapor; and by other agencies still, might be separated into two invisible gases, — oxygen and hydrogen. Metals may in like manner be converted into gases; and, in the laboratory of the chemist, all kinds of matter easily pass through every grade of transmutation, from the most dense and compact to an aëriform state. We cannot, therefore, refuse our assent to the conclusion, that the entire mass of our globe might be resolved into a permanently gaseous form, merely by the dissolution of the existing combinations of matter.

From the light thus shed by modern astronomy upon many of the dark and mysterious pages of the earth's physical history, we learn that the changes which have taken place in the substance of our globe — all the wonderful transmutations of its crust revealed to us by geological investigations — may be referable to the operation of the one simple and universal law by which the condensation of nebular masses into worlds, through periods of time so immense as to be beyond the power of human comprehension, is governed.

The internal heat of the globe, — the evidence afforded by fossil organic remains, of a higher and more equally diffused temperature of the surface in an earlier state of the earth, — and the elevations and dislocations of its crust, which have taken place, and are still going on, — all refer to such an origin, and to such a constitution of our planet, as that contemplated by the nebular theory. We shall hereafter give a more particular view of the changes which have been effected in the earth's surface by the influence of those two great agents, fire and water, and which seem destined to aid in carrying out that great law of the universe, which requires every particle of matter within the remotest bounds of space, to coöperate actively in fulfilling the purposes of the Almighty.

PHYSICAL STRUCTURE OF THE EARTH.

The Earth as viewed from the Moon:

The globe we inhabit may be described as a planetary orb of about twenty-four thousand miles in circumference, and of a spheroidal shape; its figure being such as a body in a fluid state, and made to rotate on its axis, would assume. Its mean density is five times greater than that of water, the interior being double that of the solid superficial crust; the internal part of the earth, if cavernous, as is supposed by some, must therefore be composed of very dense materials. Its surface is computed to contain one hundred and ninety millions of square miles, of which three fifths are covered by seas, and another large proportion by vast bodies of fresh water, by polar ice and eternal snows; so that, taking into consideration sterile tracts, morasses, &c., scarcely more than one fifth of the surface of the globe is fit for the habitation of man and terrestrial animals. The area of the Pacific Ocean alone is estimated to be equal to the entire surface of the dry land. The distribution of the land is exceedingly irregular, the greater proportion being situated in the northern hemisphere; as a reference to a terrestrial globe, or a map of the world, will clearly demonstrate.

In a geological point of view, dry land may be considered as so much of the crust of the earth as is now above the level of the water, beneath which it may again disappear. From accurate calculations, it is proved that the present land might be distributed over the bed of the ocean, in such a manner that the surface of the globe would present an uninterrupted sheet of water. Thus we perceive that every imaginable distribution of land and water may take place; and, consequently, that every variety of organic life may find at different periods suitable abodes.

The investigation of the laws which govern the geographical distribution of animals and vegetables is highly interesting; but it will be sufficient for our present purpose to state, that, although it might have been expected, that, all other circumstances being equal, the same animals and plants would be found in places of like climate and temperature, this identity of distribution does not exist. When America was first discovered, the indigenous quadrupeds were all dissimilar to those of the old world. The elephant, rhinoceros, hippopotamus, giraffe, camel, horse, ox, lion, tiger, &c., were not met on the new continent; while the American species of mammalia, as the llama, jaguar, paca, coati, sloth, &c., were unknown in the old. New Holland contains, as is well known, a most singular assemblage of mammalia, consisting of more than forty species of marsupial animals, of which the kangaroo is a familiar example. The islands of the Pacific Ocean possess no indigenous quadrupeds, except hogs, dogs, rats, and a few bats.

The distribution of vegetable life, although perhaps more arbitrarily fixed by temperature and by local influences than that of animals, presents many anomalies. From numerous observations, however, it appears that vegetable creation took place in different centres, each having been the focus of a peculiar genus or species; for many plants have a local existence, and vegetate naturally in one district alone: thus, the cedar of Lebanon is indigenous on that mountain, and does not grow spontaneously in any other part of the world. It is also ascertained that certain great divisions of the vegetable kingdom are distributed over certain regions.

The temperature of the surface of the globe depends on the action of solar light and heat; hence the difference of the seasons and climates of various latitudes. But there are many causes which modify the distribution of the sun's influence, and produce great local variations; under equal circumstances, however, the temperature is found progressively to diminish from the equator to the poles. There is also an internal source of heat, the cause of which has not yet been determined, but it is probably connected with the original constitution of our planet. It has been ascertained, by careful experiments, that, below the depth to which the solar heat can penetrate, there is an invariable increase of temperature, amounting to 1° of Fahrenheit for every fifteen yards: so that it is possible, that, at the depth of one hundred miles beneath the surface of the earth, even the least fusible mineral masses may be in a state of incandescence.

DEFINITIONS OF GEOLOGY.

Various definitions of this science have been given by different writers. By one it is termed the Physical History of the Earth; and in this view comprehends the investigation of its structure, and the character and causes of the various changes which have taken place in the organic and inorganic kingdoms of Nature. By another it is defined as an Inquiry into Universal Nature, extending throughout all her kingdoms, animal, vegetable, and mineral; and comprising in its investigations all time past, present, and to come.

These can hardly be viewed in the light of precise or scientific definitions. The following are better entitled to this character. Geology, according to Professor Hitchcock, is the history of the mineral masses that compose the earth, and of the organic remains which they contain. Professor Whewell has proposed to divide it into, 1. *Descriptive or Phenomenal Geology*, which embraces the facts; 2. *Geological Dynamics*, which gives an exposition of the general principles by which such phenomena can be produced; 3. *Physical Geology*, which states the doctrines as to what have been the causes of the existing condition of things.

Other writers divide geology into but two branches: 1. *Geognosy*, or Positive Geology, which embraces only the known facts of the science; 2. *Geogony*, or Speculative Geology, which attempts to point out the causes of those facts, and the inferences that result from them. The following is likewise offered as a division of the subject, of practical use: 1. *Economical Geology*, or an account of rocks with reference to their pecuniary value, or immediate application to the wants of society; 2. *Scenographical Geology*, or an account of rocks as they exhibit themselves to the eye in their general outlines; in other words, an account of natural scenery; 3. *Scientific Geology*, or the history of the rocks in their relation to science or philosophy.

This science is not so particularly concerned with the whole mass of our globe as with its upper crust. The rind or covering, in which lies its peculiar domain, is but a small part of the whole. Its thickness is estimated most frequently at about ten miles, — which is only one eight hundredth part of the whole diameter of the globe. It is like the peel of an orange to the whole orange, or rather as the thickness of paper to a globe a foot in diameter; and the greatest inequalities of its surface, its mountains of five miles in height, resemble but the mere roughnesses seen on the rind of the fruit; and the vast oceans which cover our globe would be shown in their true proportion by a film of liquid, such as would be left on the model globe of a school-room by a brush dipped in color and drawn over those parts intended to represent the sea.

The earth has never been penetrated deeper in mines than about half a mile; so that its internal structure has been the subject of conjecture only. The probability of correct conclusions, however, is strong, as will appear from numerous facts which will be stated in the course of the following pages.

CLASSIFICATION OF ROCKS.

THE rocks of which the globe is composed are divided into two great classes, the *Stratified* and the *Unstratified*. The latter are of igneous origin, and consist of various rocks, including granite, lava, basalt, trap-rocks, &c. We find them at various depths, and in every variety of position; sometimes at the very surface, and again at great depths. They are frequently found breaking through the stratified rocks, lifting their peaks into the form of lofty mountains. The stratified rocks are disposed in beds and layers, and are of aqueous origin. These abound with the fossil remains of animals and vegetables.

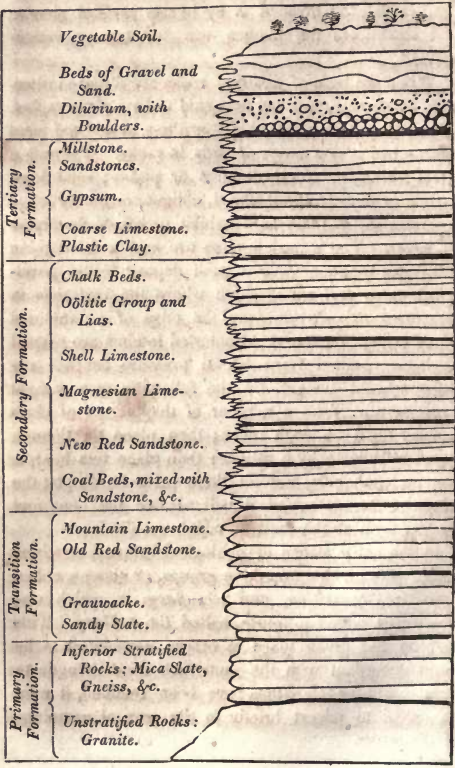
STRATIFIED ROCKS. By the strata of the globe is meant the whole mass of a rock, while the subdivisions formed on the same plane with it are termed beds or layers. Stratification, therefore, is the division of a rock into regular parallel masses, varying in thickness.

In general, the division is by nearly parallel planes; but sometimes the masses are tortuous or wedge-shaped.

When the beds of different rocks are found in alternate succession, they are then said to be *interstratified*. *Laminæ* are thin plates, which are to a single bed what such a bed is to a series of beds in rocks. There is a great variety of these laminæ or plates; sometimes coarse or fine, parallel, waved, oblique, or contorted.

Strata and laminæ both exhibit proofs of the action of water. The waved laminæ are said to be nothing but ripple marks; while a quiet deposit leaves parallel laminæ, and a deposition where the materials in formation are driven over the edge of an inclined plane is an oblique one. Contorted laminæ are proved to have resulted from lateral pressure beneath superincumbent weight, by the following very simple experiment. Take a number of thicknesses of cloth and lay them on each other; then place on them a board held down by a weight; then place two boards, one on each side, and let them press hard upon the edges of the cloth, and it will assume the bent and waving form of the rocks to which we allude.

In the early stages of geological science, stratified rocks were divided into three groups, or classes, called *primitive*, *transition*, and *secondary*, to which was afterwards added a fourth, called the *tertiary*. This division has given place to others, considered to be more accordant with the numerous facts brought to light. Still, as the names have been retained, it may be useful to advert briefly to the several meanings of the terms.


Vegetable Soil.
Beds of Gravel and Sand.
Diluvium, with Boulders.
Tertiary Formation.
Millstone.
Sandstones.
Gypsum.
Coarse Limestone.
Plastic Clay.
Secondary Formation.
Chalk Beds.
Oölitic Group and Lias.
Shell Limestone.
Magnesian Limestone.
New Red Sandstone.
Coal Beds, mixed with Sandstone, &c.
Transition Formation.
Mountain Limestone.
Old Red Sandstone.
Grauwacke.
Sandy Slate.
Primary Formation.
Inferior Stratified Rocks; Mica Slate, Gneiss, &c.
Unstratified Rocks: Granite.

The *primitive*, or, as now called, *primary* rocks, are such as gneiss, quartz, hornblende, &c., consisting of a crystalline structure, and have evidently been produced by the action of fire. They are the lowest of all, and form the foundation on which the other and later strata have been deposited. They were called primitive, because, as they contained no organic remains, it was inferred that they had been formed before the creation of vegetables or animals; but it is said to have been ascertained, that granite and the rocks found with it are of various ages, and that they are sedimentary deposits, altered by exposure to a high temperature.

The *transition* strata rest on the primitive, are more or less stratified, presenting especially alternations of slate and shale with slaty limestone and conglomerate rocks, and contain remains of fishes, shells, and vegetables. They were called transition, because they were supposed to have been formed when the surface of the earth and seas was in a transition state, or passing into a state fitted to receive organized beings. This theory, however, has been modified, as they have been shown to be like primary rock strata, modified by the effects of heat, under great pressure. The coal formations belong to this class.

The *secondary*, including the *lias* and *oölite* formations, various limestones, sandstones, conglomerates, &c., containing more organic remains than the transition, are said to have clearly originated from the destruction of the more ancient rocks, and to have been deposited by the action of rivers and seas in the hollows or depressions. Most of them exhibit zoophytes and shells; the rest, vegetable remains and fishes; then, not only fishes, shells, zoöphytes, and plants, but insects, and bones of enormous reptiles, birds, and one or more genera of the marsupial or opossum-like animals. The chalk is the uppermost or most recent of this formation. Originally the depositions were in horizontal layers, or nearly so; but they have, in a great degree, been broken up, and lie more or less inclined to the horizon.

The *tertiary* are such as consist chiefly of alternate strata of marine and fresh-water deposits, and contain abundant remains of plants and animals more nearly resembling the species which are now found inhabiting our globe. They lie in hollows or basins of chalk and other secondary rocks, and are formed of the ruins or detritions of more ancient beds of rocks. Still later than these last are the *alluvial* deposits, which comprise the vast quantities of materials worn by water and spread over almost every country, containing remains of existing races of animals and plants, together with those not now found on the face of the earth. By some geologists, the more ancient of these have been called *diluvial*, and the more modern *alluvial*.

The igneous and primary rocks in our country constitute mainly the hills of New England, and the mountain group in the northern part of New York; also the Blue Ridge and its collateral elevations, extending southwest through the Atlantic States. The transition and secondary rocks, especially the former, constitute the greater portion of the interior of the United States west of New England. The tertiary deposits constitute a large portion of the shores and low country of the States south of New England and bordering on the Gulf of Mexico. The alluvial deposits are found in the Western States.

To form a clear idea of the arrangement of rocks on the earth's surface, it has been said, that, if we were to place ourselves in a meadow which has resulted from successive deposits of annual floods, and begin a perpendicular excavation into the earth, we should pass through the different classes of rocks in the following order: —

For a few feet only, — rarely as many as one hundred, — we shall pass through layers of loam, sand, and fine gravel, arranged in nearly horizontal beds. This deposit, being from an existing river, is denominated *alluvium*. All deposits from causes now in action are generally regarded as alluvial.

The second formation which we shall penetrate is composed of coarse sand and gravel, with fine sand and sometimes even clay, containing, however, large rounded masses of rocks called *boulders;* the whole mixed together, yet distinctly and horizontally stratified. This formation — evidently the result of the agency of ice and water — is that which we have called *drift.* It is distinguished from alluvium by its lying below it; by the marks it exhibits of more powerful agency; and by extending over regions where no existing streams, or other causes now in action, could have produced it.

The third series of strata is composed of layers of clay, sand, gravel, and marl, with occasional quartzose and calcareous beds, more or less consolidated, all deposited in comparatively quiet waters and separate basins. They are usually horizontal, though they sometimes dip at a small angle. These are the *tertiary* formation.

After passing the tertiary, we come to solid rock formations, made up, however, of sand, clay, and pebbles, bound together with some kind of cement. Among these are mingled, in strata, many varieties of limestone. They sometimes lie horizontally, but generally dip at greater or less angles. These are the *secondary* formation.

Below the secondary lie the *primary;* which Mr. Lyell proposes rather to call the primary *hypogenes*, that is, *nether-formed* rocks, or rocks which have not assumed their present form and structure at the surface.

Below the primary stratified rocks are found the unstratified ones; and hence it is inferred, that the internal parts of the globe, beneath its comparatively thin crust, are composed of such rocks, at least to a great depth. Most frequently, gneiss lies above granite in the primary rocks. Among the rocks which contain it, it is found that there exists an invariable order of position. The new rocks are occasionally found beneath the older ones, in consequence of having been thrown out of their place; they sometimes, however, after having descended in this order for one thousand feet or more, again bend round in such a manner as to be restored to their proper position. Sometimes, by the deficiency of some of the secondary rocks, those of different ages are brought into juxtaposition. This, however, does not disturb the preceding order of arrangement.

Although, as we have said, this division of the stratified rocks is the most common, others have been proposed by different writers. De la Beche divides the stratified rocks into ten groups, — named for the most part after the prevailing characteristics; Dr. Conybeare, into five orders.

Mr. Lyell proposes the appellation of periods and groups. The first he calls the *Post Pliocene Period*, which includes alluvium and drift. The second, the *Tertiary Period*, which is subdivided again into the *Newer* and *Older Pliocene*, *Miocene*, and *Eocene*. The third he calls *Secondary*, which extends to the bottom of the old sandstone. The next is the *Primary Fossiliferous Period*, which includes all the remaining fossiliferous rocks. The *Metamorphic Rocks* include all the stratified groups which do not contain fossils. Various other arrangements have been made, which may be readily compared by consulting the table in Professor Hitchcock's "Elementary Geology," page 42.

UNSTRATIFIED ROCKS. The *unstratified* rocks have also been variously classified. They are found associated with strata of all characters and all ages. Sometimes, as already stated, they appear at the surface of the earth, and at other times are found only at great depths. Their relative antiquity, compared with other rocks lying near, may often be ascertained. If we find, for instance, as is frequently the case, a mass of granite breaking through a stratum and branching out into veins, we conclude that granite is the more recent of the two, as well as that it owes its position to the action of fire.

The same inferences may be drawn from the fact, that, where slate rocks are intersected by granite veins, they have a peculiar appearance, like mica slate or hornblende; and that beds of shale, under the same circumstances, are reduced to jasper, and compact limestone and chalk are converted into crystalline marbles.

In general, it may be stated, that the unstratified rocks lie beneath the stratified, and form the bed upon which they rest. They are supposed to form the essential composition of the globe, perhaps to its centre, if it be not hollow. The total thickness of all the stratified rocks in Europe is estimated by Dr. Buckland to be only about ten miles.

It should be borne in mind, that, while all the unstratified rocks are supposed to be of igneous origin, fire is supposed to be also an element in the formation of the primary stratified rocks. These have been subjected to numerous disturbances, and often a stupendous force has been exerted in giving them their present position. At Westfield and Pittsfield, in Massachusetts, there are primary stratified rocks coming up to the surface in nearly perpendicular positions, showing the layers to be twenty miles in thickness. This, and other facts, enable us to judge of the materials which lie below the superficial crust of the globe, at least to a considerable extent.

CHANGES OF THE EARTH'S SURFACE.

THE earth, in its physical structure, has undergone great changes; and the distribution of land and water, also, has been subject to similar mutations. We have already noticed the two great theories which have been propounded to account for the appearance of the rocks found on our globe, — one denominated the *Neptunian*, so named from the supposed general action of water, — and the other, the *Plutonian* or *Vulcanian*, from the supposed action of fire. They are also termed the *Wernerian* and *Huttonian*, after Werner and Hutton, the authors of the two systems. Both of them have found their advocates, and warm contests have been carried on between the respective parties.

The question concerning the various changes observable on the crust of the earth is an interesting one, particularly on account of its relation to the Scriptures. It will be more convenient, however, to reserve a discussion of this subject for a later stage of our work. It is enough to remark here, that, while the discoveries of geology were at first hailed by infidels as giving the lie to the Mosaic account of creation, later investigations have shown conclusively, that geology, so far from being adverse to, is in perfect harmony with, the Scriptural account of the formation of all things.

DESCRIPTIVE GEOLOGY.

Our principal object in this volume is to exhibit what may be called the *Wonders* of geology; and, as our space will not allow an extended account of its scientific relations to chemistry, mineralogy, and other branches of knowledge, we shall not confine ourselves to the order which might, with such a reference, be properly adopted. The arrangement of Professor Hitchcock will be the guide we shall principally follow; according to which, the stratified rocks first demand our attention.

STRATIFIED ROCKS.

ALLUVIUM.

In geology, every part of the masses of the globe, which is not either animal or vegetable, — including even air and water, — is regarded as belonging to the mineral kingdom. The whole solid mass of the earth — containing the loose soils, clay, sand, and gravel — is embraced under the general title of rocks.

Alluvium includes the most recent formations, chiefly occasioned by the action of air, water, solar heat, &c.,

and by processes of nature now in visible operation. Among the prominent objects of this class are soil, sand, peat, marl, calcareous tufa, coral reefs, rock salt, bitumen, sulphate of lime, sandstones, conglomerates, breccias, &c.

Omitting the descriptions of soils, sand beds, &c., we may notice, as among the most curious objects of nature, the *calcareous tufa*, *sinter*, *travestin;* or, in more common language, new limestone. The process of its formation is as follows. In consequence of the greater or less quantity of carbonic acid which certain springs contain, their waters dissolve, in some degree, the beds of limestone over which they flow, or through which they penetrate. When they come in contact with the atmosphere, a portion of the acid escapes in the form of gas, and the lime, held in solution in the water, is precipitated, and hardens. The experience of every day presents to our view phenomena of this kind. The water of many springs and wells, by evaporation in vessels, gradually forms a calcareous precipitate, which finally hardens into a solid crust.

These new lime-formations are, in many respects, interesting and important. The long, uninterrupted continuance of their formation; the immense size of the masses, which are formed in the course of time; the frequency of their occurrence, in comparison with other new formations; and the value of the material for the purpose of building, impart to them a peculiar importance. The loose, porous masses, which are formed in this way, are called *calcareous tufa;* the more solid and compact are designated *travestin.* The pride of ancient as well as of modern Rome, the Coliseum and St. Peter's church, are built of this; the most ancient masterpieces of Grecian architecture, the celebrated temples of Pæstum, are also constructed of the same material.

What renders travestin peculiarly valuable in architecture is the fact, that it acquires great solidity by the influence of the atmosphere; it becomes hard, almost indestructible, and frequently endures longer than marble. Buildings of travestin stand many centuries. In the course of time, it assumes a reddish color, and this property has contributed to impart to the ruins of Roman glory that venerable and gloomy aspect which they possess. Many natural structures of calcareous tufa are very solid and endure a long time. Thus, the calcareous deposits of springs formed an arch over a chasm near the town of Clermont in Auvergne, about the middle of the last century; it was a kind of bridge, of two hundred feet in length, and in the middle of the arch it was two feet thick. Loaded wagons could pass over it with safety.

The immense masses of travestin and calcareous tufa of Italy are indebted for their existence to the springs of the Apennines. The waters wash away portions of the limestone rocks, dissolve them, and deposit the solution at the base of the mountain.

What has been said of springs is also applicable to lakes. In times when natural history did not enjoy the important aid of chemistry, waters producing calcareous incrustations were termed *petrifying;* the common people regarded them as wonders. Ancient authors mention the fact, that the water of the Silarus incrusted the leaves of the trees which fell into it. This river, the Sele of the present day, flows near Pæstum, a region of country very interesting in phenomena like those we are now considering.

South of Naples, on the shores of the wide bay, surrounded by romantic hills, in the midst of a beautiful, fertile valley, are seen the ruins of ancient Pæstum. Remains of walls, constructed of solid blocks of limestone, are still found; but the city which they once inclosed has long been utterly destroyed. Even Roman poets sung of the beauty of the roses which bloomed on the site of Pæstum; yet the place is now overgrown with grass and bushes. The immense ruins of three temples stand as monuments of its former glory; they are those extraordinary works of ancient architecture which have been just mentioned, as being constructed of travestin. A lake in the immediate vicinity of Pæstum furnished the material. A spacious grotto, and other deep excavations, are still shown, which were formed in ancient times by breaking off immense masses of stone. It is evidently the same kind of stone of which the temples are built. A stream, which flows by the ruins, is constantly depositing tufa in such quantities, that the old walls have considerable masses of it adhering to them. A staff, immersed in the water, is incrusted with lime in the course of a few hours; moss, and stalks of grass, perfectly covered with the crust, retain their green color almost unaltered; so sudden is the precipitate of earthly particles. Plants growing on the banks are colored gray by the calcareous crust. Other waters, possessing this property, exhibit the remarkable phenomenon, that plants growing in them have the parts which are immersed incrusted with the same material. It hence appears that their internal delicate texture is not injured by this process.

The fable of the "floating islands" had its origin from the lake at Pæstum. It was supposed to be unfathomable; the bubbles on its surface, the consequence of the escape of carbonic acid gas, were regarded as the ebullitions of boiling water, and thus it was believed that the sea boiled in the lowest depths, and forced up islands. The phenomenon is easily explained. Reeds, rushes, and other aquatic plants on the shore, are covered with calcareous tufa. In the winter, large masses of these vegetables are torn loose, by the violence of the waves, and carried to the stream, which flows out of the lake. These can with no greater propriety be regarded as floating islands, than the immense fragments of calcareous deposits, now forming on the shores of Lake Erie, in North America, which, in cold weather, are attached to blocks of ice and float on the surface of that inland sea.

Among the most celebrated petrifying waters are those of Carlsbad, in Germany. Here almost every kind of natural productions, flowers, ears of grain, fruits, leaves, shells, dead crabs, and works of art, of various kinds, are covered with *sinter*, in the short space of eight days; that is, with a thin, calcareous crust, colored more or less brown, with the oxyde of iron. The thickness of the coating depends on the time during which the article is exposed to the influence of the water; in the course of a few months, the coating becomes half an inch, or more, thick. But the beds of calcareous sinter, which are formed by the fountain, where the waters gradually deposit their lime, are of far greater interest to us. Thick beds of sinter are produced by degrees, divided into their parallel strata. The process by which one stratum was formed must have been interrupted before a new one could have been deposited; for the cohesion of two strata, although strong, is far less so than that of the parts constituting each separate layer. When struck, the different parts fall asunder like shale. Facts similar to this will be considered, when we come to speak of the formation of strata.

The incrustations of Carlsbad have great celebrity. Not only are they found in all the cabinets of Europe, but they adorn collections in North and South America. They take a very fine polish, and are manufactured into the most elegant ornaments, of the greatest variety. The curved, striped colors give them a very beautiful appearance.

The beautiful incrustations formed in caves, in different parts of the world, are also deposits of the carbonate of lime, made by springs. These are called *stalactites*, or *stalagmites*. The former are those which hang like icicles from the roof; the latter are those which rise from the floor upward, and are formed by the droppings of water from above. The mode of their production is as follows. Whenever water filters through a limestone rock, it dissolves a portion of it, and, on reaching any opening in the cavern, either at its sides or roof, forms a drop, the moisture of which is soon evaporated by the air, leaving a small circular plate of calcareous matter; another drop succeeds in the same place, and adds, from the same cause, a fresh coat of incrustation. In time, these successive additions produce a long, irregular, conical projection from the roof, which is continually increased by fresh accessions of water loaded with calcareous or chalky matter, which it deposits on the outside of the stalactite already formed, and, trickling down, adds to its length by subsiding to the point, and being dried up as before. The process is precisely the same as that in the formation of icicles during frosty weather; these are *stalactites of ice*, or frozen water, and are often formed on the eaves of buildings.

When the supply of water holding lime in solution is too rapid to allow of its evaporation at the bottom of the stalactite, it drops to the floor of the cave, and, drying up gradually, forms in like manner a stalactite rising upwards from the ground, instead of hanging from the roof; these are called, for the sake of distinction, *stalagmites*. Frequently stalactites and stalagmites meet, and thus form pillars, as it were, supporting the roof of the grotto; and the forms assumed by their concretions, as seen in caverns, are often most fantastic and beautiful.

The Grotto of Antiparos, in the Grecian Archipelago, discovered in the seventh century, has long been justly celebrated on this account. Various descriptions have been given of it, from which we compile the following. The traveller first enters into a cavern, but, after advancing a short distance, frightful precipices surround him on every side. The only means of descending these steep rocks is by ropes and ladders which have been placed across wide and dismal cliffs. Below, at the depth of eighteen hundred feet from the surface, is found a grotto three hundred and sixty feet long, three hundred and forty feet wide, and one hundred and eighty feet in height, gorgeously decorated with the most beautiful stalactites. The

The Grotto of Antiparos.

roof, which is a fine vaulted arch, is hung all over with seeming icicles, of a white shining marble, some of them ten feet long and eighteen inches thick at the root; among these are disposed a thousand festoons in the form of leaves and flowers of the same substance; but so glittering, when seen by torchlight, that no eye can endure the light. The sides of the arch are planted with seeming trees of the same white marble, rising in terraces one above another, and often inclosing the points of the icicles. From these trees there hang also festoons, strung from one to another, in vast quantities; and in some places there seem to be rivers of marble winding through them in a thousand meanders. The floor is rough and uneven with crystals of all colors growing irregularly out of it, — red, blue, green, and some of a pale yellow; these are all shaped like pieces of saltpetre, but they are so hard that they cut the shoes. Among these, placed here and there, are icicles of the same shining white marble as those above, and seeming to have fallen down from the roof and fixed themselves there, except that the larger end is attached to the floor. "To all these," says a traveller, from whom we are quoting, "our guides had tied torches, two or three to a pillar, and kept continually beating them, to make them beam brightly. You may guess what a glare of splendor and beauty must be the effect of this illumination, among such rocks and columns of marble. All round the lower part of the sides of the arch are a thousand masses of white marble in the shape of oak-trees; one of these chambers has a fair white curtain, whiter than satin, of the same marble, stretched all over the front of it. In this we cut our names, and the date of the year, as a great many people have done before us."

Some most remarkable caverns of a similar description are found in various parts of our own country. Among these is Wyer's Cave, in Augusta county, Virginia, discovered by a Mr. Wyer, in 1806, while hunting in the Blue Mountain ridge. The Mammoth Cave, in Kentucky, is one of the most stupendous natural curiosities of the kind in the world. It is frequently visited, and a hotel has been built within the mouth of it, for the accommodation of strangers. It has had twenty permanent lodgers at a time, and frequently entertains sixty or seventy persons at dinner. A recent traveller gives us the following account of it.

"I have just returned from a visit to the greatest of all wonders, — the 'Mammoth Cave,' — in company with the author of the 'Juvenile Catherine,' where we spent several days most agreeably, I can assure you. Why is it that this cave is not more visited than it is? Can it be that people living at a distance do not give credence to the reports of its magnitude and extent, — of its varied beauty and grandeur? Through it flow several rivers, one of them more than thirty feet deep, containing a finny tribe of *transparent*, *eyeless* fish! Surely, there are no well informed persons at this day who are skeptical about the existence of this wonderful cave, the greatest and most stupendous freak of nature on the globe. Should there be any such, however, to them I would say, '*Minor est ipsa infamia vero*.' No description can do it justice; and even a sketch of every part could not be given, unless the writer who attempted it were to travel *under ground* a much longer time than most foreign tourists do over America. There are no less than two hundred and forty-two branches or avenues in the cave, now explored, varying from a quarter of a mile to nine miles in length; and new ones are discovered almost every day.

"The proprietor, Dr. Croghan, of Louisville, has built a comfortable hotel at the place, and employed an accommodating landlord, whose table is loaded with every luxury an epicure could desire; his wines, too, are of the best quality. Careful guides are in readiness, at any and every hour of the day, to accompany visiters into the cave.

"I have collected some small but beautiful specimens of the formations in the interior of the cave for 'York's Tall Son,' which I intended to have sent on by one of our merchants, who unfortunately set out for the East before my return home. I also procured one of the *Pisces Bartimei*, or blind fish, which I have preserved in alcohol, and intend as a rival of the Texas 'horned frog.'

"I cannot refrain from giving you an account of an incident that happened in this cave last spring. A wedding party went to the cave to spend the honeymoon. While there, they went to visit those beautiful portions of the cave which lie beyond the river 'Jordan.' In order to do this, a person has to sail down the river nearly a mile before reaching the avenue which leads off from the river on the opposite side, — for there is no shore, or landing-place, between the point above on this side, where you come to the river, and that below on the other; for the river fills the whole width of one avenue of the cave, and is several feet deep where the side walls descend into the water. This party had descended the river, visited the cave beyond, and had again embarked on the water for their return homewards. After they had ascended the river about half way, some of the party, who were in a high glee, got into a romp and overturned the boat. Their lights were all extinguished, their matches wet, the boat filled with water and sunk immediately; and *there they were*, in 'the blackness of darkness,' up to their chins in water. No doubt, they would all have been lost, had it not been for the guide's great presence of mind. He charged them to remain perfectly still; for, if they moved a single step, they might get out of their depth in water; and swimming would not avail them, for they could not see where to swim to. He knew, that, if they could bear the coldness of the water any length of time, they would be safe; for another guide would be sent from the cave house, to see what had become of them. And in this perilous condition, up to their mouths in water, in the midst of darkness 'more than night,' *four miles under ground*, they remained for upwards of five hours; at the end of which time, another guide came to their relief. Matthew, or Mat, the guide who rescued them, told me, that, 'when he got to where they were, his fellow-guide, Stephen, (the Columbus of the cave,) was swimming around the rest of the party, cheering them, and directing his movements, while swimming, by the sound of their voices, which were raised, one and all, in prayer and supplication for deliverance.' "

Professor Hall, who visited this cavern some years since, has furnished the following minute and accurate description of it. It is proper to say, however, that, since his visit, various avenues have been discovered and explored to a great extent.

" We entered the main cave at two o'clock, P. M., and proceeded in a tolerably direct course *two miles* to the 'Temple,' passing, on our way, the 'Narrows,' the 'First Hoppers,' the 'Church,' — where, when the nitre manufacturers were here, there was occasionally preaching, — the 'Well Cave,' the 'Ox-trough,' the 'Steamboat,' the 'Salts Room,' where Epsom and other salts are crystallized on the walls, the 'Devil's Looking-glass,' and the 'Cataracts,' which are two streams of water, issuing from holes in the ceiling, about as large as a hogshead. After a heavy rain, the noise of the water, pouring into the abyss below, is heard at a distance like the rolling sound of thunder.

"The 'Temple' is an immense apartment. Its floor was formerly said to comprehend *eight superficial acres.* Lee, who has accurately examined it, narrows it down to two acres. His estimate is, it seems to me, too large. The apartment is, however, higher and more capacious, beyond doubt, than any other subterranean room in our own or any other country. In the centre there is a vast pyramidal heap of fragmentary rocks, the *débris* of the lofty vault above. The guide clambered up, and placed his lamp on its pinnacle. From that elevated position it sent forth its rays in all directions, illuminating, though dimly, the whole inclosed space, and gave me a passably good impression of the vast amplitude of the apartment. There are reported to be more than a hundred rooms, of different dimensions, in this overgrown under-ground mansion. The 'Temple' is far the most spacious, but you must not understand that it is built in the remotest extremity of the cave. It is not so. The opening runs more than a quarter of a mile beyond it. But my curiosity impelled me no further.

"There are branches innumerable passing off in all directions from the main cave, some of which are more than a mile in extent. These branches are all named; but when they were christened, or by whom, I know not. One of them — the 'Solitary Cave' — we explored. Its entrance is low. We were obliged, for the distance of five or six yards, to become quadrupeds. That passed, we raised our crouched frames, and stalked along as men erect, and might have done so, had we been ten feet taller. The ceiling and walls are bleached with calcareous incrustations, and look as if they had recently been whitewashed. Here, too, every object has its appellation. You see the 'Coral Grave Branch,' 'Alexander's Pit,' 'Robber's Kettle,' 'Tecumseh's Grave,' &c. &c.

"We proceeded onward, more than half a mile, without encountering any thing very remarkable. This brought us to the 'Fairy Grotto,' — a splendid grove of stalactites and stalagmites, of all sizes, shapes, and ages. The sound of the drops of lime water, ever and anon falling on the floor, *splash*, *splash*, *splash*, comes to the ear, hollow and dismal, long before you reach the spot. The work goes on briskly, and without cessation, amid the darkness of a double midnight. The light of the lamps exhibits all the steps in the process of the formations, from the nascent protuberance, swelling and trembling on the ceiling above, and the mammillary bubble, just beginning to rise from below, to the full-grown pillar; that is, to the perfect union of the stalactite and stalagmite in the form of a complete cylinder. What is there not in this admirable workshop? Here are superb pillars, bearing rich entablatures, with elegant cornices and pedestals, in all the architectural orders; alabaster fireplaces of every fashion; urns, and vases, and sarcophagi of snowy delicacy; a range of white, translucent curtains, thrown gracefully around a magnificent pulpit; little images, resembling pigmies, sitting in marble chairs, or reclining on lily settees; and whatever other imitative forms the most vivid imagination can conjure up. It is idle to write. To *enjoy*, you must yourself *see*. Many of the tall pillars are half a yard in diameter, and of the purest white calcareous alabaster, capable of being wrought, and will, I have no doubt, hereafter be wrought, into candlesticks, snuff-boxes, vases, and numberless other articles. After loading the guide and myself with specimens of the productions of this enchanting grotto, we made our retreat to the main cave.

"Here, my lamp, for want of oil, went out. 'What would you do,' said I to my cicerone, 'if yours were to be extinguished? Could you find your way to the daylight?' 'No,' he replied; 'I would not attempt it, for fear I should break my neck by tumbling over the heaps of rocks which have come down from the top, or fall into some of the deep holes which lie along this dark passage. My wisest course would be to remain where I am, until the people in the house, alarmed at my long absence, should come to search for me with a light.' Indeed, an imprisonment in this 'big, dark grave' is a thing which I would by no means covet. It would be, if possible, more dismal than confinement in a cell of the Bastille. We were, in fact, in some danger of falling into such a dilemma; for my attendant's last wick was nearly burnt out, the light grew dim, and we were obliged to add new celerity to our weary steps. We reached the outlet at precisely eight in the evening, having passed six hours in our subterranean wanderings. The air in the cave is cool and agreeable; but on coming out, and plunging suddenly into the heated atmosphere of the outer world, I felt, for a few moments, no slight degree of debility and exhaustion.

"I have touched only on a few points, and those, perhaps, not the most interesting. To explore minutely all its parts, and describe them, would be the work of a month. What shall I say of this wonder of nature, as a whole? I had heard and read descriptions of it, long since; but the half, the quarter, was not told. Its vastness, its lofty arches, its immense reach into the bosom of the solid earth, fill me with astonishment. It is — like Mount Blanc, Chimborazo, and the falls of Niagara — one of God's mightiest works. Shall I compare it with any thing of a similar description, which you have seen on the other side of the Altantic? with the Grotto of Neptune, or that of the Sibyl, at Tivoli, or with any of Virgil's poetic Italian machinery? No comparison can be instituted. I speak, as you are aware, from personal knowledge. You, seated on the opposite bank of the Anio, have seen me clamber up, from the noisy waters below, to the entrance of the far-famed Grotto of Neptune, which I leisurely explored. In point of capaciousness, it has little more to boast of than the cellar of a large hotel, and, like that, was, as I think, excavated by human hands. That of the Tiburtine Sibyl is still more limited in its dimensions. Indeed, every cavern which I have ever seen, if placed alongside of this, would dwindle into insignificance. O, that we had a Virgil, as superior to the Mantuan bard, as our caves, and rivers, and mountains are superior to those which he has celebrated in immortal song!"

Coral Reefs are extensive deposits of carbonate of lime, formed by myriads of *polyparia*, or radiated animals, in shallow water, in the South Seas. They form the habitation of these animals, and of course are organic in their structure. These are among the most interesting phenomena in geology. When we view the enormous masses of which they consist, forming reefs in the ocean of hundreds of miles in circuit, and rising into extensive islands, and consider that all this is the work of an animal so insignificant as to be hardly discernible, we are lost in wonder and admiration.

The process by which the corallines perform their work is curious. They begin their foundation upon some rock in the sea. Here the windward side of the structure, which is exposed to the break of the sea, rises vertically like a wall; while to the leeward it shelves away. This enables them to work with facility, for they are thus protected from the violence of the waves, which would otherwise impede or destroy them.

There are two kinds of these animals distinguished by M. Lesson. One, which he calls *zoöphytes saxigènes*, are employed in the construction of the exterior walls. The other, the *saxigènes délicats*, are protected by the first, and never work except in shallow basins, where the water is warm.

Dr. Mantell furnishes us with the following description of some of the corallines. If we extend our observations to the patches of white calcareous matter, called *flustra*, that may be seen on every sea-weed or shell on the shore, appearing like delicate lace-work, we shall discover that these apparently mere specks of earthy substance also belong to the animal kingdom. Many species of this zoöphyte are common along the English coasts, and we will describe their structure somewhat in detail, as their examination will serve to illustrate the nature of those corals, which, from their magnitude and extent, become such important agents in the economy of nature.

The flustra, when taken fresh and alive out of the water, presents to the naked eye the appearance of fine net-work, coated over with a glossy varnish. With a glass of moderate power, this substance is discovered to be full of pores, disposed with much regularity. If a powerful lens be employed, while the flustra is immersed in sea-water, very different phenomena appear; the surface is found to be invested with a fleshy or gelatinous substance, and every pore to be the opening of a cell, whence issues a tube, with several long feelers or arms; these expand, then suddenly close, withdraw into the cells, and again issue forth. The whole surface being studded with these hydra-like forms, the flustra thus constitutes, as it were, a family of polypes, each individual of which is permanently fixed in a calcareous cell, and the whole connected by one common integument.

The surface of the flustra, viewed with a lens, exhibits a series of cells symmetrically arranged, their forms and dispositions varying in the different species. When highly magnified, each cavity is seen to be the receptacle of a polype, which appears like a transparent gelatinous mass, having a stomach or sack, the external margin of which terminates in eight or ten feelers or tentacula, that have the power of extending and retracting with great rapidity. A still higher power discovers that these tentacula are, in many zoöphytes, furnished with cilia or vibratory organs; and the existence of similar instruments is inferred in the minute species where they have not yet been detected, because these atoms present the same phenomena of currents as the larger polyparia.

However improbable it may appear to the mind unaccustomed to investigate the works of the Creator, that beings so minute as those under examination should prey upon living forms of yet more infinitesimal proportions, the fact is nevertheless unquestionable. It is even possible to select the food of animalcules much smaller than the polypi of the flustra, and thus exhibit their internal structure! The animals called *monads* may be considered as the lowest limit of animated nature, so far as is cognizable to man, their diameters varying from the twelve hundredth part of an inch to the *twenty-four thousandth;* and the powers of the microscope at present extend no farther. These creatures are of a cylindrical or spherical form, having a mouth by which their nutriment is taken in, and a stomach or digestive apparatus. The latter is visible only when these living atoms are fed with coloring particles, the animals being transparent and colorless, and their natural food equally so.

Dr. Ehrenberg, of Berlin, by furnishing these infusoria with coloring matter for nourishment, has been able to illustrate their organization in an extraordinary degree. He employed a solution of pure indigo for this purpose; and the results of his experiments are highly interesting. Immediately on a minute particle of a very attenuated solution of indigo being applied to a drop of water containing some of the pedunculated *vorticellæ*, the most beautiful phenomena are observable. Currents are excited in the fluid in all directions, by the rapid motion of the cilia, which form a crown round the anterior part of the body of the animalcule; and the particles of indigo are seen moving in different directions, but generally all converging towards the orifice or mouth, which is situated, not in the centre of the crown of cilia, but between the two rows of these organs, which exist consecutive to one another. The attention is no sooner drawn to this beautiful phenomenon, than presently the body of the animal, which was before quite transparent, becomes dotted with distinctly circumscribed spots, of a dark blue color, exactly corresponding to that of the moving particles of indigo.

But, although, as we have already stated, the monad, in the present state of our knowledge, and with the wonderful instruments which the ingenuity of man has constructed, is the lowest known term of organization; yet it is impossible to doubt that there are myriads of living forms concealed from our observation, some of which serve as food to these miniatures of life. We may here observe, that the structure of many of the animalcules is as varied and complicated as that of the larger, and, to our imperfect conceptions, more important, orders of animals.

If our observations on the living polypi be continued for a sufficient period, we shall at length perceive a small globule thrown off from the mass, and become attached to the sea-weed or the rocks: this is the germ of a new colony of this compound animal. As it increases in magnitude, the usual character of the flustra may be detected; and if the *fleshy* film be removed, a *spot of calcareous matter* is left attached. In the larger and free masses of flustra, the decomposition of the animal substance after death is very manifest. A specimen of *flustra foliacea*, which was dredged up twenty miles south-southwest of Brighton, in England, in water eighteen fathoms deep, affords a fine example of this brittle species. At first, it was highly offensive, from the emanations evolved during the decomposition of the animal matter. It soon became a calcareous skeleton, with here and there portions of the shrivelled integument, and of course without any traces of polypi in the cells.

Let us now refer to our previous investigations, and inquire if the flustra present the essential characters of animal existence. Its polype possesses a determinate form, and has a calcareous skeleton, covered by a soft, fleshy substance, that can for a certain period resist chemical and mechanical agency. It is furnished with instruments capable of moving with great celerity, susceptible of external impressions, and expanding and contracting at will. Here, then, is evidence of sensation and of voluntary motion; and although, from the extreme minuteness of the structure, nerves cannot be detected, yet there can be no doubt that the animal possesses a nervous, and also a circulatory system, for effecting nutrition and reparation. We find also, that, when the flustra is removed from the element in which it lived, the substance of which it is composed, like the flesh of the larger animals, undergoes putrefaction,— in other words, that the creature dies,— it has lost the vital principle by which it previously resisted chemical agency, and now submits to the effects of those laws which act upon inorganic matter; the calcareous substance that formed its support or skeleton, and which, like the bones of mammiferous animals, was secreted by the fleshy mass, alone remains.

We may here particularly remark, that the stony matter or support of all zoöphytes is formed by a similar process; the substances called corals being secretions from an animal substance by which they were permeated and invested, in like manner as the bones and nails in man are secreted by the tissues or membranes designed for that purpose, and acting without his knowledge or control. Nothing can be more erroneous than the common notion, that the cells in the larger corals are built up by the polypi which are found in them, in the same manner as are the cells of wax by the bee or the wasp.

From what has been advanced, we perceive that the flustra is a compound animal, composed of an immense number of individuals united in one body, and consisting of a fleshy substance, secreting a calcareous skeleton, and studded over with cells containing polypi, which may be considered as foci of vitality, by whose agency the life of the whole mass is maintained. Whether these separate centres of life are susceptible of pain and pleasure independently of the whole, it may not be possible to determine; we have a living proof in the Siamese twins, that even in our own species there may be a united organization with distinct nervous systems, and individual sensations; and as it is certain that each polype enjoys distinct volition, it is most probable that the sensations of each individual are independent of the general mass. However this may be, we are at least certain that the Eternal has bestowed on these, as on all his creatures, the capacity and means of enjoyment.

In the flustra, then, we have the elements of zoophytal organization, and all the varied and extraordinary forms which will hereafter come under our notice are but modifications of this type of animal existence. In some, the skeleton or support consists of earthy matter, as in the flustra, but solid and hard as adamant; in many examples, it branches out like a tree; in others, it constitutes hemispherical masses, having numerous convolutions on the surface, somewhat resembling in appearance the brains of quadrupeds; and in some, it forms an aggregation of tubes, terminating in star-like openings. Among the branched varieties, some are covered by pores so numerous as to be called *millepora;* in many, the openings are distant; some have star-like markings here and there; while in others the whole surface presents a stellated structure. In many species, the fleshy animal matter entirely covers and conceals the stony skeleton during life; in others, the latter becomes exposed, and forms a trunk, having branches covered by living polypi; while in another and numerous division (of which the common *sertularia* is an example,) the skeleton is secreted by the *outer* surface of the animal substance, and constitutes an external protection to the polypi.

Some of the different kinds of corals are thus described by Mantell. The *red coral* is a branched zoophyte, somewhat resembling in miniature a tree deprived of its leaves and twigs. It seldom exceeds one foot in height, and is attached to the rocks by a broad expansion or base. It consists of a brilliant red, stony axis, invested with a fleshy or gelatinous substance of a pale blue color, which is studded over with stellular polypi. This coral, as is well known, is so dense and compact as to bear a high polish; it is obtained by dredging in different parts of the Mediterranean and Eastern seas, and forms an important article of commerce. It varies much in hue, according to its situation in the sea; in shallow water it is of the most beautiful color, a free admission of light appearing necessary for its full development. It is of slow growth; eight or ten years, in a moderate depth of water, being necessary for it to reach maturity. Arrived at this period, it extends but very slowly, and is soon pierced on all sides by those destructive animals which attack even the hardest rocks; it loses its solidity, and the slightest shock detaches it from its base. Becoming the sport of the waves, the polypi perish, their brilliant skeleton is exposed, and thrown upon the shore; the bright color soon disappears, and the coral is reduced to fragments by the attrition of the waves, or mixed with the remains of shells and other marine exuviæ. In this state it is thrown up by the tides, and, being drifted inland by the winds, assists in forming those accumulations of the spoils of the sea, which constitute many of the modern conglomerates.

The *Tubipora*, or *organ-pipe coral* is well known, from the elegance and beauty of one species (*Sarcinula musicalis*), which is common in most collections. This is composed of parallel tubes united by lateral plates, or transverse partitions, placed at regular distances; in this manner large masses, consisting of a congeries of pipes or tubes, are formed. When the animal is alive, each tube contains a polype of a beautiful bright green color, and the upper part of the surface is covered with a gelatinous mass formed by the confluence of the polypi. This species occurs in great abundance on the coast of New South Wales, in the Red Sea, and in the Molucca Islands, varying in color from a bright red to a deep orange. It grows in the shape of large hemispherical masses, from one to two feet in circumference; these first appear as small specks adhering to a shell or rock; as they increase, the tubes resemble a group of diverging rays, and at length other tubes are produced on the transverse plates, thus filling up the intervals, and constituting a uniform tubular mass; the surface being covered with a green, fleshy substance, beset with stellular animalcules.

In the red coral, no cells are formed on the skeleton to serve as a protection to the polypi; but in the family of branched, or arborescent, calcareous polyparia, called *madrepores*, the little cups or cells, with radiating lamellæ, in which the polypi are situated, are composed of the substance of the skeleton. When the animals die, and the outer fleshy investment perishes, the axis is seen to be studded over with elegant, lamellated, stellular cells, variously formed and arranged, in different genera and species. In some, the cells are very distinct; in others, they are exceedingly minute. The white-branched corals, usually seen in collections, belong for the most part to this genus; it is not, therefore, requisite to describe this form of zoöphyte more minutely. In the water the madrepores are invested with a fleshy integument of various colors; and each cell has a polype similar to those of the corals previously described, and in the living madrepore a polype is seen to issue from each of the projecting cells, the branches being covered with their hydra-like forms.

In another division of corals, the cells are few, and of considerable dimensions, the polypi being of proportionate size, and bearing considerable analogy to the actiniæ, or sea-anemones, which are so common on the rocks and in the shallows on our shores; a few observations on these animals will therefore enable us to comprehend the nature of this group of polyparia. The actinia, or sea-animal flower, as it is often termed, appears, when quiescent, like a mass of tough jelly, of a sub-cylindrical form, and of various tints of crimson, green, blue, or brown; when expanded, it presents a broad disk, surrounded by tentacula, having in the centre a corrugated surface, which is contracted into a marsupial or purse-like form. The actiniæ are affixed to the rocks by a broad base, but they can detach themselves, and change their position.

Among the various corals, one of the most curious is that of the brain-stone, deriving the name from its

Brain-stone Coral.

resemblance to the convolutions of the brain. In the engraving, the polyparia are retracted and concealed. As one fleshy mass of these creatures expires, another appears, and gradually expands, pouring out its calcareous secretion on the parent mass of coral; thus successive generations go on accumulating vast beds of stony matter, and lay the foundations of coral reefs and islands. We may compare, observes Mr. Lyell, the operation of the zoöphytes in the ocean, to the effects produced on a smaller scale on land, by the plants which generate peat; in which the upper part of the *sphagnum* vegetates, while the lower is entering into a mineral mass, in which the traces of organization remain when life has entirely ceased. In corals, in like manner, the more durable materials of the generation that has passed away serve as the foundation over which their progeny spread successive accumulations of calcareous matter.

The *Gorgonia flabellum*, or Venus's fan, is a flexible coralline, that is an inhabitant of almost every sea,

Sea-Fan.

and frequently attains a height of four or five feet. When fresh from the water, it is of a bright yellow color. This species exhibits the usual structure of the corticiferous polyparia, or zoöphytes, which are composed of an internal axis or skeleton, of a tough, horny consistence, and of an external envelope or rind, which entirely invests the former.

The appearance of living corals is said to be singular and replete with marvels. In some parts of the sea, the eye perceives nothing but a bright, sandy plain at bottom, extending for many hundred miles; but in the Red Sea, the whole bed of this extensive basin of water is absolutely a forest of submarine plants and corals. Here are sponges, gorgoniæ, madrepores, fungiæ, and other polyparia, with fuci, algæ, and all the variety of marine vegetation, covering every part of the bottom, and presenting the appearance of a submarine garden of the most exquisite verdure, enamelled with animal forms, resembling, and even surpassing in splendid and gorgeous coloring, the most celebrated parterres of the East.

Ehrenberg was so struck with the magnificent spectacle presented by the living corals in the Red Sea, that he exclaimed with enthusiasm, "Where is the paradise of flowers, that can rival in variety and beauty these living wonders of the ocean?" Some have compared the appearance to beds of tulips or dahlias; and, in truth, the large fungiæ, with their crimson disks, and purple and yellow tentacula, bear no slight resemblance to the latter.

Captain Hall thus describes the great coral reef near the island of Loo Choo. "When the tide has left the rock for some time dry, it appears to be a compact mass, exceedingly hard and rugged; but as the water rises, and the waves begin to wash over it, the polypi protrude themselves from holes which were before invisible. These animals are of a great variety of shapes and sizes, and in such prodigious numbers, that in a short time the whole surface of the rock appears to be alive and in motion. The most common form is that of a star, with arms, or tentacula, which are moved about with a rapid motion in all directions, probably to catch food. Others are so sluggish, that they may be mistaken for pieces of the rock, and are generally of a dark color. When the coral is broken about high-water mark, it is a solid, hard stone; but if any part of it be detached at a spot where the tide reaches every day, it is found to be full of polypi, of different lengths and colors; some being as fine as a thread, of a bright yellow, and sometimes of a blue color. The growth of coral appears to cease, when the worm is no longer exposed to the washing of the sea. Thus a reef rises in the form of a cauliflower, till the top has gained the level of the highest tides, above which the animalcules have no power to advance, and the reef of course no longer extends upwards."

The coral banks are everywhere seen in different stages of progress. Some are become islands, but not yet habitable; others are above high-water mark, but destitute of vegetation; while many are overflowed with every returning tide. When the polypi of the corals at the bottom of the ocean cease to live, their skeletons still adhere to each other, and the interstices being gradually filled up with sand and broken pieces of corals and shells, washed in by the sea, a mass of rock is at length formed. Future races of these animalcules spread out upon the rising bank, and in their turn die, increase, and elevate this wonderful monument of their existence.

The reefs which raise themselves above the level of the sea are usually of a circular or oval form, and surrounded by a deep and oftentimes unfathomable ocean. In the centre of each there is generally a shallow lagoon, with still water, where the smaller and more delicate kinds of zoöphytes find a tranquil abode; while the stronger species live on the outer margin of the isle, where the surf dashes over them.

When the reef is dry at low water, the coral animals cease to increase. A continuous mass of solid stone is then seen, which is composed of shells and echini, with fragments of corals, united by calcareous sand, produced by the pulverization of the shells of friable polyparia. Fragments of coral limestone are thrown up by the waves; these are cracked by the heat of the sun, washed to pieces by the surge, and drifted on the reef. After this, the calcareous mass is undisturbed, and offers to the seeds of the cocoa, pandanus, and other trees and plants, floated thither by the waves, a soil on which they rapidly grow, and overshadow the white, dazzling surface. Trunks of trees, drifted by currents from other countries, find here at length a resting-place, and bring with them some small animals, as lizards and insects. Even before the trees form groves or forests, sea-birds nestle there; strayed land-birds find refuge in the bushes; and at a still later period, man takes possession of the newly created country. It is in this manner that the Polynesian Archipelago has been formed. The immediate foundations of the islands are ancient coral reefs, and these, in all probability, are based on the cones or craters of submarine volcanoes, long since extinct. There is another circumstance worthy of remark; most of these islands have an inlet through the reef opposite to the large valleys of the neighbouring land, whence numerous streams issue and flow into the sea; an easy ingress is thus afforded to vessels, as well as the means of obtaining a supply of water.

Of the grand scale on which the operations here contemplated are going on, we may form some idea from the facts stated by competent observers, that in the Indian Ocean, to the southwest of Malabar, there is a chain of coral reefs and islets four hundred and eighty geographical miles in length; on the east coast of New Holland, an unbroken reef of three hundred and fifty miles long; between that and New Guinea, a coral formation, which extends upwards of seven hundred miles; and that Disappointment Islands and Duff's Group are connected by six hundred miles of coral reefs, over which the natives can travel from one island to another.

There is so much of the marvellous and sublime in the idea of the creation of islands and continents by the ceaseless labors of numberless myriads of living instruments, that we cannot be surprised that this interesting subject has attracted the attention of one of the most elegant of our modern poets. The following extract, which is alike poetic and descriptive, we take from "The Pelican Island" of James Montgomery.

"I saw the living pile ascend,
The mausoleum of its architects,
Still dying upwards as their labors closed.
Slime the material, but the slime was turned
To adamant by their petrific touch.
Frail were their frames, ephemeral their lives, —
Their masonry imperishable. All
Life's needful functions, food, exertion, rest,
By nice economy of Providence,
Were overruled to carry on the process
Which out of water brought forth solid rock.
Atom by atom, thus the mountain grew
A coral island, stretching east and west;
Steep with the flanks, with precipices sharp,
Descending to their base in ocean gloom.
Chasms, few, and narrow, and irregular,
Formed harbours, safe at once and perilous, —
Safe for defence, but perilous to enter.
A sea-lake shone amidst the fossil isle,

Reflecting in a ring its cliffs and caverns,
With heaven itself seen like a lake below.
Compared with this amazing edifice,
Raised by the weakest creatures in existence,
What are the works of intellectual man,
His temples, palaces, and sepulchres?
Dust in the balance, atoms in the gale,
Compared with these achievements in the deep,
Were all the monuments of olden time;
Egypt's gray piles of hieroglyphic grandeur,
That have survived the language which they speak,
Preserving its dead emblems to the eye,
Yet hiding from the mind what these reveal;
Her pyramids would be mere pinnacles,
Her giant statues, wrought from rocks of granite,
But puny ornaments for such a pile
As this stupendous mound of catacombs,
Filled with dry mummies of the builder-worms."

Mr. Richardson, who is a poet as well as a geologist, furnishes us with the following description.

"THE CORALS.

"Beneath the realm which the waves o'erwhelm,
In the seas of the torrid zone,
Our ancient race have a dwelling-place,
In a world that is all our own.

"Earth boasts no spots like the fairy grots
Where we build our sparry cell;
Nor can its bowers produce such flowers
As in depths of ocean dwell.

"And our forms so strange we ever change,
As over the deep we roam;
And our varied hue is ever new,
As we vary our ocean home.

"In tranquil calms, we wave like palms,
Or bend like the drooping willow;
Or we climb to the verge of the foaming surge,
And dash to the winds its billow.

"In peaceful haunts, like tender plants,
We twine our fragile forms;
Or we build a rock to the tempest's shock,
That mocks its fiercest storms.

"And we rear the walls of those marble halls
As a precipice high and steep,
Till a new-found isle is seen to smile
Like a beacon o'er the deep.

"By viewless hands those new-born lands
Are strewn with blessings rife;
Till man appears, and claims the spheres
To being raised and life.

"And we join the piles of those fossil isles
Till they spread from shore to shore;
And we build from the caves of the ocean waves
A world unknown before.

"Then say, proud man, how poor the plan
Of thy pyramids, castles, and towers;
How vain the boasts of thy mightiest hosts,
Or their labors, — compared with ours!

"Though such our lot, yet we are — what,
In the scale of being vast? —
The meanest germs of life's poor worms, —
The lowest and the last!

"Yet, though obscure, and low, and poor,
And lost in distance dim,
We still can raise our Maker's praise,
And pour our thanks to him"

Silicious sinter, or *tufa*, a deposit of silica made by the water of hot springs, which sometimes hold this earth in solution, belongs also to alluvium. Layers of this and clay in succession often occur, and these are sometimes broken up and re-cemented, and thus form breccia, a beautiful variegated species of marble-like stone. There are many of these hot springs in different parts of the globe. A high temperature is necessary to enable water to dissolve a large proportion of silex; and hence it is, that the hot springs, by which these deposits are produced, are in the vicinity of volcanoes, or in volcanic regions.

The boiling fountains of Iceland, called the *Geysers*, have been celebrated for many years, for possessing in a remarkable degree this extraordinary property of silicious deposition; holding a large quantity of silex in solution, and depositing it, when cooling, on vegetables and other substances, in a manner similar to that in which the carbonate of lime is precipitated by the incrusting springs. They are several in number, but the most celebrated of them is called the *Great Geyser*, in the vicinity of Mount Hecla. The water boils with a loud, rumbling noise, in a well of an irregular form, about ten feet in diameter, widening near the top, and opening into a basin fifty-six by forty-six feet. Its explosions are announced by sounds resembling the low report of artillery. The first jets which are thrown up seldom exceed fifteen or twenty feet, but the highest often exceed eighty feet. On the propulsion of the jet, the great body of the column rises perpendicularly, and then divides into beautiful curvated ramifications, which are projected in every direction. The explosion of the Great Geyser takes place at intervals of six hours.

Dr. Mantell, speaking of the Geysers, says: "A fountain of boiling water, accompanied with a great evolution of vapor, first appears, and is ejected to a considerable height; a volume of steam succeeds, and is thrown up with great force, and a terrible noise, like that produced by the escape of steam from the boiler of a steam-engine. The operation continues sometimes for more than an hour; an interval of repose, of uncertain duration, succeeds, after which the same phenomena are repeated. If stones are thrown into the mouth of the cavity from which the fountain has issued, they are ejected with violence after a short interval, and again jets of boiling water, vapor, and steam appear in succession."

Sir George Mackenzie, describing the eruptions of the Great Geyser, witnessed by himself, represents, that they were preceded by a sound like the distant discharge of heavy ordnance, and the ground shook sensibly; the sound was repeated, when the water in the basin, after heaving several times, suddenly rose in a large column, accompanied by clouds of steam, to the height of ten or twelve feet. The column seemed to burst, and sinking down produced a wave, which caused the water to overflow the basin. A succession of eighteen or twenty jets now took place, some of which rose to the height of fifty or sixty feet. After the last eruption, which was the most violent, the water suddenly left the basin, and sunk into the pipe in the centre, to the depth of ten feet. After a few hours, the eruption was repeated;

the jets sometimes attaining ninety feet in altitude. The basin of the Great Geyser is an irregular oval, about fifty-six feet by forty-six, formed of a mound of silicious depositions nearly seven feet high; the pipe through which the water is ejected being sixteen feet in diameter at the opening, but lower down contracting to ten feet; its perpendicular depth is estimated at sixty feet.

Sir George Mackenzie supposes that the water from the surface percolates through the crevices into a cavity of the rock, and heated steam produced by volcanic agency rises through fissures in the lava. The steam then, as he thinks, becomes in part condensed, and the water, filling the lower part of the cavity, is raised to boiling temperature, while steam under high pressure occupies the upper part of the chasm. The expansive force of the steam becomes gradually augmented, till at length the water is driven up the fissure or pipe, and a boiling fountain is produced, which continues playing till all the water in the reservoir is expended, and the steam itself escapes with great violence till the supply is exhausted. The silicious concretions formed by these springs cover, it is said, an extent of four leagues.

Mr. Eugene Robert states, that this curious formation may be seen passing, by insensible gradations, from a loose, friable slate, the result of a rapid deposition, to the most compact and transparent masses, in which impressions of the leaves of the birch-tree and portions of stems are distinctly perceptible, presenting the appearance of the agatized woods of the West Indies. Rushes, and various kinds of mosses, converted into a white silicious rock, in which the minutest fibres are preserved, also occur; but on the margin of the Geysers, from the splashing of the water, the depositions resemble large cauliflowers; and, on breaking these masses, vegetable impressions are often discovered.

Peat is another of the alluvial deposits. This is a substance derived from the matter of decomposed vegetables. It generally forms a stratum on the alluvial soil; but in some cases it alternates with sand, gravel, clay, or beds of shells. It can be formed only under a particular temperature, and to this effect moisture is essential. In hot climates, it can be formed only under water, or in elevated places, as otherwise the decomposition of vegetable matter would be too rapid; but in cold climates, it may be formed at the level of the sea. In England, it is formed principally from a species of moss growing in damp situations. Forests, also, which have been overthrown by storms, often contribute to form peat. The decay of the leaves and small branches commences the process, and the interstices are gradually filled up till the trunks are inclosed and covered. In the valley of the Somme, a mass of peat reposes on an immense quantity of the branches and trunks of dicotyledonous trees, heaped on each other and resting on clay. On the borders of the Rhine there are similar masses, in which the trunks are so flattened, that trees of a foot in diameter are said to present only a thickness of two inches. Most of it, however, results from the moss of the genus *Sphagnum*, which decays at the lower extremity, while the top continues to flourish with vigor. In some instances, the beds are said to be more than forty feet thick. When perfectly formed, peat is destitute of a fibrous structure; when wet it is a fine black mud, and when dry a powder, consisting chiefly of decomposed organic matter called *geine*, or *humic acid*, with other acids, phosphates, &c., of which, part are soluble and part insoluble in water.

In tropical climates, except on high lands, the decomposition of vegetable matter is so rapid, that it is resolved into its ultimate elements before peat can be produced. For this reason, peat is limited chiefly to the colder parts of the globe. In Ireland the peat bogs are said to occupy one tenth of the surface, and one of them on the Shannon is fifty miles long, and two or three broad. In Massachusetts, besides what is found in the four western counties, it has been estimated that there is peat to the amount of one hundred and twenty millions of cords, which is thought by an able writer to be below the truth.

Peat, by the long continued action of water and other agents, is changed into bitumen and carbon, and thus constitutes lignite and bituminous coal. Peat-bogs are said to possess great antiseptic power, and some remarkable instances of the preservation of animal remains in them are recorded. In some instances bodies are found to have been converted into a fatty substance called *adipocere*, resembling spermaceti.

In a peat-bog in Jutland, there was once found the mummy of a female completely sunk in the ground, and fastened to a stake by means of clamps and hooks. The fragments of clothing that remained enabled the antiquaries to decide, with tolerable certainty, that it belonged to the last period of paganism; and M. Petersen has endeavoured to prove, in an able historical essay, that it was the body of Gunhilda, queen of Norway, whom King Harold, by a promise of marriage, enticed to Denmark, A. D. 965, and put to death by sinking her in a bog.

The growth of peat is various, according to circumstances. On the continent of Europe, it is said to have gained seven feet in thirty years; and in some peat-bogs large trees have been found standing where they originally grew, twenty feet deep.

Silicious marl is a deposite much resembling the calcareous marl, both of which are found a few inches thick beneath beds of peat and mud in primary regions. The description given of it is, that when pure it is white, and nearly as light as the carbonate of magnesia; but it is usually more or less mixed with clay. By analysis, it is found to be nearly pure silica; and what is most wonderful is the discovery, that it is almost entirely composed of the silicious shields or skeletons of those microscopic animals called *infusoria* or animalculæ, which have lived and died in countless numbers in the ponds at the bottom of which this substance has been deposited. The animals are not often discernible without the aid of powerful microscopes. To a Prussian naturalist, Professor Ehrenberg, belongs the honor of discovering their remarkable relation to geological science. In the course of his investigations, he has described seven hundred and twenty-two living species, which exist in countless numbers in fluids, and even in the fluids of living and healthy animals. These creatures were supposed to be very simple in their organization, — a kind of animated atoms; but the naturalist just mentioned has discovered in them mouth, teeth, muscles, stomach, nerves, glands, eyes, and organs of reproduction. Some of the smaller animalculæ are said to be not more than the twenty-four thousandth part of an inch in diameter, and the thickness of the skin of their stomachs not more than the fifty millionth part of an inch. They are viviparous, oviparous, and geminiparous. A single individual of one species increased in ten days to one million; on the eleventh day to four millions; and on the twelfth day to sixteen millions. In another case, Ehrenberg says, that one individual, in four days, can become one hundred and seventy billions, — as many as are contained in two cubic feet of the slate of Bilin. This increase is said to take place by voluntary division. An animal capable of self-division first doubles the inner organs, and subsequently decreases exteriorly in size. Self-division proceeds from the interior towards the exterior.

The infinitesimal minuteness of these animals may be seen from what Leeuwenhoek states, — that one billion of the animalculæ, such as occur in common water, would not altogether be so large as a grain of sand; and Ehrenberg estimates that five hundred millions of them are actually living in a single drop of water. They are found in the red-colored snow of the Alps; and it is very curious, that, if the snow has been melted but a short time, so as to become a little warmer than the freezing point, the animals die *because they cannot endure so much heat.* These animals are of various shapes, and bear different names. Some of their shields resemble a tubular chain. But the most wonderful fact relating to them is the incredible number of their skeletons or shields found in a fossil state, in various districts, actually constituting the whole mass of soils and rocks, several feet thick, and many acres in extent. Many strata are entirely composed of the shields or skeletons of infusoria; and in Sweden, an edible earth, which is used with flour for bread, resembling fine flour, and celebrated for its nutritious qualities, wholly consists of the shells of microscopic animalcules. This earth occurs in layers nearly thirty feet in thickness.

Deposits formed by the infusoria are constantly in process of formation, wherever a condition suitable to their economy exists. In lakes, marshes, and peat-bogs, the animalcules which inhabit the water pass through their brief period of existence, and their indestructible skeletons then sink to the bottom and form new deposits. Professor Bailey discovered in a peat-bog, near West Point, layers, several hundred yards in extent, of a white earthy substance, which is wholly made up of the silicious shells of these animals. The polishing slate of Bilin, in Germany, which forms a bed fourteen feet thick, and the eatable earth of Luneburg, a similar bed twenty feet thick, are composed of these animal remains. Yet it would take, it is said, forty-one thousand millions of their skeletons to make a cubic inch; their weight being only two hundred and twenty grains. A single shield or skeleton weighs about the one hundred and eighty-seven millionth of a grain.

Entire masses of flint are thus composed of the fossilized remains of beings as wonderful in their structure and organization as any of the colossal forms of animal existence. Some kinds of opal appear to have been formed of the dissolved silicious skeletons of animalcules; and the more durable forms are seen preserved in it like insects in amber. The well known bog-iron ore is ascertained to be composed of the thread-like carcasses of animalcules so inconceivably minute, that every cubic inch contains no less than two millions of millions of these once living organized forms; in other words, more than two million times the number of the whole human race now existing over the entire face of the earth. The fossil animalcule found in iron ochre is only the one twenty-first part of the thickness of a human hair; and one cubic inch of this ochre must contain one billion of the skeletons of these once living beings.

The deposits of which we are speaking are not confined to one country, but they appear to be common in all parts of the globe. They abound in Massachusetts; and specimens have been examined by Professor Hitchcock from Barre, Manchester, Wrentham, North Bridgewater, Andover, &c. It may be proper to add, that some of these deposits belong to the tertiary, and some to other than alluvial formations; but it seemed proper, while treating of the subject, to introduce them here.

In view of the wonders which open on us as we dwell on the facts brought to light by the discoveries of Ehrenberg, we may well adopt the language of a distinguished European writer, Professor Hausenon, who says, — that a mass more than twenty feet in thickness should consist almost entirely of the coverings of animals which are invisible to the naked eye, and which can only be recognized with the assistance of a high magnifying power, is an extraordinary fact, and one which the mind cannot fully comprehend without some difficulty. The further we attempt to pursue the subject, the more we are astonished. That which occurs in an invisible condition in the fluid element, and which cannot be recognized by the human senses without the assistance of art, becomes, by immense accumulation and solidification, one of the circle of phenomena which are witnessed by us in the ordinary way; a compact mass is formed, which can be weighed, felt, and seen; and this mass is presented to us in such quantity, that, when regarded only in *one* direction, it surpasses by three times the height of the human figure. Who could venture to calculate the number of infusory animals which would be required to produce even one cubic inch of this mass? And who could venture to determine the number of centuries during which the accumulation of a bed twenty feet in thickness was taking place? And yet, this mass is only the product of yesterday, compared with the more compact silicious masses for which the infusoria of a destroyed creation afforded materials. But what would become of that loose, light silica, — which, by its great porosity and power of absorbing water in quantity, in some measure indicates its origin, — if, instead of its being covered by soil one foot and a half in thickness, it had been covered by a great mass of earth or rock, or if another power, such as the action of fire, had caused its solidification? In that case we should have had no bed twenty feet in thickness, but should perhaps have found a compact stony mass, capable of scratching glass, affording sparks with steel, and polishable, — a substance, which, were it not for the abundant evidence furnished by the discoveries of Ehrenberg, it would be still more difficult to suppose had resulted from the coverings of invisible animals. Such a consolidation and hardening of this loose silica might, perhaps, be partly accomplished in another way, by making the experiment of employing it for the manufacture of glass, or as one of the ingredients in porcelain; by which means a discovery, so very remarkable in a philosophical point of view, might at the same time become of practical importance. *Glass formed from the coverings of infusory animals!* Who would, a few years ago, have believed in the possibility?

Bitumen appears under various forms, sometimes combined with coral, but generally in the form of naphtha, petroleum, or asphaltum, issuing from springs. Large quantities of it are thus obtained in different parts of the world. It is said to be the result of changes effected in vegetable matter during its mineralization, and it often goes by the name of mineral oil.

Naphtha is described as being nearly colorless and transparent, burning with a blue flame, emitting a powerful odor, and leaving no residuum. Genoa is lighted by naphtha from a neighbouring spring.

Petroleum is of a dark color, and thicker than common tar. From a careful analysis of petroleum, and certain turpentine oils, Dr. Mantell says, it is clear that their principal component parts are identical; and he remarks, it appears evident that petroleum has originated from the coniferous trees, whose remains have contributed so largely to the formation of coal, and that the *mineral oil is nothing more than the turpentine oil of the pines of former ages.* Not only the wood, but also large accumulations of the needle-like leaves of the pines, may have contributed to this process.

The occurrence of petroleum in springs does not seem to depend on combustion, but is simply the result of subterranean heat. According to the information we now possess, it is not necessary that strata should be at a very great depth beneath the surface to acquire a heat equal to the boiling point of water or mineral oil. In such a position, the oil must have suffered a slow distillation, and have found its way to the surface; or have impregnated a portion of the earth, so as to enable us to collect it in wells. Petroleum, it is said, is now daily discharging into the soft mud and gravel in the beds of the Muskingum and Hews rivers.

The amount of bituminous matter discharged from certain springs is very great. In the Birman empire, a group of springs, it is said, at one locality, yielded annually four hundred thousand hogsheads. It is often called *Seneca oil* in this country, from having been early found on the surface of some springs at Seneca, in New York. It is thrown up in considerable abundance, also, at the salt-borings on the Kenawha River, in Ohio, where, a few years ago, a large quantity of it, floating on the surface of a small stream, took fire, and the river, for half a mile in extent, appeared as a sheet of flame. The Dead Sea is called the Lake Asphaltites, from the asphaltum which formerly abounded there.

In Cumberland county, Kentucky, some years since, in boring for salt water, at the depth of one hundred and eighty feet, a fountain of petroleum, or mineral oil, was struck. When the auger was withdrawn, the oil was thrown in a continued stream more than twelve feet above the surface of the earth. Although the quantity somewhat abated, after the discharge of the first few minutes, during which it was supposed to emit seventy-five gallons a minute, it still continued to flow in a stream, which made its way to the Cumberland, for a long distance covering its surface with its oily pellicle.

But the most remarkable locality of bituminous matter is said to be the Pitch Lake, in the island of Trinidad, in the West Indies. It is three miles in circumference, and of unknown thickness. It is sufficiently hard to sustain men and quadrupeds, though at some seasons of the year it is soft. Near Ait, on the Euphrates, is a collection of springs of petroleum, which make a noise like a smith's forge, incessantly puffing and blowing so loud that it may be heard a mile off. It is hence called by the Arabs *Bab el Jehennam*, that is, *hell-gate*. The liquid swallows up heavy animals that venture upon its surface, and many camels from time to time fall into the pits and are lost. It issues from a lake, and, sending forth a pitchy smoke, continually boils over, and spreads itself around to a great extent. Were it not that the inundations of the Euphrates carry away the pitch which covers the sands from the place where it rises to the river, there would have been mountains of it long since. Southey alludes to this scene in the following lines.

"From Ait's bitumen lake
That heavy cloud ascends,
That everlasting roar,
From where its gushing springs
Boil their black billows up. . . . . .
Along the verge of that wide lake, ...
Toward a ridge of rocks that banked its side,
There, from a cave, with torrent force
And everlasting roar,
The black bitumen rolled. . . . . .
The affrighted countrymen
Call it the mouth of hell."

Mineral oil is said to have been a principal ingredient in the cement used for the walls of Babylon, and of the Temple in Jerusalem. Asphaltum, too, has recently been employed to form a pavement for streets.

Alluvial sandstone, *conglomerate*, and *breccia* are formed by the cementation of sand, rounded pebbles, or angular fragments, by iron or carbonate of lime, which is infiltrated through the mass in a state of solution, thus forming them into a compact mass. When sand is thus cemented, it is called sandstone; rounded pebbles produce a conglomerate or pudding-stone; and angular fragments, breccia. Of the latter, the beautiful columns of the Hall of Representatives, at Washington, are formed.

These varieties of alluvium, which we have thus described, may be regarded as a *formation*, in a geological sense. The period during which the process of deposition has been going on is called a *geological period*, and the point of time at which a general and important change occurs is called an *epoch*. Many such epochs are indicated by the condition of the various masses found upon the surface of the globe.

DRIFT, OR DILUVIUM.

The next system of the stratified rocks is that which was formerly called *diluvium*, but more recently *drift*. Some have termed it the *bowlder* formation, or the *erratic block* group. Diluvium seems to refer its origin to a deluge, and therefore, says Professor Hitchcock, is objectionable. He prefers, and uses, the appellation of *drift*.

The greatest portion of it is composed of sand and gravel, of different degrees of fineness, confusedly mixed together. A remarkable fact is, that this gravel is not derived from the rocks beneath it, but from those at a distance of several miles, and, in this country, usually from ledges, lying in a northwest direction from the beds or deposits. The surface of this gravel is often scooped out into deep basin-shaped depressions, and raised into corresponding elevations; the difference of level being sometimes twenty or thirty, and even one hundred or two hundred feet. Scattered through this gravel are rounded masses of rock, of a size larger than pebbles, which are called *bowlders*, and also *erratic blocks*, and *lost rocks*. There are a number of curious facts observed with respect to these bowlders. Sometimes they are seen on the surface, and even on the summit, of mountain ridges. They are likewise found so poised, that a small force will move them. These are the rocking-stones, which are mentioned as existing, of greater or less size, in almost all the Eastern States.* These weigh fifty and sometimes even one hundred tons or more.

Lying over the gravel, and on many plains where there is now no water, are found thick beds of sand and clay, which were deposited, no doubt, more quietly, and yet about the close of the same period as common drift. The coarse material comes first, then clay, then sand. Sometimes the sand and gravel consolidate into sandstone and conglomerate, by the infiltration of iron or carbonate of lime. Many of the precious stones and metals, as the diamond, sapphire, topaz, ruby, and zircon, platina, gold, and tin, are found in drift. Platina, gold, and diamond are sought for almost exclusively in this formation.

Drift is distinguished from the deposits of alluvium, 1. By its being found where no action, no existing agency, could have produced it; 2. By its requiring, if not a different agency, yet a greater intensity of action, for its production; 3. By the evidence of there having been a very different climate between the two periods.

It differs likewise from the deposits of the tertiary system; for that is found in limited troughs and basins, whereas drift is scattered over almost all the northern regions of the globe, and even on the tops of the highest mountains; thus showing that it must have resulted from some general cause. It is also unstratified, and its situation is such, that it could not, in general, have

* There is one of these on the land of Kilby Page, Esq., at Jamaica Plain, Roxbury. There is another at Barre, and still another at Fall River.

been deposited by water; yet the sand and clay which form its upper part must have been deposited in quiet waters. It is likewise almost destitute of organic remains of animals and plants living at the time when it was produced, while the contrary is the fact in respect to the tertiary strata. Finally, when the drift was deposited, the climate must have been colder than at present; whereas the reverse may be stated of the tertiary formations.

In the dispersion of drift, there is the evidence of two distinct kinds of action, though these may have resulted from the same cause, operating differently in different circumstances. First, the drift has been carried away from the line of axis of the tops of particular mountains, and spread over the adjoining plains. Secondly, the agency employed in the dispersion has operated on a more extended scale, and driven it southerly to a great distance.

The character of the erratic blocks, or bowlders, which are scattered over the plains in many countries, correspond to rocks often far distant, and have no similarity to those which are near them. The best example of the mode of dispersion first mentioned above is said to be found in the Alps. The bowlders there have usually been carried down the valleys, and they are now found in great abundance opposite their lower openings. On the eastern side of the Jura, where that chain of mountains is separated by the long and broad valley of the Aar, we also find large blocks of granite, often thirty feet in length, and twenty in thickness, lying at an elevation of more than fifteen hundred feet above the valley. That these blocks came from the opposite Alps is very probable, as the Jura mountains are of a different kind of rock. Similar blocks of granite have been found in Iceland, which is itself formed of lava. In the North of Germany these bowlders of limestone are found, containing fossils which do not belong to that locality, and hence must have come across the Baltic from Scandinavia.

The evidence, where they are found, is very decisive of the direction they have taken. For instance, on the Western continent, the bowlders spread over the southern part of Nova Scotia were derived from the ledges in the northern part of the province. So, through the whole of Maine, there is the same striking evidence of the dispersion of the drift a few degrees east of south. They are found even near the top of Mount Katahdin, in Maine, above five thousand feet high.

In Massachusetts, the drift is said to have varied from north and south, to northeast and southwest; generally, the course was a few degrees east of south. The current was thus carried obliquely across the most precipitous ridges of the mountains; but the bowlders kept on their course with remarkable uniformity. The largest blocks are described as lying nearest to the bed from which they came, and thus they decrease in size and quantity in a southeast direction for several miles; sometimes, it is said, fifty or sixty, and even one hundred miles. They are found likewise on the islands many miles distant from the coast, as on Long Island. In Western Massachusetts, the bowlders must have been carried over mountains from one thousand to three thousand feet in height.

In the eastern part of New York, the course was the same as in Massachusetts, — southeast; but in the western, it seems to have been sometimes west of south. In the southeastern part of that State, its direction varied several degrees west of south to southeast, and near the city of New York the course is said to have been northwest and southeast. "In the fossiliferous regions of Western New York," says Professor Hitchcock, to whose "Geology" we are indebted for most of these facts, "and in the States south of the western lakes, great numbers of bowlders of primitive rocks are strewed over the surface, significantly called *lost rocks.* These have been satisfactorily traced to the beds from which they were derived, in the western part of Michigan, and on the north side of the lakes in Upper Canada. Similar evidence of a southeasterly drift exists in Virginia. According to Dr. Drake, primitive pebbles occur on the right bank of the Mississippi, as far south as Natchez. Vast quantities of bowlders of primary rocks are also said to be scattered over the great valley of the Missouri and Mississippi, from the Yellowstone almost to the Gulf of Mexico, which have been drifted thither from the northwest."

At the Red Pipestone quarry there are five granite bowlders from fifteen to twenty-five feet in diameter, which it is supposed must have been carried several hundred miles, from the north. The bowlders strewed over Ohio were doubtless derived from the primary rocks on the north side of the great lakes, and must have been carried from four hundred to six hundred miles.

In Great Britain the course of drift is said to have been a little east of south; modified, however, more or less, by the shape of the mountains; some of which appear not to have been passed over by the bowlders, except at their lowest points. In the eastern part of England, the drift appears to have been derived from Norway.

On the continent of Europe, the Netherlands, Denmark, the plains of the North of Germany, and of Poland and Russia, are strewed over with bowlders and pebbles, which can be traced to the parent rocks, in Sweden, Lapland, and Finland; in which countries they are yet more numerous on the surface. In most cases, these bowlders must have crossed the Baltic Sea. In Sweden, the current appears to have set south-southwest. The blocks decrease in size, on going south; and finally, at a great distance, — more than four hundred miles, — they disappear.

In Northern Syria, sixty or seventy miles north of Beyroot, is a volcanic region with a remarkable locality of greenstone. The pebbles of this locality, it is said, are scattered over the whole distance to that city. They are small at this place, but increase in size as we advance towards the north.

In the equatorial regions of South America, it is stated that there are no bowlders; but beyond forty-one degrees of south latitude they appear, in Chili and Patagonia. Some have inferred from this, that drift is confined to the colder regions. But it is also found in the West Indies, and probably, as the equatorial regions are more carefully examined, it may be found even in other parts of them. Cases of erratic bowlders are said to occur in the hill-country at the foot of the Himalaya Mountains.

The crests and steep sides of high mountains and alluvial plains, in nearly all parts of the northern hemisphere, are covered with a coat of bowlders, gravel, and sand, whose thickness varies from a few inches to one or two hundred feet. It is stated, that scarcely any mountains there, except perhaps the Pyrenees, the Apennines, the Carpathians, and those of Bohemia, are destitute of drift; and sometimes very large blocks are poised on their summits.

Drift is found in its greatest quantities, however, in the hilly regions; but chiefly in the valleys, and near gorges and defiles. It is generally composed of rounded bowlders, pebbles, sand, and even mud, piled up in ridges, straight, curved, and winding, and also in regular heaps. These ridges, or mounds, especially in the vicinity of the Alps, are called *moraines.* This term is also applied to those heaps of ruins of rocks and earth, formed by the grating of icebergs along the bottom of the sea, as well as those which have been produced by the action of glaciers. These moraines are found in great frequency in New England, and, as Professor Hitchcock observes, are sometimes so crowded together as to exhibit a picturesque appearance, being made up of winding and conical elevations, with deep intervening cavities, as if scooped out by the hands of a Titan. Some of them, in the vicinity of Plymouth and near the termination of Cape Cod, are two or three hundred feet high. These are distant fifty to one hundred miles from any mountains higher than they are. They are supposed to have been left by the ice in the same state in which they are now found, as the hollows between these hills are not valleys, but irregular depressions, and therefore have not been afterwards subject to the action of water. Similar moraines to those found in this country are met with in Armenia, Syria, and Scotland.

The magnitude of bowlders, which have evidently been transported hundreds of miles, is sometimes enormous. One, of which a pedestal was formed for the statue of Peter the Great, is said to have weighed fifteen hundred tons. The Needle Mountain in Dauphiny, said to be a bowlder, is described as being one thousand paces in circumference at the bottom, and two thousand at the top. Mention is also made of a block of granite near Neufchatel, in Switzerland, forty feet high, fifty feet long, and twenty feet broad, which weighs three millions eight hundred thousand pounds, and contains ten thousand two hundred and ninety-six cubic feet. The rock of Horeb, which the monks point out as the one struck by Moses at the command of God, and out of which gushed forth water, is a bowlder of granite six yards square, and contains five thousand eight hundred and twenty-three cubic feet. It lies in the plain near Mount Sinai, and probably once belonged to the mountain, whence it may have fallen by its own weight.

Great numbers of bowlders occur in this country, sometimes thirty feet square, and containing twenty-seven thousand cubic feet, and weighing not less than two thousand three hundred and ten tons. One is mentioned at Fall River, formed of conglomerate, which weighs five thousand four hundred tons, or ten million eight hundred thousand pounds.

In the drift of the northern hemisphere have been discovered the remains of a variety of animals, mostly such as live in tropical climates. Of these there are not less than one hundred species, of which half are extinct. These facts seem to show that the climate in these countries was once much warmer than at present, and when the action of the ice commenced, it must have taken place suddenly; for sometimes the animals are found undecayed, having evidently been wrapped almost instantaneously in the ice.

The appearance of many rocks in the drift regions is often very remarkable, as they bear marks of having been smoothed, rounded, scratched, and furrowed, apparently by the action of the masses borne along by the icebergs. Many instances of these peculiarities are mentioned, as having been met with on mountains, at elevations of two or three thousand feet above the level of the sea. These scratches, or *striæ*, as they are called, often run directly across the strata, and appear as parallel lines. Sometimes there are two or more sets, one crossing the other.

The mountains of many northern countries show their northern and northwestern sides to be worn and rounded. This is the case in Sweden, as well as in New England. Professor Hitchcock cites Mount Monadnock, in New Hampshire, as an instance of this, which is the more striking because it is mostly naked rock. He adds, the surface of the mountain is very uneven, but the protuberances are nearly all rounded, and few are left angular except on the southeastern side. The axis of the intervening hollows usually corresponds nearly to the direction of the striæ, so that the surface appears like the swell of the ocean after a storm.

Viewed in a certain direction, these swells appear like domes.

Similar rocks are seen on the top of the White Mountains, and even within twelve hundred feet of the summit of the highest peak, — Mount Washington, — which is over six thousand feet above the level of the sea. The tops of the mountains, instead of being merely scratched, are sometimes ploughed up in furrows, evidently by the action of ice and water. These furrows are quite parallel, and correspond to the course which has been taken by the drift.

Another circumstance respecting drift, which deserves to be noted, is, that in some cases it has been carried *from a lower to a higher level.* Bowlders are found thus transferred; the striæ are sometimes seen commencing at the lower level, and the rounding of the rocks indicates the same course.

Clay is not unfrequently discovered above the drift in the larger valleys, showing that they were once filled with water by the melting of the ice, and as if they were lakes in which deposits were made above the body of the drift, while the waters were wearing away passages through the mass of ruins of other rocks and earth. Sometimes these deposits are from one to two hundred feet thick. It is not easy to say where the action of the ice terminated, and where that of alluvial deposits began. The action of the ice is exhibited in certain cases by the horizontal fissures which have been produced, as well as by the driving of the upright strata from their perpendicular direction. Examples are found, which indicate that the force which thus crushed the top of a hill and bent the strata must have been very great.

The phenomena of drift have been accounted for in different ways. They were formerly referred to the powerful action of currents of water; and the effects were ascribed to the Noachian deluge. But the facts, that the remains of man are not found in it, that the remains of animals found are of extinct species, and that the period of the deluge is too short for the purpose, have induced the ablest geologists to set aside this theory.

The *Iceberg* theory has been a favorite one with some eminent geologists. This, as its title indicates, imputes most of the phenomena of drift to icebergs, carried southerly by the currents of the ocean, while the continents where drift occurs were yet beneath the ocean. As these were gradually raised from the deep, the mountains, which would form islands, would send down glaciers to their shores, and thus masses of ice would be broken off, to be floated away, loaded with detritus. In many places, large bodies of water would remain after the ocean had retired, in which deposits of clay and sand would take place.

In support of this theory, it is said, that, in high northern and southern latitudes, the process which this theory assumes is daily going on. Icebergs frequently transport towards the equator blocks of great size, which are dropped upon the bottom of the ocean. Mr. Scoresby saw upon several icebergs, in latitude 70° N., masses of earth and rock, weighing from fifty thousand to one hundred thousand tons; and a deposit of drift is now actually accumulating in the southern hemisphere, in latitudes no higher than Northern Italy, Switzerland, and England. It is also urged, that there is evidence daily accumulating of the existence of a much lower temperature in northern latitudes, when the drift was depositing, than is now found in the same latitudes; and, therefore, glaciers might have existed in much lower latitudes than at present; and icebergs might have been carried nearer to the equator than they now are, before melting.

Some serious objections are urged against this theory, and it must be admitted that it does not explain all the phenomena that have been observed and recorded.

The *Glacier* theory, which has many advocates, supposes, that, at the close of the tertiary period, a sudden reduction took place in the temperature of the surface of the globe, whereby all organic life was destroyed; and, in high latitudes at least, glaciers were found on mountains of moderate altitude; indeed, that vast sheets of ice were spread over almost the entire surface, extending south as far as the phenomena of drift have been observed. The northern regions, especially around the poles, are supposed to have formed one vast sea of ice, which sent out its enormous glaciers in a southerly direction by the force of expansion; and the advance and retreat of these glaciers accumulated the moraines, and produced the striæ and embossed appearances upon the rocks. When the temperature was raised, the melting of the immense sheet of ice produced vast currents of water, which would lift up and bear along huge icebergs loaded with detritus, and thus scatter bowlders over wide surfaces. The blocking up of gorges by moraines would form lakes and ponds, in which clay and sand, such as now lie above the drift, might have been deposited; and afterwards the barriers of these lakes, consisting of loose matter, may have been cut through, and the waters gradually drained off, while they assumed their present levels. In some parts of the world, the elevation of mountains, — as the Alps, for instance, — during the same period, might have increased the effects that have been described.

The perfectly preserved elephants and rhinoceroses of Siberia, in frozen mud, show that the change of climate there must have been very sudden from quite warm to intense cold. The general absence of organic remains in the clay and sand lying above the drift makes it probable, that, during their deposition, the climate was too cold to favor the existence of animals and plants, while the highly arctic character of the few species of shells that have been found in these deposits in New York, Canada, Scotland, Sweden, and Russia, confirms this conclusion.

The history of the effects of glaciers is the history of the phenomena of drift in miniature. In the first place, the moraines of glaciers correspond to the accumulations of drift that are so common in northern regions. The latter are, indeed, somewhat modified, partly by subsequent agency, and partly by a somewhat different mode of production, so that the several varieties of moraines accompanying glaciers are not always to be distinguished. Secondly, the smoothing, rounding, and polishing of the rocks are the same beneath the glaciers as over the whole northern hemisphere. Thirdly, the parallel striæ upon their surfaces are perfectly explained by the passage of ice over them in unbroken sheets, with angular fragments fixed into their lower surface. Fourthly, the parallel furrows and valleys produced by the agency under consideration upon the crests and sides of steep mountains are very analogous to those beneath the glaciers, the result of the joint action of ice and water. Fifthly, this same joint action may have transported bowlders to great distances, and lodged them upon precipitous ridges and on sandy plains. Finally, these effects are inexplicable by currents alone.

This theory furnishes an adequate agency for smoothing and furrowing the slopes of mountains, and for the transportation of drift from lower to higher levels by an ascending force; facts more difficult to explain than almost any other phenomenon connected with drift. This might have been both by the expansive force of ice, pushing one extremity of the sheet up the hill, and by water lifting up icebergs with detritus from the bottoms of the valleys, and, as it rose, carrying them to higher levels. It shows how deposits of clay and sand might have been formed above the coarse detritus in lakes produced by the moraines and melting of the ice, and how their barriers afterwards might have been removed. It gives a reason why those clays and sands are so destitute of organic remains, namely, a cold climate. It provides an agent sufficiently powerful to break down the tops of ledges of rocks, as appears to have been done, at least in a few instances, in New England, by an enormous force operating obliquely downwards in connection with the formation of drift. The expansion and great weight of a huge sheet of ice might exert a force upon obstacles almost irresistible.

It must be admitted, that objections lie against this theory, also; and Professor Hitchcock, from whom we have taken these views, concludes by remarking, that probably the true philosophy of drift will be found in a union of the iceberg and glacier theories. It may be proper to add, that other modes of accounting for the various phenomena presented by the drift formation have been suggested; but those we have mentioned appear to be the most rational, and to be maintained by the highest authorities.

TERTIARY FORMATION.

THE next strata, according to the arrangement we have adopted, is the *tertiary*. This corresponds with the *supercretaceous* group of De la Beche, and, with that of drift, with Mr. Lyell's tertiary period.

The tertiary rocks have been divided into four distinct groups of marine strata, distinguished by the peculiarities of their organic remains. These, which are also separated from each other by strata which contain fresh-water and terrestrial remains, have been named *eocene*, *miocene*, and *older* and *new pliocene*. In the eocene, — which lies at the bottom, and hence is called the earliest, — the number of shells, of which similar living species are found, is only about three fifths *per cent.;* in the miocene, it is seventeen *per cent.;* in the older pliocene, thirty-five to fifty *per cent.;* and in the newer pliocene, ninety to ninety-five *per cent.*

The tertiary rocks are usually stratified; the layers being horizontal. Sometimes, however, they incline at a large angle. The manner in which the materials of which they are formed are disposed indicates very clearly that they were originally deposited by water. The strata are parallel, and the materials are clay, sandstone, and carbonate of lime; which facts correspond with what is now observed respecting the agency of water.

There are two processes by which rocks are deposited by water; the first, *mechanical* or *sedimentary*,—that is, formed by the mere subsidence of materials from mechanical action and gravity; the second, *chemical*, the materials being precipitated in a state of solution. The lower we descend, in general, the less we find of the mechanical, and the more of the chemical deposits. In the rocks which contain fossils there is sometimes found an alternation of the two kinds of deposits, but in general they seem to have been both going on at the same time. In order to be consolidated, rocks generally require more or less of chemical agency; but in the tertiary rocks the mechanical agency predominates, though there are beds of gypsum, limestone, and rock-salt formed by chemical solution.

In the tertiary strata a great variety of rocks are found, as the concretionary, the tufaceous, argillaceous, and silicious; or limestone, marl, plastic clay, silicious and calcareous sands, green sand, gypsum, lignite, rock-salt, and mill-stone or burr-stone.

The deposits of the tertiary formation are of immense extent, and great diversity of feature and quality. Some are *fluviate*, formed by rivers; some *lacustrine*, formed in lakes; some are marine, and some volcanic. Many of the wonders of the tertiary period will be considered hereafter, and the peculiar features of the strata may then be more fully illustrated. We may here sum up the general characteristics of the system, in the words of Richardson, as follows:

1. They are all deposited in hollows or depressions, usually of chalk, and occasionally of older rocks.

2. They evince proofs of important changes in the relative level of land and sea, during that period of the history of the earth in which they were deposited.

3. They afford like evidence, that, during the same epoch, the central part of Europe was the site of enormous lakes, which, at the present day, have no analogy in that part of the globe, but which have their type in the vast lakes of the American continent.

4. They likewise show that volcanic agency was developed, at this period of nature's history, on a vast and magnificent scale.

5. They testify the gradual refrigeration which took place during this era, and the approximation, consequent on the change of climate, to the forms of vegetable and animal life prevailing at the present day. Thus, while the dicotyledonous plants first assume their present preponderance in these deposits, animals of the class mammalia, that is, such as give suck to their young, first appear in any numbers on our earth.

6. Finally, owing to their position at the surface, and their having undergone less pressure than the rocks beneath, they constitute a vast depository of fossil shells, which are preserved in such number and perfection, as to form a scale by which the relative age of these formations is usually determined.

SECONDARY ROCKS.

Under the *secondary* rocks may be included all the strata in which fossils are found, below the tertiary. Some writers prefer to retain the distinction of *transition;* though there is a difference of opinion as to where the transition should commence, some beginning it at the coral formation, some with the carboniferous limestone, others with the old red sandstone, and yet others with the grauwacke.

The secondary formation comprises a number of very important systems, which, in their turn, admit of numerous subdivisions. The *cretaceous* system, most commonly distinguished by the presence of *chalk*, is said to be wanting in our country ; but the *ferruginous sand formation* here is deemed its equivalent. Chalk, which is a species of carbonate of lime, is remarkable, in some of its beds, for the great quantity of flints which are dispersed through it, generally in a parallel position.

Dr. Tilton has divided the *cretaceous* system into chalk, green sand, and wealden. Green sand is mixed with a green substance, much resembling chlorite, or green earth. The wealden formation derives its name from its being found chiefly in the *wealds*, or woods, of Sussex and Kent, in England. It is said to be composed of beds of limestone, conglomerate, sandstone, and clay, and to abound in remains of fresh-water and terrestrial animals, that have been deposited in an estuary which once occupied that part of England.

The *oölitic* system is the second embraced under the secondary formation. This is so called, because in many of the rocks are found imbedded small calcareous globules, resembling the roe or spawn of fish. The rock is therefore named *oölite*, or sometimes *roe-stone*. Such a structure, however, is not confined to this rock; nor does it extend through the whole of this system. Other strata, as layers of clay, sandstone, marl, and limestone, are found between the series of oölitic rocks. The lowest of the oölitic group is called *lias*, and consists of argillaceous limestone.

The *saliferous* system belongs also to the secondary formation. This is composed of rocks which have sometimes a slaty and sometimes a conglomerate structure, with fine sandstones, stratified with each other in endless variety. These rocks are, in composition, silicious, argillaceous, or calcareous, and are often highly charged with the red oxide of iron.

The *carboniferous* system embraces three extensive deposits, the *coal measures*, *carboniferous limestone*, and *old red sandstone*.

The vast extent of the coal formation may be conceived, when it is stated, that in England not less than six millions of tons are annually raised from the mines of Northumberland and Durham. At this rate, they will be exhausted in two hundred and fifty years. In South Wales there is said to be a coal-field embracing twelve hundred square miles, with twenty-three beds, ninety-five feet thick, which will supply coal for two thousand years, at the present rate of mining. The number of steam-engines put in operation by the use of coal in Great Britain is stated to be fifteen thousand, by which a power is supplied equal to that of two millions of men. The whole machinery thus moved by this power is supposed to be equal to three or four hundred millions of men, by direct labor.

In Pennsylvania, in 1837, not less than nine hundred thousand tons of coal were carried to market from the mines in that State alone. No one can form an adequate idea of the quantity of this mineral existing there. The bituminous coal-field, embracing the western part of Pennsylvania and a part of Ohio, extends over an area of twenty-four thousand square miles. These measures can probably be traced almost continuously from Pennsylvania to the Mississippi, and even into Missouri, two hundred miles west of that river. Coal also exists on the eastern slope of the Rocky Mountains.

One of the most remarkable considerations respecting these immense beds of coal is, that they are now universally admitted to be nothing more than vegetable matter, converted into its present state by heat and pressure; that they are, in short, the luxuriant vegetation of the ancient earth, which, ages ago, was buried beneath the waters, either where it grew, or at the mouths of estuaries, to which it was borne by floods. It is supposed to have been deposited in places alternately occupied by fresh and salt water, where, under the heat generated by moisture, and the presence of the slime, mud, and clay deposited above, the vegetable masses have been elaborated into coal.

This theory may be sustained by very clear proofs. Vegetable matter in similar circumstances of moisture and pressure is known to ferment, and produce spontaneous combustion. Thus, if hay be closely packed while moist, it ferments, takes fire, and is consumed.

If, however, the fire be interrupted, and combustion be prevented, the hay is found to have acquired a dark brown color, a glazed or oily surface, and a bituminous odor. The same facts have been observed in the case of flax. Now, were vegetable matter in a moistened condition placed under pressure so as to prevent the gaseous principle from escaping, bitumen, lignite, or coal would be produced, according to the various stages of the process. Professor Göppert, of Berlin, to test this point, having observed that the leaf in iron-stone nodules might occasionally be separated in the form of carbonaceous flint, placed fern leaves in clay, dried them in the sun or air, exposed them to a red heat, and thus obtained a striking resemblance to fossil plants. According to the degree of heat, the plant had become brown, shining, or black, or was entirely lost, leaving only the impression.

Dr. Lyell, alluding to the vegetable origin of coal, remarks, that, after cutting a slice of coal so thin that it should transmit light, it was found, that in many parts of the pure and solid coal, in which geologists had no suspicion that they should be able to detect any vegetable structure, not only were annular rings of the growth of several kinds of trees beautifully distinct, but even the medullary rays, and, what is still more remarkable, in some cases even the spiral vessels, could be discerned.

The inference has also been drawn, from numerous facts, that the carboniferous formation of Europe and America is made up of comparatively recent plants, — though still at a remote period. In the first place, the boughs and leaves of ferns are most frequently and strikingly met with. So perfectly are they preserved, that the species may be designated by attending to the veining of the leaves. At least one hundred species have been thus determined. The most numerous of these are what are called *sigillaria*, or *tree ferns.* The stems are fluted vertically, and on the flutings are places indicating where the leaf adhered. They have never been found with the leaf attached, but in the same beds are loose leaves, which have no trunks. What is also worthy of notice is, that the tree ferns are known to be only the productions of a climate far warmer and more humid than that where coal is now found; for it is discovered even as far north as Melville's Island and Baffin's Bay. The same remarks apply also to certain species of the fir tribe, and other plants, found in coal; from which Dr. Lyell infers, that the climate in the frigid zones must have been much warmer and more moist than it now is in any part of the globe.

Of the two theories respecting the formation of coal beds, Dr. Lyell seems to lean to that which attributes the accumulation of these large beds of coal to the growth on the spot, rather than to the principle of drift. He states many interesting facts which sustain this hypothesis, and which have been found to occur both in Europe and this country. Mr. Richardson adopts the same conclusion, and states, as an objection to the drift origin, that the coal in that case would have been mixed with foreign substances, which is not the fact. The uniform thickness of each coal seam presents another difficulty. By being washed away, the vegetable matter deposited would have been found disposed in unequal layers, heaps, and hillocks, which is far from being the fact. The great minuteness, too, of many of the seams forbids the supposition of so violent action as that which the drift theory supposes. The enormous depth of many of the seams is likewise considered an insurmountable objection. Some of these are of fifty or sixty feet in thickness.

It is well known that the bulk of substances may be greatly reduced by pressure. On one occasion, a mass of rubbish, which was left in a worn-out vein of iron-stone for two years only, was in that time reduced from seven to not more than two feet in thickness, and to so hard a substance, as to present one mass of rock, which required blasting to break it. Now, considering the immense mass of vegetable matter required for the coal formation, — for it must be remembered that it has been under pressure much more likely to affect it, from its compressibility, than mineral rubbish, — and this, too, not of a few yards, but of many thousand feet, and during countless ages, — it is evident that an adequate supply could not be transported by the action of water sufficient to form such beds. The high state of preservation in which many of the objects occur; the perfect condition of the leaves, and other parts of many of the ferns; the preservation of the sharp angles of numerous stems of plants known to be of a soft and juicy nature, with the surfaces of the *sigillariæ*, especially, marked with lines, streaks, and flutings so delicate, that the mere drifting of a day would have inevitably destroyed them; together with the occurrence of certain fruits which are found in heaps and clusters; with many other facts of a like nature, and leading to similar conclusions, — convince us that these objects have never been subjected to drift, but were buried on the spots where they lived and flourished. Another fact is urged, founded on a chemical view of the subject; which is, that, if vegetable matter were swept away by a flood, such an agency, by allowing the gaseous particles to escape, would never be adequate to produce the desired results. We may add, that the close analogy presented by peat to lignite and coal affords a striking corroboration of the justice of this view.

Another circumstance, alleged as conclusive against the idea of transport, is the multiplied instances of trees found erect on the spot where they grew. Sometimes not less than forty of these, standing a few feet apart, and in short forming a perfect fossil forest, have been discovered. These, being merely the discoveries of chance cuttings, and of observations of very limited extent, lead to the conclusion, that the earth contains innumerable forests entombed on the spots where they grew.

In consequence of the investigations already made, the conclusion has been formed, which, as stated by Mr. Richardson, is in substance as follows. It is conceived that the vegetation which produced coal grew in broad and shallow lagoons and sheets of water, receiving at intervals deposits of silt and mud, the rubbish of neighbouring lands, and situated on an island or seashore. These streams were speedily filled up by the growth of a profusion of *stigmariæ*, a marshy, juicy plant, until, by the accumulation of mud, silt, sand, and the mixture of decayed vegetable matter, the lagoon was converted into a morass. A fresh vegetable growth now followed, of reedlike plants, the *equisetæ* and *calamites*, with here and there a larger tree. The spoils of these plants may thus have furnished materials for beds of peat, and of coal resting on a base composed entirely of the remains of *stigmariæ*. These spots may, by repeated subsidences, have been so reduced beneath the level of the sea, as to have rendered them the receptacles of alternating deposits of sand and clay, and may thus have produced the strata of limestone which occur between seams of coal. As each deposit was formed, it may have been covered, either wholly or in part, by a lagoon, when the succession of vegetable growth and earthy deposit may have followed, and fresh supplies of mineral fuel may have been produced.

The alternation of beds of coal with marine deposits is explained by the supposition, that an extensive subsidence of the estuaries, which were the site of the lacustrine and terrestrial vegetation above described, may have reduced these estuaries beneath the level of the sea, where the submerged soil with its vegetation was covered with accumulations of encrinital limestone and other marine sediments, and that, in course of time, either by drifts of sand, or clay, from the land, or by the elevation of the bed of the sea, the estuaries were again filled, and became the area of the vegetable growth above named; while the repetition of such changes would account for the alternation of marine and vegetable deposits, which so frequently occur in our beds of coal. It is said, that not less than one hundred and twenty species of ferns, most of them extinct species, have been discovered in coal.

A peculiarity of the coal which is mentioned, and one which in Europe greatly assists in working it, is the *faults* which constantly occur in the beds. These are caused by fissures traversing the strata, extending often for miles, and penetrating to a depth ascertained only in a few instances. There is usually a subsidence of strata on one side, or an elevation on the other, and sometimes the effect is caused by both. These breaks or dislocations have been produced by violent mechanical convulsions subsequent to the formation of the strata; and as the change of level sometimes exceeds five hundred feet perpendicular, the power which could move upward such enormous masses must have been very great.

SILURIAN SYSTEM.—The next system of the secondary rocks has been called the *Silurian*, because it was first developed in a part of England which belonged to the ancient kingdom of the *Silures*. It embraces the upper members of that vast deposit which has been called *grauwacke*, and *grauwacke slate*, or *shale*. It bears marks of being of sedimentary origin, as it is sandy, clayey, and also characterized by the presence of lime. It has been subjected to a more powerful chemical action than the rocks which lie above it. The materials often vary in fineness, sometimes affording delicate slates, and others of a coarser kind, even running into conglomerates. These varieties are often found in successive strata.

The *limestone* appears to owe its origin more to chemical than to mechanical action, and sometimes the structure is crystalline. The whole formation abounds in organic remains. This system has been found not only in England, which has been described by Mr. Murchison in two of the most splendid quarto volumes ever published on geology, but also in the United States, in the Russian empire, in Sweden, and Norway.

CLAY SLATE AND GRAUWACKE SYSTEM.—This, which, by Mr. Sedgwick and some other writers, is called the *Cambrian* system or group, is found in Wales, a deposit of vast thickness, and embracing the lower part of the grauwacke group and clay slate. The whole, as described by Professor Hitchcock, is eminently argillaceous or clayey, but it greatly varies in fineness, being sometimes found of the finest clay slate, and at other times in conglomerates, with fragments of quartz, feldspar, mica, jasper, &c., half an inch in diameter. The cement which unites them, however, is always argillaceous. These conglomerates are also mixed with strata of slate, which have been called grauwacke and clay slate. It is by no means certain, says Professor Hitchcock, that the Cambrian system of rocks ought to be separated from the Silurian; for though the organic remains are quite different in form from those in the latter, yet the number is small.

PRIMARY STRATIFIED ROCKS.

THE last formation of the stratified rocks is called *primary*. These are seated below the secondary, and comprise a variety of groups or systems, which will be mentioned in the order adopted by Professor Hitchock.

Clay Slate, or Argillaceous Slate. — This rock is composed of fine clayey matter, which has a structure that can be divided or split, and is more or less shining on its surface. Its chief deposit, as before mentioned, belongs to the Cambrian system; but it is often found in mingled strata with mica slate and quartz, and on this account must be considered a primary rock, which is not fossiliferous. It, however, also occurs in strata connected with the fossil-bearing grauwacke. It belongs, therefore, both to the strata that bear fossils and those which do not.

The farther we go from the line that divides these two classes of rocks towards the oldest, the more highly glazed is the clay slate, until it passes at length insensibly into mica, talcose, or hornblende slate. But in the other direction the surface becomes more dull, and the texture looser, until it forms what is usually termed *shale;* and yet higher up it gradually changes into unconsolidated clay. Among the varieties of clay slate are the whetstone slate, and graphite or drawing slate, the latter of which contains several *per cent.* of carbon. The popular notion, that *hones* are composed of petrified wood, is groundless. Some of the best are of compact feldspar.

Quartz Rock. — This consists essentially of quartz, either granular or sandy. The varieties are formed by the mixture of mica, feldspar, talc, hornblende, or clay slate. In these the strata are very regular, but in the pure granular quartz it is often difficult to trace the lines of the strata. It mingles in layers with all the primary rocks, as well as with grauwacke, and, in this last case, is said to be decidedly mechanical in its structure, which feature also is sometimes to be observed where it belongs to the primary rocks. The sandy varieties of this rock are said to bear a great degree of heat, though some specimens of mica surpass it in this respect.

HORNBLENDE SLATE. — In this rock *hornblende* prevails, and some of its varieties contain feldspar, quartz, and mica. When it is pure hornblende, it often has an indistinct mode of forming its strata, and, by taking into its composition feldspar, it passes into a rock like greenstone. It occurs in connection with all the primary rocks, but more commonly with clay slate, mica slate, and gneiss.

TALCOSE SLATE. — *Talc* is an essential ingredient of this rock, and, though occasionally found in a pure state, yet it is oftener mixed with quartz and mica, and sometimes also with limestone, feldspar, and hornblende. It is likewise met with in connection with clay slate or with grauwacke, but in this country it is usually found with mica, and also, though seldom, with gneiss. Some of its varieties are called chloride slate, and *steatite ;* the latter being the stone used for furnaces, fireplaces, &c., called *soap-stone.*

SERPENTINE. — This rock is described by most European writers as belonging to the unstratified rocks ; but Professor Hitchcock, while admitting that it often occurs without any parallel divisions into strata, and in the form of veins, says, that in the primitive regions of New England vast beds of it are often distinctly stratified. We place it, therefore, among both the stratified and the unstratified rocks. He says, it usually appears as a *metamorphic* rock; that is, one which has been subjected to so high a degree of heat as to change its character, and yet not so great as to destroy the original marks of stratification.

PRIMARY LIMESTONE. — This rock alternates with the primary strata. By some this characteristic is considered as proof that limestone is primary. Others, however, make its primary character to depend mainly on its crystalline state. This kind of rock is generally white and crystalline, and, on account of its resembling in appearance loaf-sugar, it is sometimes called *saccharine*. It is, however, occasionally found of a dark color, owing to its being penetrated by other rocks, as also to its being more compact.

Some writers have proposed to include this limestone among the unstratified rocks, because, when it occurs in the unstratified class, and also in some of the older stratified ones, it is often nearly or quite destitute of stratification. In many cases, however, it is distinctly stratified. But, says Professor Hitchcock, looking at all the facts on the subject, they seem more satisfactorily explained by supposing primary limestone a metamorphic rock, like serpentine, which may therefore be found both stratified and unstratified, than by regarding it as always unstratified and of igneous origin.

MICA SLATE. — In this rock, which is a mixture of mica and quartz, the former predominates. *Garnets* and *staurotides* are said to be so abundant in it, as properly to be regarded constituents; hence, mica slate is distinguished into varieties, as containing garnets or staurotides.

Gneiss. — Gneiss is composed of quartz, feldspar, and mica. Hornblende, also, is sometimes found in it. The arrangement of the materials is more or less in thin plates, and the rock exhibits strata. It likewise passes, however, into granite, which is composed of the same ingredients; and then the stratification, as well as the arrangement in plates, becomes very obscure, and it is impossible to draw a line between these two. Some specimens of gneiss, as well as mica slate, are remarkable for the crooked and irregular strata which they exhibit; though, in other places, the same rocks are likewise distinguished for their regular and even stratification. This last feature renders them particularly valuable for certain purposes. They are much used in some parts of the country for flagging stones. When gneiss contains crystals of feldspar, which give it a spotted appearance, it bears the name of *porphyritic gneiss;* and when talc is found in the place of mica, it is called *protogine.*

Remarks on Stratified Rocks. — It may be useful to add some general inferences respecting the stratified rocks, before we proceed to the consideration of the characteristics of the unstratified rocks.

One of these is this. If all stratified rocks have been deposited from water, the layers must have been originally nearly horizontal. The present inclination of the deposits rarely exceeds ten degrees; though sometimes the strata have been affected by a subsequent elevation. If, therefore, we get the perpendicular thickness of a series of strata, we may ascertain, as far as that depth, the character of the crust of the globe.

The total thickness of the fossil-bearing strata in Europe has thus been ascertained to be not less than six or seven miles. In Pennsylvania, the fossil-bearing rocks which lie below the coal measures are forty thousand feet, or more than seven and a half miles, in thickness. In the peninsula of Tauris, Pallas describes a continued series of primary strata, inclined forty-five degrees over a distance of eighty-six miles, which would give a perpendicular thickness of more than sixty-eight miles. In New England, also, — as we have already stated, — there are strata of primary rocks nearly perpendicular, not less than twenty miles in thickness. Thus we know the general structure of the crust of the globe to the depth of from seven to sixty-eight miles, although artificial excavations have been made in the earth not more than half a mile.

PRIMARY ROCKS — UNSTRATIFIED.

We last of all come to the *unstratified* rocks. These originally lie below the rocks we have above described. We find among them several varieties, which result from two principal causes, — a difference in their chemical composition, and the different circumstances of their production. The varieties insensibly pass into each other, even in the same mountains. The two chief minerals, however, in their composition, are those known as *feldspar* and *augite* or *hornblende.* Recent researches have rendered it probable that these two last named are only varieties, differing in crystalline structure, &c., in consequence of the difference of cooling when melted more or less rapidly.

Some of the most important of the unstratified rocks deserve a description.

GRANITE. — The chief materials of which this rock is composed are quartz, feldspar, and mica. Its color is most frequently gray, though often of a flesh-colored tinge. The ingredients are sometimes very coarse, the crystalline fragments being a foot or more in diameter, and at other times scarcely discernible by the naked eye. Of course, between these extremes there exists a very great variety. The *graphic* granite, which is composed of quartz and feldspar, has an arrangement of the quartz, which imparts to the surface of the rock an appearance somewhat resembling letters, from which circumstance it derives its name.

SYENITE. — This is another of the unstratified rocks. It is composed of feldspar, quartz, and hornblende, — the feldspar being the prevalent material. It is sometimes found compounded with mica also, and then it is called *syenitic granite*. The name was taken from the famous rock at Syene, in Upper Egypt, of which many celebrated monuments were formed; but this has been found to be nothing but granite with black mica, while that of Mount Sinai is composed of genuine syenite; on which account it has been proposed by a French geologist to substitute sinaite for syenite; but this suggestion, it appears, has not been adopted.

PORPHYRY. — Rocks are called *porphyry*, when they are formed of a compact earthy base, with similar particles, having crystalline masses disseminated through them, which belong to the same period as the base.

The classical porphyry referred to by the ancients has feldspar for its base, and compact feldspar with crystals of feldspar imbedded in it. The name, porphyry, is derived from a Greek word signifying *purple*, because this was most usually the color of the ancient porphyries; but the rock exhibits almost every variety of color. It is the hardest of all rocks; and, when polished, is probably the most enduring.

GREENSTONE. — There are several unstratified rocks, the chief materials of which are feldspar and hornblende or augite, and which are called *trap rocks*. The name is derived from a Swedish word signifying *a stair*, on account of these rocks being arranged like stairs or steps. Greenstone most commonly consists of hornblende and feldspar in which hornblende predominates. When it is almost entirely greenstone, it is called *hornblende rock;* and when the grains of feldspar and hornblende are quite coarse, it is called *syenitic greenstone.*

TRACHYTE. — Another unstratified rock is *trachyte*, which is of a whitish or grayish color. It is usually porphyritic, having for its principal materials glassy feldspar, with hornblende, mica, &c. It is called *trachyte*, on account of its roughness to the touch, from a Greek word signifying rough. It was an abundant product, while volcanic action lasted, in the tertiary period; and is commonly, to appearance, older than basalt, though lavas of a similar description are thrown out even at the present day. It is said to constitute the loftiest summits of the Cordilleras.

BASALT. — This rock appears to be composed of augite, feldspar, and what is called titaniferous iron.

Augite, however, predominates over all the others; though sometimes hornblende takes its place. Basalt also passes insensibly into all the other varieties of trap rocks.

AMYGDALOID. — This is rather a particular form, extending to the whole trap family, and derived from a Greek word signifying *almond*. Like porphyry, it is not confined to any one species of rock. It abounds in rounded hollows, which are filled up with various minerals, as calcareous spar, quartz, &c. Sometimes they are found lengthened to a cylindrical shape by the hot melted matter flowing into them, so that they are several inches long. When they are not filled with any material, the rock is said to be vesicular.

The trap rocks are peculiarly distinguished by being found in the form of columns, or regular prisms, with from three to eight sides, mostly about five or six, and often reaching to a great length, even as much as two hundred feet. These columns are likewise frequently jointed, or divided into separate blocks, placed one on the top of another; the surface of one being concave, and the next convex, so that they exactly fit into each other. When these columns stand upright, as they often do, they look as if they had been formed by art. Though the blocks will cleave off at the joints, yet they are so compactly united, that there is no space to be perceived between them, or between the different columns. They vary from three to five feet in thickness. They form what is called the Giant's Causeway, in Ireland, where they extend along the coast for many miles. Fingal's Cave, too, in the island of Staffa, one of the Western Isles of Scotland, furnishes a remarkable display of scenery formed by these basaltic columns.

The whole island is a complete mass of basalt, covered by a thin layer of soil. It is about two miles in

Island of Staffa.

circumference, and forms a table-land with an irregular surface, being surrounded on every side by steep cliffs, about seventy feet high, which are formed of clusters of angular columns, with from three to six or seven sides each. It is intersected by a deep gorge, which separates the higher and more celebrated columnar portion from the other division of the island. At the highest tides, the columns which form the southwestern cliffs appear to terminate abruptly in the water; but the retiring tide exposes a causeway of broken columns at their base. The greatest elevation of this island is about one hundred and twenty feet, and its surface is covered with soil of considerable depth, clothed with herbage.

Fingal's Cave, first made known to the public in 1772, by Sir Joseph Banks, is on the southeast corner of the island, and presents a magnificent chasm forty-two feet wide and two hundred and twenty-seven in length. The roof, which is one hundred feet high at the entrance, gradually diminishes to fifty, and is composed of the projecting extremities of basaltic columns; the sides, of perpendicular pillars; and the base, of a causeway of the same materials. The vaulted arch presents a singularly rich and varied effect; in some places, it is composed of the ends of portions of basaltic pillars, resembling a marble pavement; in others, of the rough surface of the naked rock; while in many, stalactites mingle with the pillars in the recesses, and add, by the contrast of their colors, to the pictorial effect, which is still further heightened by the ever-varying reflected light thrown from the surface of the water, which fills the bottom of the cave.

The depth of the water is nine feet, and a boat can therefore, in tolerably calm weather, reach the extremity of the cave; but when the boisterous gales of that northern clime drive into the cavern, the agitated waves, dashing and breaking against the rocky sides, and their roar echoed with increased power from the roof, present to the eye and ear such a scene of grandeur as bids defiance to any description. The short columns composing the natural causeway before mentioned continue within the cave on each side, and form a broken and irregular path, which allows a skilful and fearless climber to reach the extremity of the eastern side on foot; but it is a task of danger at all times, and impossible at high tide, or in rough weather.

It would be useless to attempt a description of the picturesque effect of a scene, which the pencil itself is inadequate to portray. But even if this cave were destitute of that order and symmetry, that richness arising from multiplicity of parts, combined with greatness of dimension and simplicity of style, which it possesses, — still, the prolonged length, the twilight gloom, half concealing the playful and varying effects of reflected light, the echo of the surge, as it rises and falls, the transparent green of the water, and the profound and fairy solitude of the whole scene, could not fail strongly to impress a mind gifted with any sense of beauty in art or in nature.

The basalt of which the columns are composed is of a dark greenish-black hue, highly colored by iron; a thin layer of silicious cement is seen between the joints, or articulations, which is called mortar by the islanders, and strengthens their persuasion that this wonderful cave is the work of art. Another cave, but of inferior extent, lies at a short distance; and many others of less note are seen in various parts of the cliffs, into which the sea breaks with a noise resembling that of distant heavy ordnance.

The Giant's Causeway forms a magnificent range of basaltic pillars, on the northern coast of Antrim. It consists of an irregular group of hundreds of thousands of pentagonal jointed basaltic columns, varying from one to five feet in thickness, and from twenty to two hundred feet in height. The structure of these masses, as well as their color, is the same as those already described. In the cliffs, a chasm, formed by the inroads of the waves, presents a natural cavern, about sixty feet high, and of great picturesque effect. The entrance is nearly thirty feet in width, and the walls are formed of dark basalt. But the chief interest of this spot, in a geological point of view, is the altered structure observable in the sedimentary rocks, wherever they have been traversed by the basalt.

By an experiment, Mr. Gregory Watt proved very conclusively that the columnar structure of basalt arises from the pressure of numerous spheroids on each other in the act of cooling. He melted seven hundred weight of basalt, called the Rowley rag-stone, keeping up the fire for six hours, and allowed it to cool so slowly that it was eight days before it was taken from the furnace. The mass is said to have been wedge-shaped, four feet and a half long, two feet and a half broad, eighteen inches thick at one end, and four at the other, — a form well adapted to exhibit the different rates of cooling, and the various kinds of texture produced. Where it was thinnest, and cooled most rapidly, the texture was glassy; where it was thickest, and cooled most slowly, the structure of it became stony; while the intermediate parts exhibited a transition from one state to the other. Very many spheroids were formed; where two came in contact, they were compressed, and when several met, they formed prisms. An idea of the arrangement may be obtained by conceiving of a number of cannon balls piled on each other, and then reduced to a nearly fluid state, or partially melted, — when the pressure of these globular bodies on each other would produce the columnar arrangement which is so evidently visible in basalt.

Sometimes the columns of greenstone, when found in an overhanging situation, as they project, become exfoliated, so as to present a convex surface downward. Such is the case with a group at Mount Holyoke, and which Professor Hitchcock denominates *Titan's Piazza.* He observes, that, when the trap vein, or dyke, as it is termed, is columnar, the columns are often horizontal, or rather perpendicular to the sides of the vein; and thus is produced a wall of stones regularly fitted to one another and laid up apparently by man; while a decomposition of the surfaces of the blocks often produces a powder resembling crumbling mortar. A wall of this sort has been discovered in Rowan county, North Carolina, which projected above the rock it traversed, in consequence of the decay of the rock, and it was for a long time confidently believed to be the work of human skill, — proving the former existence there of a powerful and civilized people.

Some of the most interesting scenery in this country is formed by greenstone columns, standing upright, or leaning only a few degrees. The Palisadoes on the Hudson River are a well known example; but the most extensive formation of this kind is said to be in the country west of the Rocky Mountains, where the Columbia River passes through mountains of trap, and probably basalt, from four hundred to one thousand feet in height, and where successive rows of columns stand one over another, separated only by a few feet of amygdaloid conglomerate, or breccia.

SERPENTINE. — An account was given of this rock among the class of stratified rocks. The beautiful verd-antique marble, which is found at New Haven and Milford, in Connecticut, and other parts of this country, is a variety of this rock; besides which there are also other interesting varieties, founded on the greater or less mixture of serpentine with limestone, talc, hornblende, and feldspar.

LAVA. — By lava is meant all the melted matter of various descriptions thrown out from volcanoes; the greater part of it being composed of feldspar and augite. When feldspar prevails, a light-colored lava is produced; when augite prevails, the darker varieties are the result. Many other minerals also occur in lava; not less than one hundred species having been detected in the lava of Vesuvius.

The *feldspathic* or *trachytic* lava, when cooled under pressure, produces solid rock; but when cooled in the air, it is porous, fibrous, and light enough to swim on the water, like pumice; large masses of which are sometimes found floating in the midst of the ocean. The *basaltic* or *augitic* lavas are said very greatly to resemble the older basalt, and, when cooled under pressure, compact basalt is the result; but if cooled in the open air, they are *scoriaceous* or *vesicular*, and are called *scoriæ.*

There are many varieties of lava; as, the *vitreous* kind, which has a fracture like glass; *obsidian*, which is called volcanic glass; and *pitchstone*, which is less glassy, with an appearance like pitch.

The small angular fragments and dust of pumice and of scoriæ produced by an eruption, when falling into the sea, or on dry land, and mixing with sand, gravel, shells,

&c., and hardened by carbonate filtering through them, constitute what is called *tuff*. This, according as it occurs with trap or modern lava, is called *trap tuff* or *volcanic tuff*. When found with large angular fragments, it forms *volcanic breccia*. Sometimes, says Professor Hitchcock, especially at the great volcano of Kailauca, on the Sandwich Islands, when lava is thrown into the air, the winds spin it out into threads resembling flax, and drive it against the sides of the crater. This is called volcanic glass; and by the natives of the Sandwich Islands, *Pele's hair*, — Pele having formerly been regarded as the presiding goddess of this volcano. Besides these, there are also thrown out from volcanoes fragments of granite and other rocks, almost in an unaltered state; cinders and ashes; also sulphur and various salts and gases.

In general, the unstratified rocks are more easily melted than the stratified, and this property increases as we proceed from the granite to the lava; owing to the fact, it is said, that there is a greater proportion of lime, and often of alkali, in the more recent rocks.

ORGANIC REMAINS.

WE are now about to open one of the most startling pages of human science, — that which treats of *organic remains*, — and the study of which is called *Palæontology*. It is only since the discoveries in this branch of geology, that it has made such rapid advances, and taken so high a stand in the public estimation.

Allusion has been made, in the preceding pages, to the various remains found in the stratified rocks of our earth, which, in science, bear the general name of *organic remains*, though in common language they are frequently called *petrifactions*. These consist of the relics of plants and animals, and are found in a variety of conditions and circumstances.

It may be well, in the first place, to present some views of the general characteristics of organic remains, and then proceed to consider them more in detail.

Animals are sometimes found entire, in the more recent formations; and sometimes, also, parts of them, less liable to be altered, are discovered in the solid rocks, with but little change. The harder parts of the animal are, indeed, often impregnated with mineral substances, but this does not prevent the examination of the animal matter.

As an example of the first class, may be mentioned the fact, that the entire carcass of an elephant was found, at the beginning of the present century, in the frozen mud and sand of Siberia. It was covered with hair and fur, resembling those of the elephants which are now found among the Himalaya Mountains of Asia. The drift along the shores of the Northern Ocean of the eastern continent abounds with the bones of the same animal, but without the preservation of the flesh and hair. In 1771, the entire carcass of a rhinoceros was dug out of the gravel, in that frozen region.

Besides the conditions above mentioned, in which organic remains appear, sometimes the animal substance is almost entirely replaced by mineral matter, and thus a real petrifaction is formed; at other times, the animal matter, having been partially inclosed by the mineral, decays or falls out, and leaves a mould which presents its shape more or less perfectly. These moulds are often filled up with extraneous matter, and thus form a species of cast, showing what the animal was.

In other instances, the substance of the animal matter is so crushed down and flattened, that only a thin plate, seeming to indicate the form, size, and character of the animal, remains; sometimes, also, nothing is left but tracks impressed on the rocks, or fecal remains, to furnish the materials for judging of the races which have existed.

In the case of petrifaction, which is the replacing of animal or vegetable matter by mineral substances, by means of chemical action, the process is common, and often witnessed at the present day. Of this we have given several instances, in our account of alluvium. Among the mineralizers which are most commonly found are carbonate of lime, silica, clay, oxide or sulphuret of iron, and sometimes the ores of copper, lead, &c.

In the alluvial and diluvial formations, the traces of the existing orders of animated nature are everywhere apparent. Works of art, mingled with the bones of man, and the remains of vegetables and animals, are found in these modern deposits. But as we advance into the earlier formations, many species of them are absent, and finally we come upon regions where the existing races wholly disappear, and those at present unknown seem to have usurped the dominion of nature in the remote ages to which they must be referred.

ORGANIC REMAINS OF MAN. — The question has been raised, and much interest has been excited in its discussion, whether human remains exist in the geological formations which have been mentioned. It was formerly supposed that this was the case; but later investigations have proved that the fossil bones which were said to be human have no claim to be thus considered. Thus, the specimens which Scheuchzer notices, under the head of *Homo, diluvii testis*, — "Man, a witness of the deluge," — Cuvier demonstrated to be those of a large salamander. Other supposed cases have been proved to be equally unfounded. So far as the earth has been examined, there appears to be an entire uniformity in this respect. It is, indeed, regarded as conclusively established, that such animals as now exist could not have lived in that state which must have prevailed while the creatures whose remains we find in the lower formations flourished.

Certain human remains have, it is true, been discovered, imbedded in solid limestone rock, on the shore of the island of Guadaloupe. But this rock being of recent formation, and composed of fragments of shells and corals, there is no reason to believe that they are of ancient date. They have been conjectured by some to have belonged to a race of Indians who were exterminated about one hundred and twenty years since by the Caribs; while others have referred them to a Peruvian origin. A curious impression of human feet, also, was discovered, many years ago, in sandstone, on the western bank of the Mississippi, at St. Louis, which Dr. Mantell says, he has no doubt is an actual print of human feet in soft sand, which was quickly converted into solid rock by the infiltration of calcareous matter. The length of each foot is ten inches and a half, and the spread of the toes four inches, indicating the usual stature, and the nature of the impression shows that the feet were unconfined by shoes or sandals. Others, however, have been disposed to view these impressions as the work of art. It may be remarked, that none of these indications of the presence of human beings are found, except in the alluvial formations.

MODE OF DETERMINING THE NATURE OF ANIMALS FROM THEIR BONES. — Before entering upon the consideration of the principal animals found in the tertiary and secondary formations, it may be well to allude to some of the means by which the discoveries of lost species have been so wonderfully obtained. In this the science of comparative anatomy bears a striking part. To a person unacquainted with this art, the fossil bones brought to light might seem a confused medley of mere fragments, from which nothing certain could be gathered. Like the hieroglyphics, some key was needed to explain the mystery; and it is to the genius and knowledge of Cuvier that we owe the method of solving the question, What were the animals, and their habits, of which these are the mere relics? A knowledge of the structure of the living races, their peculiarities as well as resemblances, is all important to this end.

The organs of every animal, says Cuvier, may be considered as forming a machine, the parts of which are mutually dependent on each other, and exquisitely adapted for the functions they are designed to perform; and such is the intimate relation of the several organs, that any variation in one part is constantly accompanied by a corresponding modification in another. The mutual adaptation of the several parts of the animal fabric is a law of organic structure, which, like every other induction of physical truth, has only been established by patient and laborious investigation. It is by the knowledge of this law that we are enabled to reassemble, as it were, the scattered remains of the beings of a former state of the globe; to determine their place in the scale of animated nature; and to reason on their structure, habits, and economy, with as much clearness and certainty as if they were still living and before us. Of all the solid parts of the animal structure, the most obviously mechanical are the jaws and teeth; and as we know in each instance the operations they are intended to perform, they afford the most simple and striking illustration of the principles above enunciated.

On examining the jaws of *carnivorous* animals, we find a set of cutting teeth, called *incisors*, in front, *canine* teeth, or sharp fangs, on the sides, and the *molar*, — that is, bruising, grinding, or crushing teeth, — farther behind. These last rise into sharp, cutting points, and in the upper and lower jaw overlap each other, like the edges of a pair of shears. They are likewise covered with a thick crust of enamel, and are thus suited for tearing or cutting flesh, and breaking or crushing bones; but are not adapted for grinding the stalks or the seeds of vegetables. The jaws open and shut like a hinge, and thus admit of no grinding motion.

In the case, therefore, of an animal whose stomach is so organized as to fit it for the digestion of flesh alone, and that raw or fresh, the jaws will be found to be so constructed as to serve for devouring live prey; the claws, for seizing and tearing it in pieces; the teeth, for cutting and dividing it; its whole system of motion, for pursuing and overtaking it; the organs of sense, for perceiving it at a distance; and the brain, with the instinct necessary for teaching the animal how to conceal itself, and lie in wait for its victim. But to carry out these general principles, the muscles which raise the head must be vigorous, and consequently the vertebræ or bones from which these muscles spring must be of a particular form, adapted to the purpose. The paws or claws must possess a peculiarity of construction, that they may easily move and grasp with strength; and so of all the various members.

The case is different with regard to the *herbivorous* animals, or those which live on vegetables. They have no sharp canine teeth or fangs; and the enamel is not placed on the top of the teeth, but in deep vertical layers, alternating with bony matter, so as to form a grinding surface. The flat molar teeth are not fitted for cutting, but to masticate or grind, to reduce into a pulp the soft vegetable substance. The jaws, too, are loosely articulated, so as to allow a sort of rotary or lateral movement; and the muscles correspond in position and power with the design in view.

Another class of animals are called the *rodentia*, or gnawers, of which the squirrel is an example. These have long cutting teeth, like nippers; the front teeth are large, compared with the molar teeth, and are so interlocked as to allow no grinding motion; and the lower jaw is so constructed, that, instead of working in the skull transversely, or laterally, it works lengthwise, the teeth moving backwards and forwards, like a carpenter using his plane. These cutting teeth are also liable to be worn away by constant use, and therefore they are renewed by continual growth, and there is a special provision for their support in a bent socket. The enamel is very thin behind, and thick in front of the tooth; so that the cutting edges are kept sharp, as, by the act of gnawing, the hinder part wears away sooner than the fore part, and thus an inclined edge, like that of a chisel, is continued. The enamel of the molar teeth, also, is placed vertically and transversely, so as to form an admirable grinding surface.

From these examples it is evident that the practised comparative anatomist can easily discover by a tooth the class of animals to which a subject belonged, and consequently the kind of vertebræ, claws, and other bones, as well as muscles, which the creature must have had. The animal by this means may be restored, and a drawing made of him, such as he probably was when living, and his habits and economy described. The nature of the country which he must have inhabited, its climate, productions, &c., may likewise be deduced from these prior conclusions. Thus Cuvier and others have been enabled to form a numerous fossil collection of extinct species, and to describe various peculiarities they possessed, which would otherwise have remained unknown.

The laws, which have just been mentioned as applicable to quadrupeds, apply also, with certain modifications, to other beings, as birds, reptiles, insects, &c. The feet of birds correspond to the classes to which they belong. Some are designed to climb and perch on trees; some, to seize on and tear their prey; others, again, to paddle in the water; others, to frequent marshes; and yet others, to live in sandy deserts. All of these have their peculiarity of construction, by which their habits and economy may be discovered. Certain forms of different parts of the skeleton are found to be related to each other; so that, where one is found, the other must be supposed to exist. In the older fossils, the bones which are found are no longer white and glossy, like the recent skeleton, but have been changed in appearance, like bones that have lost a portion of their animal matter by being buried in a dry and loose soil. Besides the bones, there are also found the feces of animals, which have suffered such changes as to have become converted into stone, and are called *coprolites*. These likewise afford additional means of identifying the animals in connection with which they are found.

Fossil Elephants and Mammoths. — We now come to the description of particular species of fossil animals. There are two species of elephants still existing in tropical regions,—the Asiatic and the African. The Asiatic is the largest, and is found no further north than the thirty-first degree of north latitude; the African is found as far south as the Cape of Good Hope.

The colossal bones of the elephantine family, which occur in such great abundance as fossils, were formerly supposed to be the remains of giants; and the fossil tooth of an elephant, discovered at Brighton, in England, was conjectured, some years since, to be a petrified cauliflower.

We have already spoken of the elephants discovered in Siberia, in the ice of that frigid region, and of the bones of the rhinoceros and mastodon along the Arctic shores.

The teeth of the fossil elephant appear to be somewhat peculiar, though more nearly allied to the Asiatic or Indian elephant than to the African. These are sometimes water-worn, but usually are perfect. From the characteristics exhibited, Cuvier decided that the species thus indicated is extinct, and that the structure of the teeth, the configuration of the skull, and the hairy and woolly skin, proved that it was adapted to live in a colder climate than that in which the Asiatic species could exist; from which he inferred that they lived in the country where their remains were found; and from the preservation of their carcasses in ice, he further inferred that a sudden change of climate must have taken place in those regions. Mr. Lyell supposes that a large portion of Central Asia, and perhaps Southern Siberia, may have enjoyed a climate mild enough for the elephant; and that the whole tract of mountains, to the sea, may have been upheaved, and thus sudden cold have been produced through all Northeastern Asia.

Fossil elephants have been found in various countries. As many teeth have been collected on the coast of Norfolk and Suffolk, in England, as must have belonged to not less than five hundred individuals. In Essex, a large collection has been made, which comprises skulls, teeth, and tusks, from the sucking animal to that which was full grown. Similar deposits have been found also in France, along the coast.

The Mastodon, &c. — This fossil animal is incorrectly called the mammoth; but that name belongs rather to the fossil elephant; the mastodon differing from the elephant in the form of its teeth. The places that afford the bones of the mastodon in the greatest number are the salt or brackish waters of North America, which are called *Licks*. Of these, Big Bone Lick, in Kentucky, is very celebrated. The mastodon was a gigantic animal. An entire skeleton in Peale's Museum, Philadelphia, is fifteen feet long and eleven feet high. It derives its name from two Greek words, signifying mammillary teeth; because the thick enamel which is spread over the crown of the tooth, when unworn, is divided into two several transverse processes, each of which is also subdivided into obtuse points. These teeth, unlike those of carnivorous animals, have no longitudinal and saw-like cutting edge. They resemble rather those of the hog and hippopotamus, and seem designed for bruising and masticating raw vegetables, roots, and water-plants. The animal was not altogether unlike the elephant, but had a longer and thicker body. It had a trunk or proboscis, tusks, and four molar teeth in each jaw, but no incisors or cutting teeth. It probably frequented marshy places, and was undoubtedly a terrestrial animal. Among a collection of the bones imbedded in the mud, a mass of branches, grass, and leaves, in a half-bruised state, was discovered, together with a species of reed common in Virginia; the whole, says Dr. Mantell, appeared to have been enveloped in a sack, probably the stomach of the animal.* The tusks are of ivory, and vary in their curve. Cuvier thought he had discovered not less than six species of the mastodon. Some of them have been found in America only, and others in Europe. The Big Bone Lick contains a vast number of the

* Professor Owen, a British geologist of high standing, states that the young mastodon possessed four tusks, — two in the upper and two in the lower jaw. The two in the upper jaw remained through life; while the two in the lower, in females, both decayed and fell out, as the animal grew up, the sockets being obliterated; in the male, only the left one perished, and the right remained; so that the name *Tetracaulodon*, which had been given to it as a distinct species, was incorrect.

bones imbedded in a dark mud or gravel. Mr. Cooper, who examined the spot carefully, supposes that the bones of one hundred mastodons, twenty elephants, two oxen, one deer, and one megalonyx, have been carried from it. Baron Humboldt found a tooth of the mastodon near a volcano, at the height of twelve hundred fathoms.

The remains of an animal, which, from the structure of its teeth, is considered as filling up the interval between the mastodon and the elephant, have been found in the Burmese empire. The structure of the teeth in general is similar to that of the great mastodon; but the ridges in the crown of the tooth are disposed similarly to those in that of the elephant; and the worn surface of the teeth, it is said, bears an analogy to that of the grinders of the African elephant. These remains were found by Mr. Crawford, on the Irrawaddy, and are believed by the natives to be the bones of giants, who warred against Vishnu, and were destroyed. It is not a little remarkable, that, while there are many of the bones of the mastodon, showing that this animal once existed in great numbers in that country, no bones of the elephant, tiger, or hyena, animals now abounding in India, have been discovered.

The relics of the rhinoceros, horse, ox, hippopotamus, deer, and camel, are often found associated with other fossil bones. They are usually much larger than those of the existing species. The horns of the fossil ox have been found thirty-one inches long; and those of the elk have been seen, in Ireland, measuring from ten to fourteen feet between the tips, and reaching as high as ten feet from the ground. The average weight of the skull and antlers is computed to be three quarters of a hundred weight. Professor Jamieson, and others, says Dr. Mantell, have proved that this majestic creature was coeval with man. A skull was discovered, in Germany, associated with urns and stone-hatchets; and in the county of Cork, a human body was exhumed from a wet and marshy soil, beneath a bed of peat eleven feet thick; the body was in a good state of preservation, and enveloped in a skin, covered with hair, which there is every reason to conclude was that of the elk. A rib of the elk has also been found, in which there is a perforation, that evidently had been made by a pointed instrument, while the animal was alive; for there is an effusion of callus, or new bony matter, which could only have resulted from something remaining in the wound for a considerable period, —an effect like that produced by a wound from a spear or arrow.

HYENAS, &c.,—The remains of hyenas have been found singularly associated with other remains in caverns. Of these, the cave of Kirkdale, in England, is one of the best known. In 1821, some workmen, while quarrying stone, cut across the narrow mouth of a chasm, which had been choked up with rubbish, and overgrown with grass and bushes. The access was so confined, that a person could enter only in a bent position. The whole interior of the cave was covered with a bed of hardened mud or clay, averaging about a foot in thickness. The surface was perfectly smooth and level, when the cave was first opened, except where stalagmites had been formed. A thin coat of stalactitic matter, like ice, also extended over the bottom, which must have been formed after the mud was deposited. In this mud, or clay, were found great quantities of bones of various animals, many of them exhibiting marks of having been gnawed. These bones belong to the tiger, bear, wolf, fox, weasel, elephant, rhinoceros, hippopotamus, horse, ox, and deer. Bones of a species of hare, or rabbit, water-rat, and mouse, with fragments of the skeletons of ravens, pigeons, larks, and ducks, were also imbedded with these remains.

From these facts, says Dr. Mantell, it is inferred that the cave was inhabited by hyenas, for a considerable period; that many of the remains found there were of the species which had been carried in and devoured by those animals; and that in some instances the hyenas preyed upon each other. It would seem, therefore, that the wilds and forests of England were once inhabited by races of carnivorous animals, belonging to genera the species of which are now almost wholly confined to southern climates; that they continued for successive generations, and were the prey or the destroyers of each other; that the hyenas, according to their peculiar habits, dragged into their dens the creatures which they killed or found dead, and devoured them at their leisure; and that these races afterwards became extinct, and were succeeded by animals of an entirely different character.

Diseased bones of carnivorous animals are also found in Germany. In some of these, as described by Professor Walther, there has been a formation of new bony matter, to repair fractures in the joints, which adhere from inflammation; in others, the effects of the decay of the bones from disease are evident. Some, likewise, have a light and spongy character, exhibiting the want of nutriment in consequence of scrofulous affections.

SIVATHERIUM. — This is an animal which seems to have occupied a place, and formed a link, between the *ruminants* and the large *pachydermata*, or thick-skinned animals. A skull, and other parts of the skeleton, have been discovered in India, in the hills of Livalik, which belong to the Sub-Himalaya mountains. The deposits, where they were found, consist of immense quantities of fossil teeth and bones of the elephant, mastodon, and other animals, crocodiles, shells, and fishes. From the skull, it is ascertained that the animal had four horns and a proboscis; that it exceeded the rhinoceros in size, and combined the horns of a ruminant animal with the characteristics of the thick-skinned tribes. When living, it is supposed that it must have resembled an immense antelope, or gnu, with a short and thick head, an elevated cranium, crested with two pairs of horns, the front pair of which were small, and the hinder large, and set quite behind, with the face and figure of the rhinoceros. It must have had small eyes, on the side of the head, great lips, and a nasal proboscis.

Extinct species of the monkey and camel were found in the same deposit.

THE MEGALONYX. — This was an animal about the size of an ox, the bones of which were discovered in the nitre caverns of Virginia and Kentucky. They were first described by Mr., afterwards President, Jefferson. He supposed, from the form and size of the claw-bone, that it was a carnivorous animal; but Cuvier, a better anatomist, determined, from the character of its articulations, that the animal belonged to the sloth tribe. The distinctions on which the decision was founded are as follows: — The paws or feet of the dog and cat are both armed with claws. In the dog tribe, the nails are coarse and thick, and fitted to bear the friction of a long chase; while in the cat tribe, they are crooked and sharp, — a peculiarity, the preservation of which is owing to a peculiar mechanism. The last bone which supports the claw is placed sideways to the last bone but one, and is so united with it, that a tendon draws it backward, and raises up the sharp point of the claw, and the nearest end of the farther bone presses on the ground, as the animal usually runs, the claw being drawn back into a sheath; but when the animal makes a spring and strikes, then the claws are thrown out, by the action of the bending tendons, or flexor muscles. The example of the cat is familiar to all who have observed with what ease she can throw out or draw in her claws. Now, in the claw of the megalonyx, there is no such provision for drawing back the claw, and the point could not have been raised vertically, as in the case of the cat, so as to allow it to touch the ground without injury. As the articulating surface is double, and there is a ridge or spine in the middle, it must have moved like a hinge. The sloth, an existing species of the *tardigrade* animals, as they are called, has long toes and large nails, constructed similarly to those of the fossil animal. Instead of being drawn in, the nails are folded up, as when our fingers are folded under the palms of our hands. The arms are double the length of the legs; and the animal, from the peculiarity of the construction of its limbs, is thus obliged to drag itself along on its elbows. The sloth tribe, however, are designed to inhabit trees; they live on the branches, and rapidly pass from one to another. They feed on the leaves and the young shoots, and, if undisturbed, continue on a tree till they have thoroughly stripped it of its foliage. Instead of descending by the trunk, they roll themselves into a ball, and drop down to the ground. Their claws, therefore, are merely hooks to hang by on the branches, and they have great strength in their arms. They keep fast hold with one set of hooks till they catch by the other, and thus hang by their hands and feet. They sleep in the same position.

The megalonyx had a great resemblance to this animal in some of these peculiarities. The arm-bone was fitted to receive very large muscles for the purpose of moving its enormous claws; and there was also an opening for a passage of the nerves and blood-vessels, to protect them from the pressure to which the powerful muscular action employed would have exposed them, while there was a provision which allowed of a rotary motion of the arm.

The MEGATHERIUM is an animal resembling the megalonyx, and formerly existed on the *pampas* of South America, where the bones are found strewed over an extent of six hundred miles or more. It was about nine to twelve feet long, and seven or eight feet high, and thus was larger than the rhinoceros. Its proportions were colossal, the thigh-bone being three times as large as that of the elephant, and the haunch-bone twice the breadth. It had no cutting teeth; and the molar teeth, or grinders, which have been found, are seven inches long, of a prismatic form, and of similar composition to those of the elephant. The crown of the tooth always presents two cutting, wedge-shaped, salient angles. In forming the adze, a plate of steel is put between two plates of iron, so as to project in a line; in the same manner, these teeth have in their centre a cylinder of ivory, which is well protected by enamel, and thus they are admirably fitted to cut and bruise vegetable matter. The whole length of the fore-foot is a yard; and the claws, which are gigantic, are set in obliquely to the ground. This adapts them peculiarly for digging. Across the haunches, it measured five feet; the spinal marrow must have been a foot in diameter; and the tail, in that part nearest to the body, at least six feet in circumference. The megaloynx and the megatherium were neither of them adapted for climbing; but their food probably consisted of vegetables and roots, which they dug up with their claws. Referring to the means of mastication possessed by the megatherium, Dr. Buckland remarks, that the act of mastication formed and perpetually maintained a series of wedges, locking into each other like the alternate ridges on the rollers of a crushing-mill; and the mouth of the megatherium became an engine of prodigious power, in which thirty-two such wedges formed the grinding surfaces of sixteen molar teeth, each from seven to nine inches long, and having the quarter part of this length fixed firmly in a socket of great depth. It is scarcely possible, he adds, to find any apparatus in the mechanism of dentition, which constitutes a more powerful machine for masticating roots than was formed by these teeth of the megatherium, accompanied by a property which is the perfection of all machinery, namely, that of maintaining itself perpetually in perfect order, by the act of performing its work. The creature is supposed to have occupied a midway position between the *sloths* and *ant-eaters* and the *armadillo.* The bony armor and scales which were once attributed to it have been assigned by Professor Owen, a distinguished geologist and comparative anatomist, to another animal, as large as an ox, called the *glyptodon.* An entire skeleton of the megatherium is in the Museum at Madrid, in Spain.

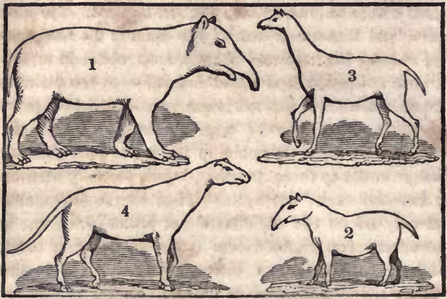
THE DINOTHERIUM. — Among the various extinct species of *mammalia*, the *dinotherium* holds the first place. This creature was even larger than the mammoth or mastodon. Its bones were first discovered in the South of France, and afterwards in Bavaria and Austria. The molar teeth or grinders resemble those of the *tapir* in form and structure; and Cuvier described the animal under the name of the *gigantic tapir.* Professor Kaup, however, regards it as a new genus, between the tapir and the mastodon, and adapted to a marshy or lacustrine condition of the earth, which seems to have prevailed during the period when the tertiary strata were depositing. The skeletons found show that the animal must, in some cases, have been at least eighteen feet long. The shoulder-blade resembled that of the mole, and the fore-leg was adapted to digging in the earth. It had likewise two strong tusks curved downward, the reverse of those of the walrus; and the lower jaw, into which they were firmly fixed, was four feet long. From the structure of the cranium, it appears, also, to have had a proboscis. It had no front cutting teeth with which to seize its food, and the jaws did not close together in front. It is mechanically impossible, says Dr. Buckland, that a lower jaw, nearly four feet long, loaded with such heavy tusks at its extremity, could have been otherwise than cumbrous and inconvenient to a quadruped living on dry land. No such disadvantage would have attended this structure in a large animal designed to live in water; and the aquatic habits of the family of tapirs, to which the dinotherium was most nearly allied, render it probable, that, like them, it was an inhabitant of fresh-water lakes and rivers. To an animal of such habits, the weight of the tusks sustained in water would have been no source of inconvenience; and, if we suppose them to have been employed in raking and grubbing up by the roots large aquatic vegetables from the bottom, they would render such service, and combine the mechanical powers of the pickaxe with those of the horse-harrow of modern husbandry. The weight of the head, placed above these downward tusks, would add to their efficiency for the service here supposed; as the power of the harrow is increased by being loaded with weights.

The tusks of the dinotherium may also, he adds, have been applied with mechanical advantage to hook the head of the animal to the bank, with the nostrils sustained above the water, so as to breathe securely during sleep, whilst the body remained floating, at perfect ease, beneath the surface. The animal might thus repose, moored to the margin of a lake or river, without the slightest muscular exertion, the weight of the head and body tending to fix and keep the tusks fast anchored in the substance of the bank; as the weight of the body of a sleeping bird keeps the claws clasped firmly around its perch. These tusks might have been further used, like those in the upper jaw of the walrus, to assist in dragging the body out of the water; also, as formidable instruments of defence. The great length of the body of the animal would not have been inconvenient to him living in the water, but would have been attended with much mechanical disadvantage to so weighty a quadruped on land.

Dinotherium.

Early Pachydermata. — A great variety of fossil remains of animals belonging to the class of mammalia have been discovered in the mud which occupied the area of the city of Paris and vicinity, called the basin of Paris. The quarries of gypsum spread over Montmartre, though known to contain fossil bones, were passed comparatively unnoticed by the naturalists of Paris, till Cuvier, after having successfully applied the laws of comparative anatomy to the investigation of fossil elephants, turned his attention to them. He now perceived that a new world was open to his researches, and, by his zeal and energy, soon obtained an extensive collection, and found himself — to use his own expression — in a charnel-house, surrounded by a mass of broken skeletons of a great variety of animals. To arrange each fragment in its proper place, and to restore order to these heaps of ruins, seemed, at first, a hopeless task; but a knowledge of the immutable laws by which the organization of animal existence is governed soon enabled him to assign to each bone, and even fragment of bone, its proper place in the skeleton, and the forms of beings hitherto unseen by mortal eye rose before him. The deduction itself is a beautiful specimen of the application of science to investigation; and the splendid triumph which followed his perseverance well rewarded his skill and toil. "I cannot," remarks this illustrious philosopher, in all the enthusiasm of successful genius, "express my delight, on finding how the application of one principle was instantly followed by the most triumphant results. The essential character of a tooth, and its relation to the skull, being determined, immediately all the other elements of the fabric fell into their places; and the vertebræ, ribs, bones of the legs, thighs, and feet, seemed to arrange themselves even without my bidding, and precisely in the manner I had predicted."

The fossil teeth, on being examined, exhibited such a form and structure as at once showed that the animals must have belonged to the *herbivorous* tribe. The following engraving will give some idea of their appearance.



1 *Palæotherium magnum.* 3 *Anoplotherium gracile.*
2 *Palæotherium minus.* 4 *Anoplotherium commune.*

The *Palæotherium magnum* was of the size of a horse, but thicker and more clumsy; its head was massive, and its legs and tail were short. It resembled a large tapir, but differed somewhat as to the teeth, and had one toe less on the fore-feet. Its height was probably from four to five feet; about equal, it is said, to that of the rhinoceros of Java. It was, no doubt, furnished, also, with a short proboscis or trunk.

The *Palæotherium minus* was smaller in size, probably not larger than the roebuck, and of similar form to the tapir. It had light and slender limbs.

The *Anoplotherium gracile* was of elegant proportions, resembling in size and form the gazelle, and must have lived after the manner of the deer and antelope.

The *Anoplotherium commune* was of the height of the wild boar, but its form was more elongated; it had a long and thick tail, like the kangaroo; and the feet had a divided hoof, or two large toes, like those of ruminating animals. It would appear to have been used to swimming, and probably frequented the lakes, in the beds of which its bones were found. Like the anoplotherium gracile, it was destitute of canine teeth; whence its name, which signifies *unarmed wild beast*, as palæotherium means *ancient wild beast*. Other animals were also discovered in the older tertiary formations, and named by Baron Cuvier. Of these, the *Anthracotherium*, so called on account of its being found in anthracite or lignite, held an intermediate place between the hog and the hippopotamus.

Plants, Shells, Insects, Fishes, and Birds. — The remains of a great variety of these are also found, as having been in existence during the various periods of the tertiary formation. Some of them are of species now existing, while others belong to extinct species. A few of these may be briefly noticed. Of the shells called *foraminifera*, there are several interesting species. These bodies are entirely distinct from the testaceous habitations of snails, periwinkles, &c.; they are, in truth, not an external, but an internal apparatus; and it is supposed, that, in addition to their having served as a point of attachment and support to the soft body of the animal, they acted as a buoy, which could be made heavier or lighter at pleasure, and by which the animal was enabled either to sink or swim. The *nummalite* — so called from its resemblance to a coin — affords a beautiful illustration of the structure of these bodies. It has a disk-like form, and varies from the microscopic size of a mere point, to an inch and a half in diameter. Its outer surface is generally smooth and marked by fine waving lines. On splitting the shell, it is found to consist of several coils, divided into a great many cells or chambers by cross partitions, having no apparent communication with each other, but which the creature probably had the power of filling with fluid or air through the *foramina* or pores. The pyramids of Egypt are composed of limestone formed of nummalites, which Strabo supposed to have been lentils scattered about by the workmen, and afterwards converted into stone! Fossil crabs and fishes, also, are found, and several species of birds, — as, the pelican, sea-lark, curlew, woodcock, buzzard, owl, quail, &c. The eggs, too, of some aquatic species occur in the lacustrine limestone of Auvergne, as do those of turtles of recent formation on the island of Ascension.

We cannot give a better view of the organic remains and changes of the tertiary period, a portion of which we have now considered, than by employing the language of Dr. Mantell.

In the pliocene, or newer tertiary, which also embraces the mammalian epoch, the fossil remains in the alluvial deposits afford incontestable proof, that the mammoth, mastodon, hippopotamus, dinotherium, and other colossal animals of extinct species and genera, together with birds, reptiles, and enormous carnivora, inhabited such districts of our continents as were then dry land; while the older tertiary, or eocene, incloses the bones of land animals, particularly those of a lacustrine character, which approximate to certain races that now exist in the torrid zone, but belong to extinct genera, that preceded the mammoth and the mastodon.

The seas and lakes of that remote epoch occupied areas that are now above the waters; and rocks and mountains, hills and valleys, streams and rivers, diversified the surface of countries which are now destroyed or entirely changed, and whose past existence is revealed by the spoils which the streams and rivers have accumulated in the ancient lakes and deltas. The ocean abounded in mollusca, crustacea, and fishes, a large proportion of which are referable to extinct species. Crocodiles, turtles, birds, and insects were contemporary with the palæotherium and anthracotherium; and animal organization, however varied in certain types, presented the same general outline as in modern times; the extinction of species and genera being then, as now, in constant activity.

The vegetable world also contained the same great divisions; there were forests of oak, elm, and beech; of furs, pines, and other coniferous trees; palms, tree-ferns, and the principal groups of modern floras; while the water, both salt and fresh, teemed with the few and simple forms of vegetable structure peculiar to that element. The state of the inorganic world is not less manifest; the abrasion of the land by streams and rivers, — the destruction of the sea-shore by the waves, and the formation of basalt and shingle, — the desolation inflicted by volcanic eruptions, — all these operations were then, as now, in constant action. The bed of an ancient sea, containing myriads of the remains of fishes, crustacea, and shells, now forms the site of the capital of Great Britain; and accumulations of tropical fruits and plants, drifted by ancient currents from other climes, constitute islands in the estuary of the Thames; while the sediments of lakes and gulfs, teeming with the skeletons of beings which are blotted out from the face of the earth, compose the soil of the metropolis of France.

Although the changes in the relative level of the land and sea during this epoch were numerous and extensive, yet there is one region which still presents traces of its original physical geography; and although the earthquake has rent its mountains to their very centre, — though hundreds of volcanoes have again and again spread desolation over the land, and inundations and mountain torrents have excavated valleys, and checkered the plains with ravines and water-courses, yet the grand primeval features of that country remain; and we can trace the boundaries of its ancient lakes, and the succession of changes it has undergone, from the first outbreak of its volcanoes, to the commencement of the present state of repose.

The lowermost lacustrine deposits in Auvergne, which are spread over the foundation rock of granite, unmixed with igneous productions, mark the period antecedent to the volcanic era. While the intrusions of lava and scoriæ in the superincumbent strata denote the first eruptions of Mont d'Or, the succeeding period of tranquillity is recorded in characters alike intelligible. The hard deposition of calcareous mud, —

the incrustation of successive generations of aquatic insects, crustacea, and mollusca, and we may even add of infusoria, — the imbedding of the bones of mammalia, birds, and reptiles, — the accumulation of lignite, and other vegetable matter, — are data from which we may, in imagination, restore the ancient country of Central France.

It was a region encircled by a chain of granite mountains, watered by numerous streams and rivulets, and possessing lakes of vast extent. Its soil was covered with luxuriant vegetation, and peopled by palæotheria, anoplotheria, and other terrestrial mammalia; the crocodile and turtle found shelter in its marshes and rivers; aquatic birds frequented its fens, and sported over the surface of its lakes; while myriads of insects swarmed in the air, and passed through their wonderful metamorphoses in the waters. In a neighbouring region, herds of ruminants, and other herbivora, of species and genera now no more, with birds and reptiles, were the undisturbed occupants of a country abounding in palms and tree-ferns, and having rivers and lakes, with gulfs which teemed with the inhabitants of the sea; and to this district the fiery torrents of the volcano did not extend.

But at length a change came over the scene; violent eruptions burst forth from craters long silent; the whole country was laid desolate; its living population was swept away; all was one vast waste; and sterility succeeded to the former luxuriance of life and beauty. Ages rolled by; the mists of the mountains and the rains produced new springs, torrents, and rivers; a fertile soil gradually accumulated over the cooled lava currents and the beds of scoriæ, to which the sediments of the ancient lakes, borne down by the streams, largely contributed; another vegetation sprang up; the mammoth and mastodon, with enormous deer and oxen, now quietly browsed in the verdant plains. Other changes succeeded; those colossal forms of life in their turn passed away, and at length the earlier races of mankind took possession of a country, which had once more become a scene of fertility and repose.

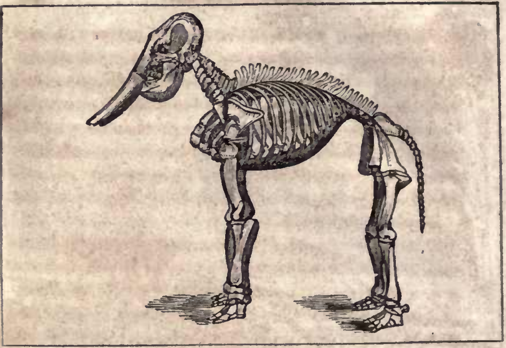
ORGANIC REMAINS OF THE SECONDARY FORMATIONS.

Our attention has been directed thus far to remains discovered in deposits made in the basins of lakes, and estuaries,—such materials as have been drifted by the action of rivers and inundations. "We have now," says Dr. Mantell, referring to the subject before us, "arrived on the shores of that ocean, of whose spoils the existing islands and continents are principally composed; the fathomless depths of the ancient seas are spread before us, and the myriads of beings which sported in their waters, and lived and died in those profound abysses, remain, like the mummies of ancient Egypt, the silent yet eloquent teachers of their own eventful history."

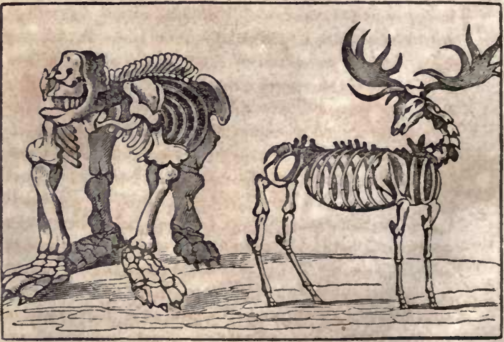
The secondary formation, it will be recollected, embraces several principal divisions, forming four natural groups,—the *cretaceous*, *oölitic*, *saliferous*, and

Ichthyosaurus, Plesiosaurus, Pterodactyle, &c., restored.

Fossil Tapir, &c., restored.



Fossil Elephant.



Fossils, Megatherium, Gigantic Elk.

carboniferous systems. The period which we are now to examine has been fitly denominated the *Age of Reptiles;* and the organic remains, called *saurians*, found in the rocks, have justly been a theme of wonder and admiration. These belong to the lizard tribe, and not less than forty species have been discovered. They are sometimes divided into the *marine*, *amphibious*, and *flying*, according as they partake of the characters thus denoted.

The Mososaurus.—The quarries of St. Peter's Mountain, near Maestricht, composed of chalk and calcareous freestone, have long been celebrated for their peculiar fossils. The bones and teeth of an unknown animal having been found there in 1770, M. Hoffmann, who was collecting specimens, discovered one which consisted of the jaws of an enormous animal. He had the mass of stone containing the remains carefully detached from the rock, watching over the operation personally, until he was enabled to take it home in triumph. The canon of the cathedral which stands on the mountain, however, laid claim to it, as being the lord of the manor, and succeeded in wresting it out of M. Hoffmann's hands. There it remained till after his death. The French Revolution having broke out, the town was bombarded, and a committee of French *savans*, who accompanied the army, having carefully shielded that part of the city where it was deposited from the artillery, sought earnestly for the treasure. The canon had concealed it, but was finally forced to give it up; and the French committee, after finding the relatives of the deceased philosopher, and paying for it a fair compensation, bore it away to Paris, where it was placed in the *Jardin des Plantes*. Here, models were made of it, under the direction of Cuvier, and sent to various museums; the original still remaining in the collection of that institution.

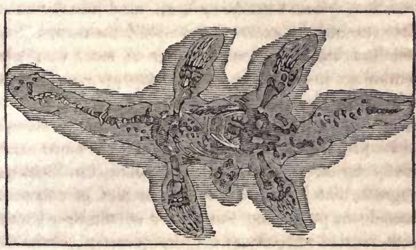
The animal was a reptile, probably about twenty-five feet long, holding an intermediate place between the *monitor* and the *iguana*, different species of the lizard tribe. It was furnished with a tail, which, by its oar-like application, enabled the creature to stem the waves of the ocean, which Cuvier supposed it to have inhabited. It had paddles instead of legs, and the number of vertebræ was one hundred and thirty-three. The most skilful anatomist, says Dr. Buckland, would be at a loss to devise a series of modifications by which the monitor could be enlarged to the length and bulk of a grampus, and at the same time be fitted to move with strength and rapidity through the waters of the sea; yet in the fossil before us we shall find the genuine character of the monitor maintained throughout the whole skeleton, with such deviations only as tended to fit the animal for its marine existence.

Specimens of the vertebræ and teeth have also been found in other places, showing that the ocean of the chalk formation was not confined to one place, but reached over the area now occupied by the Atlantic.

ICHTHYOSAURUS. — Some of the most remarkable specimens of the reptiles known by the name of *saurians* have been assigned to a genus called the *ichthyosaurus* or *fish-lizard*. There are seven or eight known species of this genus, all agreeing with one another in the general principles of their construction. This reptile, which was sometimes more than thirty feet long, had the snout of a porpoise, the teeth of a crocodile,—often amounting to one hundred and eighty,—the head of a lizard, the *sternum* or breast-bone of the ornithorhynchus, the paddles of a whale, and the vertebræ of a true fish. It thus combined in itself the mechanical contrivances belonging to individuals in the three separate classes of the animal kingdom. The position of the nostril was not, as in the case of the crocodile, near the point of the snout; but it was set as in the lizard, near the front angle of the orbit of the eye. The eye was of enormous size, far beyond that of any living animal,—in one species, the space of the orbit being fourteen inches in its longest direction. It was so constructed, therefore, as to admit a great quantity of light, and the power of vision must have been uncommon. Besides this, it is evident that it must have possessed both microscopic and telescopic powers. On the front of the orbital cavity in which the eye was placed, a circular series of petrified, thin, bony plates were placed around a central opening, where was the pupil. These plates, so arranged, by their retraction pressed forward the front of the eye, and thus converted it into a microscope; and when the eye was at rest, by resuming their position, they formed it into a telescope.

This singular provision shows that the enormous eye must have been an instrument of very great and varied power, by which the ichthyosaurus could see to a great distance, and could discern its prey in the obscurity of the night, or at the depths of the sea. Its jaws were sometimes more than six feet long, and, as in the case of the crocodile and lizard, were composed of many thin plates, so arranged as to combine elasticity and lightness with strength. To avoid the danger of fracture, to which it would have been liable had the jaw been a single bone, each side of the lower jaw was made up of six separate pieces, set in a peculiar manner; something like the method often practised in binding together parallel plates of wood or steel, to make a crossbow, or the springs of a carriage; the plates being most numerous where the strength was required to be exerted. The vertebral column was composed of more than one hundred joints, which gave the creature great strength, elasticity, and power of motion. Its ribs were slender, and so arranged as to enable the animal to introduce into its body an unusual quantity of air; so that it could remain long under water, without coming up to the surface for the purpose of breathing. A large animal, moving rapidly through the water, and breathing, must have differed in its fore-leg from the lizard tribe. Accordingly we find its feet converted into fins or paddles, of which, like the turtle, it had four, composed of numerous bones enveloped in one fold, so as to appear like a fin. The internal structure of these paddles, therefore, resembled the paws of turtles, having the short and strong bones of the arm, and those of the fore-arm, and beyond these the series of polygonal bones that made up the phalanges of the fingers. The hind-paddles were nearly one half smaller than those in front. The skin of the ichthyosaurus was naked; his food was fish, and even the young of his own species, — the remains of these having been found in its feces or coprolites.

PLESIOSAURUS.—This was one of the most remarkable animals that have yet been discovered. Indeed, Cuvier asserts that the structure is the most heteroclite, and its character altogether the most monstrous, that has yet been found amid the ruins of a former world.



Impression of the Plesiosaurus.

To the head of the lizard it united the teeth of the crocodile, a neck of enormous length, resembling the body of a serpent, a trunk and tail having the proportions of an ordinary quadruped, with paddles like those of the turtle or whale. Six species or more have been discovered, having a general structure like the ichthyosaurus. It differs, however, in the vertebræ, which are larger and less concave; and the ribs, which are connected by peculiar processes, are said to present a striking resemblance to those of the chameleon. A skeleton is to be seen in the British Museum, eleven feet long, and so nearly perfect, that the form of the original creature may be readily traced. It was probably carnivorous, and lived in shallow seas and estuaries, and breathed the air like the ichthyosaurus and our modern cetacea. The vertebræ of the neck are about thirty-three, equal to those of the longest-necked bird, the swan. This neck was probably of great use in aiding it to seize upon fish beneath the waters, and perhaps flying reptiles and insects. Its tail was so short that it could not have been used like the tail of fishes to impel the creature rapidly forward, but was doubtless employed as a rudder to steer him when swimming, as well as to raise or depress him when ascending or descending in the water. As it does not seem to have been provided with means of defence, it had probably to seek its food, as well as its safety, chiefly by artifice and concealment. Dr. Buckland suggests, that it may have been a kind of submarine chameleon, possessing the power of altering its skin by the varied intensity of its inspirations; and that this property would have been of much advantage to the animal in concealing it from its most formidable enemy, the ichthyosaurus, with which it could not contend, and from which its slow locomotive powers would not enable it to escape. Mr. Conybeare, after considering all the characteristics of the animal, draws the following inferences with respect to the habits of the plesiosaurus. That it was aquatic is evident from the form of its paddles; that it was marine is almost equally so, from the remains with which it is universally associated; that it may have occasionally visited the shore, the resemblance of its extremities to those of the turtle may lead us to conjecture; its motion, however, must have been awkward on land, and its long neck must have impeded its progress through the water, — presenting a striking contrast to the organization which so admirably fitted the ichthyosaurus to cut through the waves. May it not, therefore, be concluded — since, in addition to these circumstances, its respiration must have required a frequent access of air — that it swam upon or near the surface; arching 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 shoal water along the coast, concealed among the sea-weed, and, raising its nostrils to a level with the surface from a considerable depth, have found a secure retreat from the assaults of dangerous enemies. The length and flexibility of its neck may have compensated for the want of strength in its jaws and its incapacity for swift motion through the water, by enabling it to make a sudden and effective attack on every animal fitted for its prey, which came within its reach.

HYLÆOSAURUS. — The remains of this reptile were discovered by Dr. Mantell, in the summer of 1832, in the limestone of Tilgate forest. He denominated it the *hylæosaurus*, or lizard of the weald or wood, because it was found in the wealden formation. It blends the osteology of the crocodile with that of the lizard, and was probably about twenty-five feet long. Its most peculiar characteristic is stated to have consisted in a series of long, flat, and pointed bones, which seem to have formed an enormous fringe, like the horny spines on the back of the modern iguana or lizard. These bones vary in length from five to seventeen inches, and in width from three to seven inches and a half at the base. Large thick scales were also found together with these, which probably were lodged in th skin.

Megalosaurus. — This was a gigantic reptile of the lizard tribe, probably measuring from forty to fifty feet in length, partaking of the structure both of the crocodile and the monitor. No skeleton of it has yet been discovered entire, but so many perfect bones and teeth have been found, that the form and dimensions of its limbs are well known. It was evidently fitted, from the character of its feet, to move on land, as the hollows of the bones were filled with marrow. The form of its teeth, flat pointed, curving back in the form of a pruning-knife, and the inner edge deeply seated down to the base, thus combining the powers of the knife, sabre, and saw, shows it to have been carnivorous; and it probably fed on smaller reptiles, as crocodiles and tortoises, the remains of which are found with its bones. The shape of the head indicates it to have terminated in a long and narrow snout.

Iguanodon. — Associated with the various members of the saurian family we have now mentioned, Dr. Mantell discovered also in Tilgate forest the remains of a still more gigantic reptile, of the herbivorous class, and more nearly allied to the living iguana of the warm climates. From the resemblance of its teeth to those of the iguana, he gave it the significant name of ***iguanodon***, or the animal with teeth like the iguana. Dr. Mantell's own account, as given in his "Wonders of Geology," is, that the discovery of a mutilated tooth led him to suspect the existence of a gigantic herbivorous animal, which later researches confirmed. The fossil in question was a portion of the crown of a tooth, resembling, in its form, the incisor or cutting tooth of one of the herbivorous mammalia. The enamel was thick in front and thin behind, and by this means a sharp cutting edge was maintained in every stage. The structure of the tooth, therefore, and its worn surface, proved that it was to be referred to a species that fed on vegetables; the absence of a fang, and the appearance of the base, not broken, but *indented*, showed that the shank had been absorbed, from the pressure of a new tooth which had grown up and supplanted the old one. The teeth, when perfect, are of the prismatic form, and remarkable for the prominent ridges which extend down the front, and the serrated margins of the crown. Examined by a powerful microscope, the ivory in the teeth of the iguanodon is found to be composed of close-set tubes, radiating in a wavy course from the cavity of the tooth to the surface. These characteristics of the tooth being settled, it became necessary to find the requisite analogies, in order to know how to class the animal to which it belonged. These, after long research, were found in the teeth of the iguana, an animal of the lizard tribe, from three to five feet in length, still living in many parts of America and the West Indies. The iguana feeds on insects and vegetables, climbing trees and chipping off the tender shoots; and nestles in the hollows of rocks, depositing its eggs, like the turtle, in the sands or the banks of rivers. The teeth of the iguana differ from those of the iguanodon in one respect, however, namely, that they never present a worn surface; they are broken or chipped off by use, but not ground smooth, as in the herbivorous animals. Not being furnished with cheeks, or a movable covering for the jaws, they seize on their prey or food and swallow it whole without mastication. So great a similarity in the teeth and the mode of dentition was found to exist between the fossil and the living animal, that Dr. Mantell felt justified in giving it a name indicating such a resemblance.

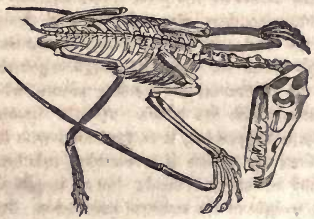
Subsequently, another collection of bones of this animal was discovered, which Dr. Mantell developed and joined together. These included two thigh-bones, each thirty-three inches long; one leg-bone, thirty inches long; bones of the toes and claws; a bone of the fore-arm; several belonging to the spine and tail; collar-bones; others which seemed to belong to the pelvis, &c. From these he was enabled to form more accurate conclusions as to the size of the animal, and its habits. The following, he remarks, is the result of a careful comparison of some of the fossil-bones with the corresponding ones of the iguana, made with the view of ascertaining the probable *average* size of the original animal. We should bear in mind that some individuals must have exceeded this estimate, and, if they bore the proportion of the recent iguana, must have been upwards of one hundred feet in length.

Length of the iguanodon, from the snout to the tip of the tail, - - - -	70 feet.
Length of the head, - - -	4½ "
Length of the body, - - -	13 "
Length of the tail, - - -	52½ "
Height, from the ground to the top of the head,	9 "
Circumference of the body, - -	14½ "
Length of the thigh and leg, - -	8 "
Circumference of the thigh and leg, -	7½ "
Length of the hind foot, from the heel to the point of the long toe, - -	6½ "

The iguanodon had also a horn, composed of bone, four inches high and of an irregular form. In this respect, too, there is an analogy with the iguana, which, besides the spiny processes on the back, has warts or horny protuberances on the head and snout.

Respecting the condition and habits of the iguanodon, it is inferred, that, as the iguana now inhabits only the warmest regions of the earth, probably a torrid climate once prevailed in the now temperate regions of the southern coast of England, where these bones have been discovered. The large bones having been evidently filled with marrow, this, with the form of the bones of the feet, shows that this animal, like the megalosaurus, was adapted and designed to move on the land. Its teeth, also, show that they were remarkably fitted for cropping tough vegetable food, such as the *clatharia*, and similar plants, which are found buried with its bones. As the iguana lives chiefly upon vegetables, it is furnished with long and slender feet, by which it is enabled to climb trees with facility in search of food; but no tree could have borne the weight of the colossal iguanodon. Its movements must have been confined to the land and water, and it is evident that its enormous bulk must have required limbs of great strength. Accordingly, we find that the hind feet, as in the hippopotamus, rhinoceros, and other large mammalia, were composed of strong, short, massy bones, furnished with claws, not hooked as in the iguana, but compressed as in land tortoises; thus forming a powerful support for the enormous leg and thigh. But the bones of the hands or fore-feet are analogous to those of the iguana, — long, slender, flexible, and armed with curved claws, the exact counterpart of the nail-bones of the recent animal, thus furnishing prehensile instruments fitted to seize the palms, arborescent ferns, and dragon-blood plants, which probably constituted the food of the iguanodon.

Pterodactyle. — "Among the most remarkable disclosures made by the researches of geology," says Dr. Buckland, "we may rank the flying reptiles which have been ranged by Cuvier under the genus *pterodactyle*, a genus presenting more singular combinations of form than we find in any other creatures yet discovered amid the ruins of the ancient earth."



Pterodactyle.

So peculiar and strange is the structure of these animals, that the first specimen discovered was classed by one naturalist as a bird, by another as a species of bat, and by yet a third as a flying reptile. The creature, indeed, combines certain characteristics of all three. The head, and the length of the neck, resemble those of a bird; its wings, in proportion and form, are like those of the bat; while the body and tail approximate in form to the body and tail of the mammalia. The skull, also, is small, and furnished with a beak which has not less than sixty pointed teeth. These singular characteristics, so puzzling to investigators, it was reserved for the genius of Cuvier to reconcile. He ranks the pterodactyles among the most extraordinary of all extinct animals; and if we could see them restored to life, they would strike us as being singularly unlike any thing that exists in the present world. Eight species have been discovered, varying from the size of a snipe to that of a cormorant. In external form, the creature bore a resemblance to the bat or vampire. The snout was elongated like that of the crocodile, and armed with conical teeth. The eye, as appears from the orbit, must have been of enormous size, thus fitting them, like the bat, to fly by night. They resembled the bat also in having fingers, terminating with long hooks, which projected from their wings. They were thus furnished with a powerful paw, which enabled them to creep, or climb, or hang from the trees. It is thought, also, that the pterodactyle, like the vampire bat of the island of Bonin, possessed the power of swimming.

As the creature had wings, it was natural to look for the structure of the bird or bat in the bones. The beak, however, had teeth, and the form of a single bone enabled Cuvier to decide that the animal belonged to the lizard tribe, so that it was a kind of flying reptile. The vertebræ of the neck, also, are to those of birds only as six or seven to from nine to twenty-three, while those of the back are in the reverse proportion; the ribs, too, like those of the lizard, are thin and thread-shaped, and thus differ from those of birds, as do the bones of the feet and toes. They are supposed to have fed on insects, and the presence of large fossil dragon-flies and other insects in the same quarries where the pterodactyles are found proves that they existed at the same period, and probably formed a portion of their food. They may also have fed on fish, and some of the small marsupial animals, or those of the opossum kind, which then existed on the earth. The creature was evidently capable of perching on trees, or standing firmly on the ground; and, by folding its wings, could hop or walk like a bird.

Dr. Buckland, alluding to the peculiarities of the pterodactyle and the age in which it lived, says: "Thus, like Milton's fiend, all qualified for all services and all elements, the creature was a fit 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 straight, rough, dense, or rare,
> With head, hands, wings, or feet, pursues his way,
> And swims, or wades, or creeps, or flies.' *

"With flocks of such creatures flying in the air, and shoals of no less monstrous ichthyosauri and plesiosauri swarming in the ocean, and tortoises crawling on the shores of the primeval lakes and rivers, — air, sea, and land must have been strangely tenanted in these early periods of our infant world."

In speaking of this age of reptiles, the period of the iguanodon, Dr. Mantell says: — "The country it in-

* *Paradise Lost*, Book II., line 947.

habited must have been diversified by hill and dale, by streams and torrents, the tributaries of its mighty rivers. Arborescent ferns, palms, and yuccas constituted its groves and forests; delicate ferns and grasses, the vegetable clothing of its soil; and in its marshes, equiseta, and plants of a like nature, prevailed. It was peopled by enormous reptiles, among which the colossal iguanodon and the megalosaurus were the chief. Crocodiles and turtles, flying reptiles and birds, frequented its fens and rivers, and deposited their eggs on the banks and shoals; and its waters teemed with lizards, fishes, and mollusca. But there is no evidence that man ever set his foot upon that wondrous soil; or that any of the animals which are his contemporaries found there a habitation; on the contrary, not only is evidence of their existence altogether wanting, but, from numberless observations made in every part of the globe, there are conclusive reasons to infer that man and the existing races of animals were not created till myriads of years after the destruction of the iguanodon country, — a country which language can but feebly portray, but which the magic pencil of a Martin, by the aid of geological research, has rescued from the oblivion of the past, and placed before us in all the hues of nature, with its appalling dragon forms, its forests of palms and tree-ferns, and the luxuriant vegetation of a tropical clime."

Fossil Footprints. — Another most interesting and comparatively still more recent branch of *palæontology* is that variously known by the names of *ichnology* or *ichnolithology*, or the *history of fossil footprints.* These are of various kinds, and are found to have been evidently made during the period of the new red sandstone formation. The first cases discovered seem to have been those of which an account was given in the "Transactions of the Royal Society of Edinburgh," for 1828. Tracks or foot-marks of some animal, with drawings of the same, are there given, as they appear impressed on red sandstone in the quarry of Corn Cockle Muir, in Dumfriesshire, Scotland. The strata which bear them lie in successive layers to the depth of forty-five feet; and after removing one large slab containing them, at a few feet, or perhaps inches, below, would be found still another, exhibiting similar impressions. They traverse the rock in a direction either up or down, and not across the surfaces of the strata, which are inclined at an angle of thirty-eight degrees. On one slab there are twenty-four continuous impressions of feet, forming a regular track with six distinct repetitions of the mark of each foot, the fore-foot being differently shaped from the hind-foot; the marks of the claws are also very distinct. By a comparison of these tracks with those made by different living species of the tortoise, it has been considered probable that they were made by the feet of land tortoises. Other foot-tracks of small animals were found, in 1831, in the layers of forest marble north of Bath, in England. They are said to occur along with ripple-marks, and were probably made by some species of crustacea crawling along the bottom of an estuary. The impression of the tail and part of the body is sometimes to be seen between the tracks.

In 1834, a similar discovery was published, of some remarkable fossil footmarks found in Saxony, at the village of Hessburg near Hildburghausen. The following is the account given of them by Dr. Hohnbaum and Professor Kaup. "The impressions of the feet are partly hollow, and partly in relief; all the depressions are upon the *upper* surfaces of the slabs of sandstone, whilst the reliefs are only upon the lower surfaces, covering those which bear the depressions. These reliefs are natural casts, formed in the subjacent footsteps, as in moulds. On one slab six feet long by five feet wide, there occur many footsteps of more than one animal, and of various sizes. The larger impressions, which seem to be of the hind-foot, are eight inches long, and five wide. One was twelve inches long. Near to each large footstep, and at a regular distance of an inch and a half before it, is a smaller print of a fore-foot, four inches long, and three inches wide. These footsteps follow one another in pairs, at intervals of fourteen inches from pair to pair, each pair being in the same line. Both large and small steps have the great toes alternately on the right and left side; each has the print of five toes, and the first or great toe is bent inwards like a thumb. The fore and hind foot are nearly similar in form, though they differ so greatly in size." On the same slab are other tracks of smaller and differently shaped feet, armed with nails, which resemble the tracks on the sandstone of Dumfries, and were evidently made by the tortoise.

Professor Kaup proposed the provisional name of *cheirotherium*, — from the obvious resemblance of the marks to the impression of a human hand, — as a name to be given to the unknown animal that formed them, and he conjectured that the creature was allied to the tribe of marsupial animals; since, in the kangaroo, the first toe is set obliquely to the others, like a thumb; and the disproportion between the hind and fore feet is also very great.

Professor Owen, having directed his attention to these footsteps, as well as to some remains of reptiles, consisting of bones and teeth, has come to the conclusion, which is considered a more probable one, that the tracks in question were made, not by an animal of the marsupial class, but by a batrachian order of reptiles, or a species of gigantic frog, to which he has given the name of *labyrinthodon*. The footprints, it is observed, are more like those of toads than of any other living animal. The size of the three species of the labyrinthodon corresponds with that of the three different kinds of footsteps supposed to belong to three different individuals of the *cheirotherium*. The structure of the nasal cavity, also, shows the *labyrinthodon* to have been an air-breathing reptile; as the posterior outlets were at the back part of the mouth, instead of being directly under the anterior or external nostrils. Five species have already been determined, to which appropriate names have been applied. Although the general characteristics evince that it was a batrachian reptile, or one of the frog kind, yet Professor Owen considers that it must have been quite distinct from any such reptile now known, in the form of its feet, and the teeth.

About the same time that the singular tracks above mentioned were discovered in Germany, another kind of very distinct footsteps, resembling those of birds, was discovered, also in red sandstone, in the valley of the Connecticut River; and an account of seven species was given by Professor Hitchcock, in the "American Journal of Science," for January, 1836, in which the name *ornithichnites*, or *stony bird-track*, was applied to them. Some of them were quite small, the toes being not more than half an inch long, and the whole track but about three or four inches. Others, however, were of an enormous size, the foot being not less than seventeen inches long, including the claw of two inches, and the steps from four to six feet, proportions twice as large as those of the ostrich. In yet another species, the whole length of the track, including the large heel, was two feet, and the step six feet.

Since the first discovery of these footprints, Professor Hitchcock says he has become acquainted with not less than thirty species of these impressions, occurring at fifteen quarries, within a compass of thirty miles, along the Connecticut River, between the north line of Massachusetts, and Middletown in Connecticut. The impressions are represented as being often very perfect, so much so, that in one specimen is shown the pitted, ridged, and furrowed skin of the bottom of the foot. The evidence appears to be strong, that a large proportion of the fossil tracks must have been made by birds of the *grallæ* family; and though some of them are said greatly to resemble the tracks of saurians, it is concluded that none of them were made by animals having more than two feet. The class which possess the greatest resemblance to the saurian family Professor Hitchcock calls *sauroidichnites*, or *tracks* *resembling those of saurians*, of which he enumerates ten species. The others he terms *ornithoidichnites*, instead of *ornithichnites*, — that is, *tracks resembling those of birds*. These he divides into two classes, according to the thickness of the toes, — *pachydactyli*, of which there are enumerated seven species, and *leptodactyli*, comprising twenty other species. He says that the pterodactyle is the only animal of those yet discovered, which could have made similar tracks, and thinks it not improbable that some of the thirty species were actually made by that animal. But the toes of the pterodactyle are, as he remarks, always four or five; whereas more than half of the tracks he has examined show the impression of only three.

In the year 1839, at the meeting of the British Association, Dr. Ward gave an account of some fossil foot-marks, being trifid, — thus resembling those in the Connecticut valley, — which had recently been discovered on the new red sandstone near Shrewsbury, in England. The three toes appear, also, like the former, to have been armed with long nails. Some singular footprints are mentioned by Dr. Cotta, as having been discovered in the red sandstone of Saxony, some twenty or thirty miles from Leipsic. They have this peculiarity, that they are two-toed, or rather, as described, resemble a horse-shoe, except that they are somewhat angular. No regular arrangement of the tracks was discovered; but Dr. Cotta gives it as his opinion, that they were produced by two-footed animals. The figures were found only in relief, on the under side of a layer, like that which contains the tracks at Hessburg.

These tracks are remarkable as showing how long the impressions thus made have probably remained. Dr. Buckland's reflections on this subject are so appropriate and striking, that we quote them at length.

"The historian or the antiquary may have traversed the fields of ancient or modern battles, and may have pursued the line of march of triumphant conquerors, whose armies trampled down the most mighty kingdoms of the world. The winds and storms have utterly obliterated the ephemeral impressions of their course. Not a track remains of a single foot or a single hoof, of all the countless millions of men and beasts whose progress spread desolation over the earth. But the reptiles that crawled upon the half finished surface of an infant planet have left memorials of their passage, enduring and indelible. No history has recorded their creation or destruction; their very bones are found no more among the fossil relics of a former world. Centuries and thousands of years may have rolled away, between the time in which these footsteps were impressed by tortoises upon the sands of their native Scotland, and the hour when they are again laid bare, and exposed to our curious and admiring eyes. Yet we behold them stamped upon the rock, distinct as the track of the passing animal upon the recent snow; as if to show that thousands of years are but as nothing amidst eternity, and as it were in mockery of the fleeting, perishable career of the mightiest potentates among mankind."

Impressions of Rain-drops. — The same red sandstone, in which, in England, the footprints are found, also contains what are supposed to be distinct impressions of drops of rain. In one quarry, where the singular tracks attributed to the *cheirotherium*, or *labyrinthodon*, were found, the under surfaces of two strata, even at the depth of thirty-two or thirty-five feet from the top of the quarry, present a singular appearance, being covered with small hemispheres of the same substance as the sandstone. These projections are casts, in relief, of indentations in the upper surface of a thin bed of clay, probably occasioned by drops of rain. The form of these indentations varies. Sometimes it is hemispherical; sometimes irregular and elongated, as if the drops struck the surface obliquely, through the force of wind accompanying the rain. Similar marks have also been discovered in this country; and by forming clay into paste, and sprinkling it with water, Professor Hitchcock says that he has produced precisely the same kind of indentations. In connection with some remarks on the footprints which have been discovered in the red sandstone, he strikingly observes: "Still more strange is it, that even the pattering of a shower at that distant period should have left marks equally distinct, and registered with infallible certainty the direction of the wind."

FOSSIL FISH. — Besides the organic remains already mentioned, several species of fossil fish have been discovered. These have been classified by Professor Agassiz according to the following orders, being the same that he has proposed for fishes, and founded on the peculiar structure of their scales.

Order I. The *Placoidians*, — from a Greek word signifying *a broad plate*. The skin covered irregularly with enamelled plates, sometimes of a large size, but frequently in the form of small points, as in the shagreen on the skin of sharks, and the tubercles on the integuments of rays; a few teeth, and possibly vertebræ, and now and then an example of the means of defence on their backs, are all the remains of this description yet discovered. This order is said to be represented by five genera, of which one, comprising twelve species, is extinct.

Order II. The *Ganoidians*,—from a Greek word signifying *splendor*, on account of the brilliant surface of their enamel. These are characterized by angular scales, formed of horny or bony plates, protected by a thick layer of enamel. This order, it is stated, comprehends three extinct genera, with three species.

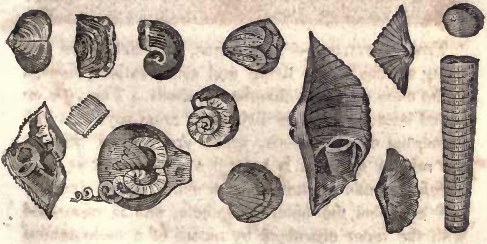
Order III. The *Ctenoidians*,—from a Greek word which signifies *a comb*. The scales of this order have their posterior margin pectinated, or like the teeth of a comb, and are composed of thin plates of bone or horn, but have no enamel.

Order IV. The *Cycloidians*,—from a Greek word which signifies *a circle*. The scales are smooth, with a simple margin, composed of thin plates of bone or horn without enamel. The teeth of some of the fossil fish of this order so greatly resemble reptiles, that it was supposed the original belonged to the extinct tribe of the saurians.

Fossil fish are termed *ichthyolites*. In the chalk formation, many teeth of fish allied to the shark family are found, and some of these are of so enormous a size that the fish must have been from seventy to one hundred feet long, and consequently as great a monster for the deep as was the iguanodon on the land. In some instances, the mouth appears to have been covered with peculiar bony processes, like a tessellated pavement. The jaw-bone also of a very curious fish, called the *chimæra*, was discovered by Dr. Mantell, in a marl-pit, and other specimens in chalk and green sand. Remains likewise of the *sauroid*, or *lizard-like fish*, have been found, which show that these fishes must have attained a great magnitude. The specimens are sometimes quite perfect. The fossil fishes of the older formations differ greatly in their organization from the existing species, and even from those found in more recent formations. This difference consists mainly in the prolongation of the vertebræ of the upper branch of the tail, which is always more or less forked. As we ascend from the lower to the higher strata, and in the upper secondary and tertiary rocks, it is entirely wanting. One of the most singular fishes is the *macropoma*. The operculum of the gills is very large, and the scales are studded with hollow tubes. In many recent fishes, it is said, there is a row of tubular scales, forming what is called a lateral line, through which flows a fluid that lubricates the surface of the body; in the *macropoma*, every scale appears to have possessed such a mechanism.

Coprolites, or the *fecal remains of fishes* and other animals, are also found, and much aid is afforded by them in determining the food, habits, &c., of the species to which they belong. Thus, a coprolite of the ichthyosaurus was shown to Professor Agassiz, that contained the small scale of a fish, which he immediately recognized as having belonged originally to a particular spot on the body of an extinct species of fish; and thus he was enabled to determine the food of the ichthyosaurus.

LOLIGO, OR CUTTLE-FISH. — The common cuttle-fish is an animal which has no external shell, but is furnished with a sort of bladder or sack, containing a black and inky fluid, by ejecting which, and thus darkening the water, it is enabled to make its escape from its enemies. Strange as it may appear, among the petrified remains of animals of a former world are found numerous specimens of the cuttle-fish, in which the ink-bags are preserved in a fossil state. A portion of the ink, thus fossilized, was submitted by Dr. Buckland to Sir Francis Chantrey, who tried it as a pigment, and when used by him in drawing, it was adjudged by a celebrated painter to be most excellent sepia. The preservation of the ink-bags shows that the animals must have died suddenly, and been buried at once in the sediment that formed the strata where they were discovered.



SHELL-FISH. — But the variety of shells found in the older formations, and even up through the more recent ones, is still greater than of fishes. We can mention only a few of the most remarkable. Notice has already been taken of the corals which abound in various parts of the globe. Both marine and fresh-water shells are discovered among other organic remains, some of which belong to extinct, and others to existing species. It may be here remarked, that many of the rocks of the globe, and constituting a large portion of its crust, are composed wholly or in part of shells.

THE NAUTILUS. — This genus, of which there are many species, some living and some extinct, belongs to the class of many-chambered shells. They are so called because they are divided by cross partitions into numerous compartments, which are pierced through the middle by what is termed a *siphunculus* or tube, which extends to the remotest cell. The animal itself occupies the outer receptacle, and is connected with the inner chambers by means of a membranous tube which lines the siphunculus. The chambers are internal air-cells, and the animal can fill the siphuncle with a fluid which is secreted in a sack around its heart; or exhaust it, when necessary. When the sack we have mentioned is filled, the siphuncle is empty, and the air in the inner chambers expands, which enables the shell to rise and float. When the animal draws its arm into the shell, the fluid in the sack is compressed and forced into the siphuncle; the air is thus condensed, and the shell sinks.

The fossil *ammonite*, or *coma ammonis*, is a many-chambered shell, coiled up in a similar manner to the nautilus; but the siphunculus, instead of being central, is placed at the back. The partitions, too, instead of being simple curves, possess every variety of turn, and the shell has generally flutings, ribs, or tubercles. The external surface has marks which resemble a fringe. The ammonite seems, however, to have been enabled to raise and depress itself in the water by a similar mechanism to that already mentioned as appertaining to the nautilus.

The whole genus of ammonites is now extinct, and Mr. Richardson has celebrated this geological fact in the following fanciful lines.

" The nautilus and ammonite
Were launched in friendly strife;
Each sent to float in its tiny boat
On the wide, wild sea of life.

" For each could swim on the ocean's brim,
And when wearied, its sail could furl;
And sink to sleep in the great sea-deep,
In its palace, all of pearl.

" And theirs was a bliss more fair than this,
Which we taste in our colder clime;

For they were rife in a tropic life,—
A brighter and better clime!

"They swam 'mid isles, whose summer smiles
Were dimmed by no alloy;
Whose groves were palm, whose air was balm,
And life one only joy!

"They sailed all day through creek and bay,
And traversed the ocean deep;
And at night they sank on a coral bank,
In its fairy bowers to sleep.

"And the monsters vast of ages past
They beheld in their ocean-caves;
They saw them ride in their power and pride,
And sink in their deep sea-graves.

"And hand in hand, from strand to strand,
They sailed in mirth and glee;
These fairy shells, with their crystal cells,
Twin sisters of the sea.

"And they came at last to a sea long past;
But as they reached its shore,
The Almighty's breath spoke out in death,
And the ammonite lived no more!

"So the nautilus now in its shelly prow,
As over the deep it strays,
Still seems to seek, in bay and creek,
Its companion of other days.

"And alike do we, on life's stormy sea,
As we roam from shore to shore,
Thus tempest-tossed, seek the loved, the lost,
But find them on earth no more!

"Yet the hope how sweet, again to meet,
As we look to a distant strand,
Where heart meets heart, and no more they part,
Who meet in that better land!"

Another fossil, called the *belemnite*, is a long, conical stone, of a crystalline, radiated structure, and generally of a brown color. It appears to be the bone of a creature which is allied to the cuttle-fish, and likewise provided with an ink-bag for defence.

Among the most interesting species of fossil shells are the *spirula* and *orthoceratite*. The latter was a long, straight shell, being sometimes found a yard in length, and half a foot in diameter; the interior was divided into separate chambers by partitions, of which not less than seventy have been counted.

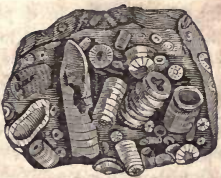
The *crinoidea* are now of rare occurrence in our seas, and only one or two species are known; but they occupied a large space among the shells of the early periods. Those that have been discovered have been arranged in four divisions, comprising nine genera, most of them containing several species. The skeleton is composed of numerous little bones, and the number in one skeleton has been computed at thirty thousand. They are described by Mr. Miller, who has written a history of them, as an animal with a round, oval, or angular column, composed of numerous articulations, and supporting at its summit a series of plates or joints, which form a cup-like body, containing the viscera, from the upper rim of which proceed fine articulated arms, divided into *tentacula*, or fingers, more or less numerous, surrounding the aperture of the mouth, which is situated in the centre of a plaited integument extending over the abdominal cavity, and capable of being contracted into a conical or proboscal shape. This column is supposed to have been covered with a leather-like integument. The animal resembles a star-fish, with a long, flexible column, attached at its base to a rock. The small detached bones occur in myriads in the mountain limestone, and other secondary rocks, forming successions of strata, it is said, many feet in thickness, and many miles in extent, showing how largely the bodies of this peculiar tribe of animals must have contributed to increase the mass of materials composing the crust of the earth.

In this class are the *pentacrinites* and *encrinites.* The latter name is given to a species in which the bones of the column are circular or elliptical, and that of *pentacrinites* to those which have angular or pentagonal stems. One of the most elegant of the

Lily Encrinite.

encrinites is called the *lily encrinite.* There are also many other varieties, some of which are called *pear encrinites* or *apiocrinites*, the body of which was pear-shaped, the stem short, smooth, and strong, the arms simple.

The Derbyshire marble, which is so extensively used for sideboards, tables, and ornaments, contains vast quantities of encrinital remains, lying in relief in



Pear Encrinites.

the blocks; casts of the interior of the columns are likewise found in the *chert*, which occurs in that stratum, — the original calcareous matter having been removed; and the sharp impressions of the encrinital stems form solid silicious cylinders, deeply marked with annular risings and depressions, which are called screw or pulley stones.

One of the most remarkable of the *pentacrinites* is called the *briarean pentacrinite*, so called on account of the number of its hands or tentacles. The bones in the tentacles are said to amount to at least one hundred thousand, and those of the side-arms to at least fifty thousand more; and allowing, as we must do, two muscles for each of these, the muscles in the animal must have amounted to not less than three hundred thousand, while the bones in a man are only two hundred and forty-one, and the pairs of muscles but two hundred and thirty-two.

The numerous side-arms, says Dr. Buckland, when expanded, would act as auxiliary nets to retain the prey of the animal, and also serve as holdfasts to assist it in adhering to the bottom, or to extraneous bodies. In agitated water, they would close and fold themselves along the column, in a position which would expose the least possible surface to the element, and, together with the column and arms, would yield to the direction of the current.

Polyparia, or Fossil Polypi. — We have already alluded to these animals while speaking of coral; but there are some particulars which deserve further mention in connection with the fossil zoöphytes. The tentacula of these animals are furnished with small, delicate hairs, called *cilia*. These can be moved with a rapid motion, so as to set and keep the water in currents, and thus bring food to their mouths. Some specimens have immense numbers of these tentacula and cilia. Thus, one kind of the *flustra* has usually twenty-two tentacula and twenty-two hundred cilia. An ordinary specimen, therefore, of this species, will contain eighteen thousand polypi, and have three hundred and ninety-six thousand tentacula, and thirty-nine millions of cilia. One other species Dr. Grant estimates to contain four hundred million cilia.

These animals multiply as if by buds. These are called *gemmules*, which, after sprouting out like a bud, fall off from the parent polype, and thus become distinct and perfect animals. By dividing them, also, each part will become a perfect polype. In a single month, one polype may thus produce a million of its young.

Trilobites. — The *trilobite* is an animal whose remains are found in formations of a very early date. It belongs to the crustacea, and appears to have been very numerous, as not less than twelve genera and sixty species have been established. In its form it is divided into three parts or lobes, and exhibits considerable variety. Some of the species could coil themselves up like a ball; others had only the central portion movable, while others still possessed a tail. They had no antennæ, and their feet or paddles, if they had any, must have been soft and perishable, as no remains of them have yet been discovered. The fore part of the body was covered with a kind of shield, while the abdomen had many segments, which folded over each other like the tail of a lobster. They vary in size from one to six inches long; the largest yet described is said to be twenty-one inches long. One of the most remarkable circumstances respecting them is, that they are found all over the globe, in Northern Europe and North America, in South America and Africa. They never occur in any strata more recent than the carboniferous.

As respects the habits of these animals, it is supposed, from their being closely allied to the recent *bopyrus*, and their feet being almost null, if not entirely so, that they were, to a certain extent, sedentary; the flat under surface of their bodies, and the side leather-like margin of several species, renders it probable that they adhered, with a soft articulated under side, to rocks or fuci. Some of the species seem to have been without eyes, and all without antennæ, or distinct feet; if they had feet, they must have been so small as to have been almost useless as organs of locomotion. That they were carnivorous is probable from the structure of the mouth; and the highly organized eyes of some of the genera prove that they had to search for food, and consequently had some power of locomotion. But their most remarkable feature was the eye, which was immovable and fixed; this apparent deficiency being compensated by an arrangement similar to that by which the fixed eyes of certain kinds of flies are furnished with a multitude of lenses. The eye is composed of a number of elongated cones, each having a crystalline lens, pupil, and cornea, and terminating in the extremity of the optic nerves. Each organ of sight, therefore, is a compound instrument, made up of a series of optical tubes or telescopes.

That any traces should remain of the visual organs of an animal which must have perished at so remote a period seems at first incredible; but there are no limits to the wonders which geology unfolds to us. The *trilobite*, like the *limulus*, was furnished with two compound eyes, each being the frustum of a cone, but incomplete on that side which is opposite to the other eye. In one species, four hundred spherical lenses have been detected in each eye; but, in general, the lenses have fallen out, as often happens after death in the eye of the common lobster. The eye was not adapted to look downward; nor was it necessary, as the creature was evidently destined to live at the bottom of the water; but for horizontal vision the structure was complete. The exterior of each eye ranges round nearly three fourths of a circle, each commanding such a field of vision, that, where one eye ceases, the other begins to see; so that, taking both eyes together, it had, as it were, a panoramic vision. The fact, that trilobites existed during the transition formation, shows that the waters could not have consisted of such a turbid, chaotic fluid as some geologists have supposed; but must have been so transparent, as, at least, to allow the passage of light to the visual organs.

Fossil Plants. — We have not room to dwell upon the particular species of plants which are found imbedded in the rocks of the various formations. Some of the most common are the giant *ferns*, *equiseta*, and *club-masses*, which are found in the coal formations. The cut below shows what may have been the appearance of the flora of the carboniferous period.

Plants of the Carboniferous Period.

Some of the *sigillaria* or *tree-ferns* which have been found are ten feet in length, and specimens are said to have been discovered which indicate a length of sixty feet, the circumference having been not less than three feet. They were evidently hollow, like the reed, and with but little substance, as they are found compressed into a flat form. Nearly fifty species are enumerated. The flutings and scars are still visible upon the numerous fossil specimens.

Another fossil plant of the coal formation is the *stigmaria*, which consists of a dome-shaped centre, three or four feet in diameter, from which proceeded branches twenty or thirty feet long, covered with tubercles, to which were attached cylindrical succulent leaves. It is supposed to have been an aquatic plant, which floated in the water, or trailed in the swamps. Other plants of this formation had whorled leaves, like the flower of the aster.

The most elegant and abundant, however, of the fossil plants of the coral formation are the *lepidodendra*, so called on account of the scaly appearance of the stems, caused by the separation of the leaf-stalks. The scars are simple, lanceolate, rhomboidal, and arranged spirally round the stem ; the latter is slight and tapering, and sometimes arborescent. The cones, which are so frequent in ironstone nodules, are the fruit of of those plants.

The recent species of the *lepidodendron* are small creepers clothed with delicate foliage, while the fossil plants probably attained a height of not less than eighty feet; the base of their trunks being more than three feet in diameter, and their leaves in some cases nearly two feet in length. They were equal in size to the large pines, and formed extensive forests, beneath the shade of which the smaller ferns, whose remains are so abundant, flourished. Other plants were of the same gigantic size ; the *equisetum*, which is not now found above half an inch in diameter, then flourished, with stems fourteen inches in diameter. The whole number of coal plants, determined, amounts to more than three hundred.

Fossil trees are also found in some of the formations. A remarkable example of a petrified forest in the Isle of Portland is thus described by Mantell. "Upon the upper layer of marine limestone, which abounds in ammonites, tregoniæ, and other characteristic shells of the oölite, is a fresh-water limestone, covered by a layer of *bituminous earth*, or vegetable mould, which is of a dark brown color, contains a large proportion of earthy lignite, and, like the modern soil on the surface of the island, many water-worn stones. This layer is termed the *dirt-bed* by the workmen; and in and upon it are trunks and branches of coniferous trees and plants, allied to the recent *cycas* and *zamia*. Many of the trees, as well as the plants, are still erect, as if petrified while growing undisturbed in their native forests, having their roots in the soil, and their trunks extending into the upper limestone.

"As the Portland stone lies beneath these strata, which are not much used for economical purposes, the fossil trees are removed and thrown by as rubbish. On my visit to the island, in the summer of 1832, the surface of a large area of the dirt-bed was cleared, preparatory to its removal, and a most striking phenomenon was presented to my view. The floor of the quarry was literally strewed with fossil wood, and I saw before me a petrified tropical forest; the trees and plants, like the inhabitants of the city in Arabian story, being converted into stone, yet still maintaining the places which they occupied when alive! Some of the trunks were surrounded by a conical mould of calcareous matter, which had evidently once been earth, and had accumulated around the bases and roots of the trees. The stems were generally three or four feet high, being jagged or splintered, as if they had been torn or wrenched by a hurricane, — an appearance which many trees in this neighbourhood, after the late storm, strikingly resembled. Some of the trunks were two feet in diameter, and the united fragments of one tree measured upwards of thirty feet in length; in other specimens, branches were attached to the stem.

"In the dirt-bed, there were many trunks lying prostrate, and fragments of branches. Fossil plants occurred in the intervals between the trees; and the dirt-bed was so little consolidated, that I dug up with a spade, as from a parterre, several specimens that were standing on the very spot in which they grew, having, like the columns of Puzzuoli, preserved their erect position amidst all the revolutions which have subsequently taken place, and beneath the accumulated spoils of numberless ages. The trees and plants are completely petrified by silex, or flint; and sparks are emitted, upon striking a piece of steel with a fragment of what was once a delicate plant."

Many other instances of buried forests are known. Mr. Parker mentions one near the cascades of the Columbia River, of twenty miles in extent; the trees standing in water twenty or thirty feet deep, with their tops just above its surface. This curious phenomenon is evidently the result of a sinking of the land, doubtless from volcanic action.

MISCELLANEOUS NOTES ON ORGANIC REMAINS.

COMPARISON OF FOSSIL AND LIVING SPECIES. — It is estimated that at least five thousand species of animals and plants have been identified, *below the tertiary strata*, and nearly all these are now extinct. Koferstein gives the following estimate of the whole number of fossil species.

Mammalia	270
Birds	20
Reptiles	104
Fishes	386
Insects	247
Spiders, Crustacea, Xyphosura, Entomostràcea, Isopoda, Myriopoda	211
Mollusca	6056
Annelides	214
Radiata	411
Polypina	907
Vegetables	803
Total	9629

The number of species of fossil shells is estimated at three thousand and thirty-six, of which five hundred and sixty-eight are identical with existing species.

The organic remains in the northern parts of the globe correspond more nearly to species now found in tropical climates, than to those at present existing in the same latitudes; a fact sufficiently indicating that the climate of the earth has at some period undergone an entire revolution, and that the polar regions have in fact once been subject to a degree of heat and moisture even greater than that of the torrid zone at the present day!

Progress of Improvement. — The deeper we descend into the earth, that is, the older the rock, the more unlike are the organic remains to living species. As we ascend, the nearer is the approximation to those which exist. From these facts we infer, that in the earlier periods of creation the forms of life were unlike the present, and that there has been a succession of creations, in each step of which there has been an advance toward the existing races. In other words, it is evident that in every successive change in the earth's surface there has been an improvement of its condition; that animals and plants of higher and finer organization have been multiplied with every revolution, until at last the earth was prepared for the existence of man, the head of creation. The progress of improvement is still going on; new and finer fruits are produced by art; the breeds of animals are improved by the same means; and doubtless the superior races of men are finally to displace the inferior ones, until at last the physical, intellectual, and moral stature of man, throughout the globe, shall be elevated to its highest standard. But we must remember the vastness of the scale upon which these changes operate, and the almost incalculable duration of years through which they must extend. Though the world has existed for countless millions of ages, still, man has just entered on the threshold of his existence; and if we would look to the period of his highest improvement, as inferred from the general course of Providence upon the earth, we must stretch our view forward into the unseen and mysterious distance of the fathomless future.

ORDER OF CREATION OF ANIMALS AND PLANTS. — It may be stated, in general, that plants and animals began first to exist on the globe during the period when the lowest rocks, in which their remains are found, were deposited or formed. The following is the order, as given by Professor Hitchcock, in which some of the most important plants and animals appeared on the earth; or, in other words, the epoch of their creation.

SILURIAN AND CAMBRIAN, OR GRAUWACKE PERIOD.

Zoöphytes.
Marine Shells.
Crustacea: Trilobites.
Fishes. Placoidians and Ganoidians (Sauroids and Sharks); also those with heterocercal tails.
Flowerless Plants, } Marine.
Flowering Plants, } Terrestrial.

CARBONIFEROUS PERIOD.

Fishes: Cephalaspis, &c.
Arachnidans: Scorpions.
Coleopterous Insects.
Fresh-water Shells.
Dicotyledonous Plants: Coniferæ (Pines, &c.), Cycadeæ.
Monocotyledonous Plants: Palmæ, Scitaminæ.

RED-SANDSTONE PERIOD.

Tracks of Birds, Tortoises, and Cheirotheria, or gigantic Batrachians.
Reptiles: Monitor, Phytosaurus, Ichthyosaurus, Plesiosaurus, Mastodonsaurus, (*Labyrinthodon*,) Thecodontosaurus, Palæosaurus.
Crustacea: Palinurus.
Fishes: Palæoniscus, &c.
Dicotyledonous Plants: Voltzia, &c.

Oölitic Period.

Mammalia (Marsupials): Thylacotherium and Phascolotherium (Didelphys of Buckland).

Reptiles: Saurocephalus, Saurodon, Teleosaurus, Streptospondylus, Megalosaurus, Lacerta Neptunia, Ælodon, Rhacheosaurus, Pleurosaurus, Geosaurus, Macrospondylus, Pterodactylus, Crocodile, Gavial, Tortoise.

Fishes: Pycnodontes and Lepidoides (Dapedium, &c.), with homocercal tails.

Arachnidans: Spiders.

Insects: Libellulæ, Coleoptera.

Crustacea: Pagurus, Eryon, Scyllarus, Palæmon, Astacus.

Plants: Cycadeæ (Pterophyllum, Zamia), Coniferæ (Thuytes, Taxites), Lilia (Bucklandia).

Wealden Period.

Birds: Grallæ (Tilgate Forest).

Reptiles: Iguanodon, Leptorynchus, Trionyx, Emys, Chelonia.

Fishes: Lepidotus, Pycnodus, &c., Fresh-water and Estuary shells.

Cretaceous Period.

Insects.

Reptiles: Mososaurus, &c.

Fishes: Ctenoidians and Cycloidians.

Crustacea: Arcania, Etyæa, Coryster.

Plants: Confervæ, Naiades.

Tertiary Period.

Mammalia: 1. *Eocene Period:* Fifty species:— Palæotherium, Anoplotherium, Lophiodon, Anthracotherium, Cheroptamus (allied to the hog), Adapis (resembling the hedgehog). *Carnivora:* Bat, Canis (Wolf and Fox), Coatis, Raccoon, Genette, Dormouse, Squirrel. *Reptiles:* Serpents.

Birds: Buzzard, Owl, Quail, Woodcock, Sea-lark, Curlew, Pelican, Albatross, Vulture.

Reptiles: Fresh-water Tortoises.

Fishes: Seven extinct species of extinct genera.

2. *Miocene Period:* Ape, Dinotherium, Tapir, Chalicotherium, Rhinoceros, Tetracaulodon, Hippotherium, Sus, Felis, Machairodus, Gulo, Agnotherium, Mastodon, Hippopotamus, Horse.

3. *Pliocene Period:* Elephant, Ox, Deer, Dolphin, Seal, Walrus, Lamantin, Megalonyx, Megatherium, Glyptodon, Hyena, Ursus, Weasel, Hare, Rabbit, Water Rat, Mouse, Dasyurus, Halmaturus, Kangaroo, and Kangaroo Rat.

Birds: Pigeon, Raven, Lark, Duck, &c.

Fishes: (In the formation generally) more than one hundred species now extinct, which belong to more than forty extinct, and as many living genera.

Insects: One hundred and sixty-two genera of Diptera, Hemiptera, Coleoptera, Aptera, Hymenoptera, Neuroptera, and Orthoptera.

Shells: In the newer pliocene period, ninety to ninety-five *per cent.* of living species; thirty-five to fifty *per cent.* in the older pliocene; seventeen *per cent.* in the miocene; and 3.5 in the eocene; amounting in all, extinct and recent, to four thousand species.

Plants: Poplars, Willows, Elms, Chestnuts, Sycamores, and nearly two hundred other species; seven eighths of which are monocotyledonous, or dicotyledonous.

Alluvial Period.

Man, and most of the other species of existing animals and plants.

From this view it appears, that in every age of the earth, amid all the diversities of organic life, the same general plan has been followed in the animal and vegetable kingdoms; for at every epoch we find the four great classes of animals, namely, the *mammiferous*, *molluscous*, *articulated*, and *radiated;* and the same divisions of plants, the *vasculares* and *cellulares.*

Remains of Man.—The remains of man have never been found in any deposit older than the alluvium, except in a few cases, where they appear to have been mingled with drift at a period subsequent to its deposition. Some human bones are, indeed, found imbedded in solid limestone rock, on the shores of Guadaloupe; but this formation was alluvial, and, as the same rock contains shells of existing species, as well as arrows, hatchets of stone, pottery, &c., it is clear that they are of no great antiquity. It appears, therefore, that man was created at a comparatively recent period, ages after many successive races had lived and perished; and furthermore, that he came into existence about the same time as the principal species of animals and plants now flourishing on the earth.

Review: Succession of Changes in the Organic Kingdom. — If we take a retrospect of the facts we have presented, beginning with the most recent formations, we shall find, says Mantell, that traces of the existing orders of animated nature are everywhere apparent; and works of art, with the bones of man and the remains of vegetables and of animals, are found in the modern deposits. In the succeeding era, many species and genera both of plants and animals were absent. Large terrestrial pachydermata greatly predominated, and the vegetation was principally of a character referable to temperate and intertropical climes; while the seas abounded in fishes, crustacea, and mollusca, as at the present time.

The next epoch presented one wide waste of waters, teeming with the general types of marine beings, but of different species and genera from those of the previous eras, and bearing a large proportion of cephalopodous mollusca; a few algæ and fuci made up the marine flora; and drifted trunks of coniferæ and dicotyledonous trees, with a few reptiles, were the only indications of the dry land and its inhabitants. The delta of a mighty river now made its appearance, containing the spoils of an extensive island or continent; and the remains of colossal reptiles, and of unknown forms of tropical plants, marked the era of the country of the iguanodon.

We were then conducted to other seas, whose waters abounded in fishes and mollusca, and were inhabited by marine reptiles wholly unlike any that now exist; while the dry land was tenanted by enormous terrestrial and flying reptiles, marsupial animals and insects, and possessed a tropical flora of a peculiar character. In the next era we found another sea, swarming with fishes, mollusca, and corals, and with reptiles similar to those of the preceding period.

The succeeding change disclosed extensive regions covered by a luxuriant vegetation, — groves and forests of palms, arborescent ferns and coniferæ, and gigantic trees related to the existing club-mosses and equisetaceæ; the numerical preponderance of the flowerless plants constituting a character wholly unknown in modern floras. The ocean abounded in mollusca, radiaria, and crustacea, of genera and species unlike any that had previously appeared.

We advanced to other oceans swarming with polyparia, mollusca, radiaria, and fishes, which bore some analogy to those of the preceding seas, but belonged to different species; interspersions of cryptogamous plants with a flora related to the one immediately antecedent marked the existence of dry land. But traces of animal and vegetable existence became less and less manifest, and were at length reduced to a few shells, corals, and sea-weeds; these finally disappeared, and dubious indications of infusoria were the last vestiges of organic life.

Such is a brief reveiw of the changes upon the surface of the globe, which geology unfolds. According to the records found in the strata of the earth, — setting aside the infusoria, — a few fuci, mollusca, and polyparia are the first evidence of organic existence; these are followed by a larger development of the same orders, and the addition of crinoidea, crustacea, and fishes. In the succeeding period, reptiles and insects appear, with sauroid fishes, and an immense development of vegetable life, particularly of the cryptogamic class. Large reptiles next prevail, to an extraordinary degree; and one genus of birds, and two genera of mammalia, attest the existence of the higher order of animals. The vegetable kingdom is greatly modified; and plants related to the zamiæ and to the ciliaceæ preponderate, with coniferæ and dicotyledonous trees. The next remarkable change is in the sudden increase of mammiferous animals, and the reduction of the reptile tribes; the large pachydermata, as the mammoth, elephant, &c., first appear. From this period, till the creation of man, there are no striking general modifications, in the various orders of animal and vegetable existence.

The physical changes that have taken place in the earth's surface are in perfect harmony with the modifications observable in animated nature; for the laws of mechanical and chemical action are indissolubly connected with those which govern vital phenomena; and we have incontrovertible evidence, that, throughout the vast periods over which geological speculations extend, the same causes have operated, the same effects followed. Thus, heat and cold, drought and moisture, and other atmospheric influences, have dissolved the loftiest peaks; rivulets and torrents have eroded the sides of the mountain-chains; streams and rivers have worn away the plains, and carried the spoils of the land into the bed of the ocean; the waves of the sea have wasted its shores, and destroyed the cliffs and rocks which opposed their progress; silt has been changed into clay; calcareous mud into limestone; sand into sandstone; pebbles into conglomerates and breccia; and animal and vegetable remains have been imbedded, and added to the mineral accumulations of the past ages of our planet.

Beneath the surface, the action of electro-chemical forces has been alike unintermitting; vegetable matter has been converted into bitumen, coal, amber, and the diamond; earth into crystals; limestone into marble; clay into slate; and sedimentary into crystalline masses. The volcano has poured forth its rivers of molten rock; the earthquake rent the solid crust of the globe; beds of seas have been elevated into mountains; subsidences of the land and irruptions of the ocean have taken place; and the destructive and conservative influences both of fire and water have been constantly exerted; the phases of action have alone differed in duration and intensity.

Rocks composed of Organic Remains. — In a previous part of this volume, we have dwelt upon the highly interesting subject of the elaboration of solid matter from gaseous and fluid elements by vital action, and the formation of islands and continents by countless myriads of living instruments. Let us now consider how far the present solid materials of the earth's surface have been derived from organized beings. The processes by which animal and vegetable structures are converted into stone, and the various states in which their fossil remains occur, have already been explained.

The strata of vegetable origin consist of peat; of forests ingulfed by subsidences of the land, or imbedded in the mud of rivers and deltas, or in the basin of the sea; of the lignite and brown call of the tertiary deposits; of the coal and shales of the carboniferous strata; and of the silicified and calcareous trunks of trees, in tertiary and secondary formations. But the deposits which are derived, either wholly or in part, from animal exuviæ are so numerous, and of such prodigious extent, that the interrogation of the poet may be repeated by the philosopher:

"Where is the dust that has not been alive?"*

Probably there is not an atom of the crust of the globe which has not passed through the complex and wonderful laboratory of life. Thus we find that all the orders of animals, from the infusoria up to man, have more or less contributed, by their organic remains, to swell the amount of the solid materials of the earth. It is supposed that limestone constitutes one seventh part of the crust of the globe, and this, with

* Young.

the immense beds of chalk, flint, marl, gypsum, sandstone, lias, jasper, are all of animal origin. The following tabular arrangement presents in a condensed form some of the most striking facts on this subject.

ROCKS COMPOSED WHOLLY OR IN PART OF ANIMAL REMAINS.

Strata.	Prevailing Remains.	Formations.
Trilobite schist	Trilobites	Silurian System.
Dudley limestone	Corals, crinoidea, trilobites, and shells	
Shelly limestone	Productæ, spiriferæ, &c.	
Mountain limestone	Corals and shells	Carboniferous System.
Encrinital marble	Lily-shaped animals and shells	
Muscle-band	Fresh-water muscles	
Iron-stone nodules	Trilobites, insects, and shells	
Lias shales and clay	Pentacrinites, reptiles, and fishes	Lias.
Limestone	Terebratulæ and other shells	
Lias conglomerates	Fishes, shells, corals	
Gryphite limestone	Shells, principally gryphites	
Shelly limestone	Terebratulæ and other shells	Inferior Oölite.
Stonesfield slate	Shells, reptiles, fishes, insects	Oölite.
Pappenheim schist	Crustacea, reptiles, fishes, insects	
Bath-stone	Shells, corals, crinoidea, reptiles, fishes	
Ammonite limestone	Cephalopoda, principally ammonites	
Coral-rag	Corals, shells, echini, ammonites	
Bradford limestone	Crinoidea, shells, corals, cephalopoda	
Portland oölite	Ammonites, trigoniæ, and other shells	

Strata.	Prevailing Remains.	Formations.
Purbeck and Sussex marble	Fresh-water shells, crustacea, reptiles, fishes	Wealden.
Wealden limestone	Cyclades, and other fresh-water shells, crustacea, reptiles, fishes	
Tilgate grit (some beds)	Reptiles, fishes, fresh-water shells	
Faringdon gravel	Sponges, corals, echini, and shells	Shanklin Sand.
Jasper and chert	Shells	
Green sand	Fibrous zoöphites	
Chalk	Corals, radiaria, echini, shells, fishes	Chalk.
Maestricht limestone	Corals, shells, ammonites, belemnites, and other cephalopoda, — reptiles	
Hippurite limestone	Shells, principally hippurites	
Hard chalk (some beds)	Echini and belemnites	
Flints	Sponges and other fibrous zoöphites Infusoria and spines of zoöphites Echini, shells, corals, crinoidea	
Limestone	Fresh-water shells	Tertiary.
Nummulite rock	Nummulites	
Septaria	Nautili, turritellæ, and other shells	
Calcaire grossier	Shells and corals	
Gypseous limestone	Mammalia (palæotheria, &c.) birds, reptiles, and fishes	
Silicious limestone	Shells	
Lacustrine marl	Cyprides, phryganæa, fresh-water shells	
Monte Bolca limestone	Fishes	
Bone-breccia	Mammalia and land shells	

Strata.	Prevailing Remains.	Formations.
Sub-Himalaya sandstone	Elephant, mastodon, &c., reptiles	
Tripoli	Infusoria	
Semiopal	Infusoria	
Guadaloupe limestone	Man, land shells, and corals	Human Epoch.
Bermuda limestone	Corals, shells, serpulæ	Human Epoch.
Bermuda chalk	Comminuted corals, shells, &c.	Human Epoch.
Bog-iron ochre	Infusoria	Human Epoch.

This list might be almost indefinitely extended, for we have omitted numerous strata, in which animal remains largely predominate; and in the tertiary and modern epochs, every order of animated nature is found to have contributed more or less largely to the sedimentary deposits, — the bones of man, &c., first appearing in the most recent accumulations; and by the geological causes now in action, not only the remains of the existing orders of living beings, but also works of human art, are added day by day to the solid crust of the globe.

GEOLOGICAL MUTATIONS.

We have had frequent occasion to advert to the fact, that the surface of the globe has been the theatre of successive changes and revolutions; and that, through these mutations, it has finally reached its present condition. We may, indeed, regard our globe as one of the works of the Creator, upon which he has exercised his amazing skill and power; and, through the revelations of modern geology, we are permitted to look in upon his laboratory, and see the processes by which he has produced such wonderful results. Let us now take a hasty view of the geological changes of the earth's surface, which will, in fact, be a brief survey of the natural history of the earth.

In the early pages of this volume, we have stated that the researches of modern astronomers have furnished substantial grounds for the belief that our globe was once a nebulous mass diffused in space, which, by a known law of matter, was at last condensed and became a solid planetary body, revolving around the sun as the centre of its orbit. It is supposed, that, at the period of its condensation, it was a molten mass; but the surface became gradually cooled, probably leaving the interior still in a melted state, and perhaps, also, leaving a vast hollow space in the centre.

In the first age of the world after its condensation, — and which, of course, goes back for myriads of ages, — it is supposed to have been in a state resembling that of the moon at the present day, presenting a surface torn and distorted by volcanic action, and doubtless destitute alike of vegetable and animal life. The bristling pinnacles of lofty mountains rose to the clouds, while deep and ghastly chasms yawned between the separate elevations. But the same causes of change which are now in operation — the wind and the rain, heat and cold, the various chemical forces, the earthquake and the volcano — began their work. The tops of the mountains were slowly, but surely, worn away, and the particles thus separated were carried by the streams to the valleys. A soil was thus formed, suited to vegetable life; the creative power of the Almighty was now put forth, and plants, suited to the state of things, began to shoot up from the ground. When a supply of food was thus provided, another creative act took place, and animals, adapted to the habitation provided for them, were seen moving upon the land and amid the waters.

At a period even anterior to this, it would appear that sea-weed and shell-fish were teeming in the marine waters, and that remains of them, in the course of ages, were deposited in the depths of the ocean, and became mingled with the masses of the land deposited there by the rains and streams that swept down from the mountains. The bottom of the sea was, in process of time, lifted, by the force of internal fires, and thus became dry land, rich with the spoils of centuries, and fitted to the production of luxuriant vegetation. Again the creative energy was put forth, and new and higher forms of organized existence appeared, and all still suited to the improved condition of the abodes they were designed to occupy.

By a succession of changes, operating through an inconceivable length of years, a succession of races such as we have described was produced, and the various rocks which now form the crust of the globe were elaborated from the great workshop of the Almighty, until, at last, the earth, designed as the abode of man, like a house ready furnished, was prepared. The tenant was then called into existence, and the work of creation was complete.

We have already adverted to the supposed discrepancy between this view, presented by geology, and that of the Scriptures as generally understood. We leave this topic for the present, remarking, that the difference is only apparent, and entirely disappears upon a full and fair examination of the question. We now propose to give, in detail, the process of the changes upon the earth's surface, effected by the great agencies of nature.

AQUEOUS AGENCIES.

Glaciers, Icebergs, and Land-slips. — *Glaciers* are masses of ice, accumulated in valleys or on the sides of mountains, and are often of vast extent and thickness. They are found at various elevations above the level of the sea, from three thousand to twenty-eight thousand feet. Those of the Alps are sometimes three hundred square miles in extent, and from eighty to one hundred and eighty feet thick. These immense masses are sometimes formed over precipices, and, breaking off, descend into the valleys, producing immense havoc in their path.

Avalanches, which are descending masses of snow, have been known, in the Alps, to destroy several villages and thousands of inhabitants in a moment.

Landslips are similar, in their movement, to avalanches. They occur most frequently in the spring, when the earth and rocks, moistened by dissolving snows, are set free by the frost, and, descending to the valleys, bury every thing beneath the mass of ruins. A celebrated occurrence of this nature took place in the White Mountains of New Hampshire in 1826, in which a deep gorge was nearly filled up, the course of a river turned, and a family destroyed.

Frost and Rains. — Water acts upon rocks and soil, both mechanically and chemically; it first dissolves some of the substances they contain, thus rendering them loose and porous, and then, by its currents, wears and carries away the particles. Freezing serves in a powerful degree to separate the fragments and grains, and thus render it easy for the water and the power of gravitation to bear them down to a lower level. This may seem a slow process, if we estimate by human measures; but in geology we must use the scale of the Eternal, to whom "a thousand years are as one day," and not the infinitesimal gauge of ephemeral man. It is, in a great degree, by the action of rain, frost, and gravity, that the great valleys of the earth are filled up, and the soil is furnished which gives support to vegetable and animal life.

RIVERS. — These produce geological changes by carrying away some portion of their sides and bed, and depositing them at their mouth, or at particular places along their course. The deposits, at their points of debouchure, are called *deltas*. The force of this agent of change may be estimated by the fact, that the delta at the mouth of the Mississippi has advanced several leagues since New Orleans was built. The delta of the Ganges is two hundred and twenty miles in extent. In two thousand years, the river Po, in Italy, has gained eighteen miles. The delta of the Niger forms an area of twenty-five thousand square miles. Nearly the whole extent of Lower Egypt consists of the delta of the Nile. The quantity of sediment annually brought down by the Ganges amounts to six billion three hundred and sixty-eight million seventy-seven thousand four hundred and forty tons. The quantity of matter carried by the River Merrimac past the town of Lowell, in Massachusetts, in 1838, was estimated at one billion six hundred and seventy-eight million three hundred and sixty-three thousand eight hundred and ten pounds. The deposits thus formed are, in process of time, converted by consolidation into rocks, such as the shales, sandstones, and conglomerates of the secondary strata.

Terraced valleys, such as may be seen along the borders of Connecticut River, are formed by the deposits of rivers upon their banks. When a barrier across a stream has been broken and worn away, so as to drain off the water and sink the channel to a lower level, the sandy banks are seen, high and dry, above the surface of the stream.

BURSTING OF LAKES. — A few examples of this phenomenon have occurred, in which a large bed of water has broken from its barriers, and inundated the country along the path of the retiring flood. A case of this kind occurred in Vermont, a few years since, in which two considerable lakes were drained in a few minutes, the waters urging their way down the bed of Barton River, for twenty miles, to Lake Memphremagog. They cut a channel twenty to forty rods wide, and fifty to sixty feet deep, inundated the low lands, swept off the cattle, horses, and inhabitants, and scattered along the margin of the flood immense quantities of timber which it had torn from the forests along its path. Other instances of the kind are on record.

AGENCY OF THE OCEAN. — This mighty instrument of geological change operates by the action of its waves, its tides, and its currents, to wear away the land, and to accumulate *detritus*, or particles of rocks and earth, so as to form new land. The force of the sea in a storm is tremendous; and not only loose soils and sands, but the solid rock, are torn away by the shock. The vast heaps of rounded pebbles at Lynn beach, Nahant, and Nantucket, sufficiently attest the giant energy of the waves. The rugged rocks along our New England shores, cut into a thousand fantastic forms, and which have received the various names of "pulpits," "castles," "bridges," &c., afford another evidence of the force of the sea in producing geological changes.

The currents of the ocean, produced chiefly by settled winds, are numerous, and some are of great velocity and extent. One of these — the Gulf Stream, as it is called — flows out of the Indian Ocean, turns Cape Horn, and runs along the coast of Africa; it then traverses the Atlantic, and strikes the eastern coast of South America; turning northward, it passes along the shore of the United States, reaches the Banks of Newfoundland, and at last goes back to the coast of Africa, to supply the deficiency of water there. Its whole length is several thousand miles, and its breadth three hundred and fifty miles. Its velocity varies from one to four miles an hour. There are other currents in various parts of the ocean. The power of these, in carrying along sand, and depositing it in new situations, is immense.

Calcareous Tufa or Travestin, Marl, Silicious Sinter, Bog Ore, Petroleum, and Asphaltum, have already been noticed, and the process of their formation has been described.

Springs. — Water is unequally distributed through the different strata; some, as the argillaceous or clayey, being almost impervious, and others, as the arenaceous or sandy, allowing it to percolate freely through them. Hence, when the former lie beneath the latter, they form basins or reservoirs. In digging wells, the general object is, to pass through the sandy strata, till the clay stratum is reached, when a sufficient quantity of water is insured.

The rocks beneath the surface of the earth often operate as conductors of water, in the manner of a syphon, and the Artesian wells are constructed on this principle. These are simple borings, of considerable depth, into the earth, from the mouths of which water flows, as from a spring. In England, these wells have been sunk to the depth of six hundred and twenty feet, and in France, near Paris, eighteen hundred feet. In New York, Baltimore, Albany, and in different parts of New Jersey, borings have been made with success.

Salt Springs. — All the waters of the earth are found to contain more or less saline matter, and many become impregnated with other substances. These are taken up by solution from the rocks and earths through which the waters pass, and thus mineral springs are formed. These are common throughout the world, and are useful for many purposes. The salt springs in the vicinity of Syracuse, New York, yield annually three million bushels of salt. In Europe, salt springs rise directly from the beds of rock-salt; but in this country no such beds have yet been found. They are supposed, however, to exist in the bowels of the earth, and to supply the springs, which are charged with large quantities of saline matter.

Drift, &c. — The agency of *glaciers* and *icebergs* in carrying away and dispersing immense masses of earth and rock has been already considered; and we refer the reader to that portion of our work for a view of this topic.

VEGETABLE AGENCY.

In our account of *peat* and *coal*, we have noticed some of the most remarkable and important operations performed by the vegetable creation in modifying the surface of the earth, and contributing to the formation of existing strata. To this we may add the accumulation of drift wood. Large rivers, which pass through vast forests, carry down immense quantities of timber. When these rivers overflow their banks, this timber is in part deposited on the low grounds. But much of it also collects on the eddies along the shores, or is carried into the ocean. After a time it becomes water-logged, — that is, saturated with water, — and sinks to the bottom. Thus a deposit of entangled trees is often formed over large areas. This is subsequently covered by mud, and then another layer of wood supervenes; so that, in the course of ages, several alternations of wood and soil are accumulated. The wood becomes slowly changed into what Dr. Macculloch terms *forest peat;* that is, peat which retains its woody fibres.

The Mississippi furnishes the most remarkable example known of these accumulations. In consequence of some obstruction in the arm of the river called the Atchafalaya, supposed to have been formerly the bed of the Red River, a raft had accumulated in thirty-five years, which, in 1816, was ten miles long, two hundred and twenty yards wide, and eight feet thick! Although floating, it is covered with living plants, and, of course, with soil. Similar rafts occur on the Red River, and one on the Washita concealed the surface for seventeen leagues. At the mouth of the Mississippi, also, numerous alternations of drift wood and mud exist, extending over hundreds of square leagues.

Similar deposits of wood and mud are found in the

River Mackenzie, which empties into the North Sea, and in the lakes through which it passes. At the mouth of the river — which is almost beyond the region of vegetation — are extensive deposits, brought from the more southern districts through which the river passes.

A part of the drift wood which is brought down the Mississippi, and other rivers along the coast of America, is carried northward by the Gulf Stream, and thrown upon the coast of Greenland. The same thing happens in the bays of Spitzbergen, and on the coasts of Siberia.

AGENCY OF MAN AND OTHER ANIMALS.

WE have already noticed the geological agency of various kinds of animals; as the infusoria, in the formation of immense beds of marl; of polyparia, in the creation of vast coral islands; of marine and fresh-water shell-fish, in producing the beds of limestone, which are supposed to constitute one seventh part of the crust of the globe; of the shells, reptiles, and fishes, which have formed various kinds of marble; of the corals, sponges, and radiata, that have formed the beds of chalk and flint; and of many others, which, in the striking language of Mantell, have caused the whole surface of our earth to pass through the "wonderful laboratory of life."

To conclude this topic, we have a few words to say of the geological influence of man. By the destruction of animals; by the distribution of plants and animals; by altering the climate of large tracts of country by means of cultivation; by resisting the encroachments of rivers and of the ocean; by reducing hills and mountains; by furnishing the spoils of his own power, and of the products of his art, to make up portions of soil; man has exerted some influence in changing the earth's surface; — but in comparison with the achievements even of animals invisible to the naked eye, — of beings which live, flourish, and die, without the notice of the lord of creation, — the labors of the human race, in a geological view, sink into utter insignificance.

General Inferences. — From a view of these facts, Professor Hitchcock draws the following conclusions. Beds of clay need only to be consolidated to become clay slate, grauwacke slate, or shale. The same is true of fine mud. Sand, consolidated by carbonate of lime, will produce calcareous sandstone; by iron, ferruginous sandstone. Drift, in like manner, will form conglomerates of every age, according to the variations in the agents of consolidation. Marls need only to be consolidated to form argillaceous limestones; and if sand be mixed with marl, the limestone will be silicious. Coral reefs, and deposits of travestin, subjected to strong heat under pressure, will produce those secondary limestones which are more or less crystalline.

The formation of such extensive beds of rock-salt and gypsum, as occur in the secondary and tertiary rocks, it is difficult to explain by any cause now in operation. This is particularly the fact in respect to the latter, since we know that few springs deposit it, and these in small quantities.

CHEMICAL AGENCIES.

We have already alluded to the importance of a knowledge of chemistry to a full understanding of the subject of geology; and we may here add, that such a knowledge only can fully apprize us of the important agency of chemical causes in producing geological changes upon the earth's surface. Even excluding earthquakes and volcanoes, — which we shall soon consider, and in the production of which, whatever theory we may adopt, chemistry is largely concerned, — we must still bear in mind, that the action of acids, alkalies, and salts ever has been, and still is, the means by which many of the earth's rocks are formed. We have already noticed some instances of this, in the production of stalactites, travestin, &c.; and we may add, that limestone, gypsum, rock-salt, and a multitude of other minerals, are known to be formed by a similar process of solution and chemical combination.

IGNEOUS AGENCIES.

VOLCANOES.

The subject of volcanoes and volcanic action is one which possesses great interest, on account of the important facts developed in relation to the history of our globe. Volcanic action, says Dr. Mantell, is defined by Humboldt to be the influence exercised by the internal heat of a planet on its external surface during its different states of refrigeration, by which convulsions of the land, or earthquakes, and the elevation and subsidence of large portions of the solid crust, are produced. The number of existing volcanoes is estimated at about two hundred; of which, one hundred and sixteen are situated in America or its islands, and the number of eruptions has been reckoned at about twenty in a year, or two thousand in a century.

Of the modern volcanoes, there are two kinds, — *extinct* and *active*. The opening of a volcano, called a crater, is usually in the form of an inverted cone, and around it rises a mountain in a conical form, with the top cut off, resembling a sugar loaf, which is produced by the elevation of that part of the earth, and the lava thrown out. Sometimes volcanoes emit nothing but watery and gaseous substances, and then they are called *solfatara*.

Volcanic openings, or vents, in general, are not formed singly, but in lines or zones, which sometimes reach half round the globe. The most remarkable of these vents or openings is that which, commencing in the peninsula of Alaska, on the coast of Russian America, passes over the Aleutian Isles, Kamtschatka, the Kurile, Japanese, Philippine, and Moluccan Isles, and then, turning, includes Sumbawa, Java, and Sumatra, and terminates at Barren Island, in the Bay of Bengal. There is also another very extensive line, which commences at the southern extremity of South America, follows the chain of the Andes, along the Cordilleras of Mexico, thence to California, and so northward to the Columbia River, crossing it between the Pacific Ocean and the Rocky Mountains. Another, also, one thousand miles long and ten degrees of latitude in breadth, reaches from the Azores to the Caspian Sea. There are other volcanoes which are not so arranged in lines or zones, and these are termed *central* volcanoes, — as those of Iceland, the Sandwich Islands, Society Isles, Island of Bourbon, &c.

As so large a proportion — two thirds, it is said — of volcanoes are situated on islands of the sea, it is inferred that water performs an important part in their agency. The commonly admitted belief is, that they are produced by the expansive force of steam and gases, as we shall show hereafter. The intervals of repose are of greater or less length, varying from a few months or years, to even seventeen hundred years. This latter period, it is said, has intervened between two eruptions. As a general fact, an eruption is preceded by earthquakes; the air sinks into a dead stillness, and becomes oppressive for breathing; noises are heard in the mountain, while the fountains near it are dried up. A sudden explosion takes place, and this is followed by vast clouds of vapor and smoke, darkening the air, except when relieved by flashes of lightning; then, again, by showers of ashes and stones; and, lastly, by streams of red-hot lava, which pour over the crater and spread themselves across the country.

Eruption on the Island of Sumbawa. — The most remarkable volcanic eruption of modern times took place in 1815, in this island, which is one of the Moluccas. It commenced on the 5th of April, and did not entirely cease till the following July. The explosions were heard in Sumatra, nine hundred and seventy miles distant in one direction, and at Ternate in the opposite direction, seven hundred and twenty miles. So heavy was the fall of ashes at the distance of forty miles, that houses were crushed and destroyed beneath them. Towards Celebes, they were carried to the distance of two hundred and seventeen miles, and towards Java three hundred, so as to occasion a darkness greater than that of the darkest night. On the 12th of April, the floating cinders to the westward of Sumatra were two feet thick; and ships were forced through them with difficulty. Large tracts of country were covered by the lava; and out of twelve thousand inhabitants of the island, only twenty-six survived.

During the great eruption of the volcano of Cosiguina, in Guatimala, on the shores of the Pacific, in 1835, ashes fell on the island of Jamaica, eight hundred miles eastward, and upon the deck of a vessel twelve hundred miles westward.

In Mexico, volcanic agency has exerted itself over a great extent, and from a very early peried. Among the most remarkable of the eruptions thus produced, that of Jorullo is deserving of notice.

An extensive cultivated plain, called the *Malpays*, covered by fields of sugar, indigo, and cotton, irrigated by streams, and bounded by basaltic mountains, constituted a district remarkable for its fertility. In June, 1759, alarming subterranean sounds were heard, accompanied by frequent earthquakes, which were succeeded by others for several weeks, to the great consternation of the neighbouring inhabitants. In September, tranquillity appeared to be reëstablished, when, on the night of the 28th, the subterranean noise was again heard, and the plain of the Malpays, from three to four miles in extent, rose up in the shape of a bladder, to the height of nearly 1700 feet, flames issued forth, fragments of red-hot stones were thrown to prodigious heights, and, through a thick cloud of ashes, illumined by volcanic fire, the softened surface of the earth was seen to swell up like an agitated sea.

A huge cone, above five hundred feet high, was thrown up, and five smaller conical mounds, and thousands of lesser cones, — called by the natives *hornitos*, or ovens, — issued forth from the upraised plain. These consist of clay, intermingled with decomposed basalt, each cone being a *fumerole*, from which issues thick vapor. The central cone of Jorullo is still burning, and, on one side has thrown up an immense quantity of scorified and basaltic lava, containing fragments of primary rocks. Two rivers of thermal water, of the temperature of one hundred and twenty-six degrees of Fahrenheit, have burst through the argillaceous vault of the *hornitos*, and flow into the neighbouring plain.

It has sometimes happened, that, during a violent eruption, the whole mountain or cone of a volcano has either been blown to pieces, or fallen into the gulf beneath, its place being afterwards occupied by a lake. As an example, it is mentioned, that, in 1772, the Papandayang, a large volcano in the island of Java, after a short and severe eruption, fell in and disappeared, spreading itself over an extent of fifteen miles long and six broad, and burying forty villages, with two thousand nine hundred and fifty-seven inhabitants.

In 1638, also, the Pic, a volcano in the island of Timor, high enough to be seen three hundred miles off, disappeared, and its place is now occupied by a lake. Many lakes in Italy are supposed to have been thus formed. It is also recorded, that a volcano, occupying the same site as Vesuvius, was destroyed in the year 79, the remains of which now constitute a circular ridge, called Somma, several miles in diameter. The present cone of Vesuvius has risen upon the ruins.

The grand European centre of volcanic power is in Southern Italy, and this has for ages been in a state of activity, Etna, Vesuvius, and the Lipari Isles being the vents through which its red-hot materials have been poured out.

VESUVIUS. — This celebrated mountain is about four thousand feet high. Its summit is now broken and irregular; but when Northern Italy was first colonized by the Greeks, "its cone was of a regular form, with a flattish summit, where the remains of an ancient crater, nearly filled up, had left a slight depression, covered in its interior by wild vines, and with a sterile plain at the bottom." From the earliest period to which tradition refers, to the first century of the Christian era, this mountain had exhibited no appearance of activity; but we then arrive at a crisis in the volcanic action of this district, which gave rise to "one of the most interesting events witnessed by man, during the brief period throughout which he has observed the physical changes of the earth's surface."

In the year 63, Vesuvius exhibited the first symptom of internal change in an earthquake, which occasioned considerable damage to many neighbouring cities, and of whose effects traces may yet be witnessed among the interesting memorials of the awful catastrophe which soon afterwards took place. After this event slight shocks of earthquakes were frequent, when, on the 24th of August, in the year 79, a tremendous eruption of the long pent up incandescent materials of the volcano burst forth, and spread destruction over the surrounding country, overwhelming three cities, with many of their inhabitants, and burying all traces of their existence beneath immense accumulations of ashes, sand, and scoriæ. All the fearful circumstances connected with this event, and the attendant physical phenomena, are so well known, that it is unnecessary to dwell upon the subject.

From that period to the present time, the internal fires of Italy have resumed their ancient focus, and Vesuvius, with occasional periods of tranquillity, has been more or less active. The principal eruptions are recorded in Mr. Lyell's interesting volume. We can allude to but one other remarkable event, which happened in 1538. After frequent earthquakes, a gulf opened near the town of Tripergola, which discharged mud, pumice-stones, and ashes, and threw up, in the course of one day and night, a mound of volcanic materials, now called Monte Nuovo, a mile and a half in circumference at the base, and four hundred and forty feet in height; at the same time, the coast to beyond Puzzuoli was permanently elevated many feet above the level of the Mediterranean.

Eruptions of Vesuvius. — In the early periods of activity, violent explosions, with showers of scoriæ, ashes, and sand, characterize the eruptions of Vesuvius;

but since the existence of the present crater, lava currents have generally been ejected. The appearance of an ordinary eruption, seen by night, is thus graphically described by a late traveller.

"It was about half past ten when we reached the foot of the craters, which were both tremendously agitated. The great vent threw up immense columns of fire, mingled with the blackest smoke and sand. Each explosion of fire was preceded by a bellowing of thunder in the mountain. The smaller mouth was much more active; and the explosions followed each other so rapidly, that we could not count three seconds between them. The stones which were emitted were fourteen seconds in falling back to the crater; consequently, there were always five or six explosions, sometimes more than twenty, in the air at once. These stones were thrown up perpendicularly, in the shape of a wide-spreading sheaf, producing the most magnificent effect imaginable. The smallest stones appeared to be of the size of cannon-balls; the greater were like bomb-shells; but others were pieces of rock, five or six cubic feet in size, and some of most enormous dimensions; the latter generally fell on the ridge of the crater, and rolled down its sides, splitting into fragments as they struck against the hard and cutting masses of cold lava. The smoke emitted by the smaller cone was white, and its appearance was inconceivably grand and beautiful; but the other crater, though less active, was much more terrible; and the thick blackness of its gigantic columns of smoke partly concealed the fire which it vomited. Occasionally, both burst forth at the same instant, and with the most tremendous fury; sometimes mingling their ejected stones.

"If any person could accurately fancy the effect of five hundred thousand sky-rockets, darting up at once to a height of three or four thousand feet, and then falling back in the shape of red-hot balls, shells, and large rocks of fire, he might have an idea of a single explosion of this burning mountain; but it is doubtful whether any imagination can conceive the effect of one hundred such explosions in the space of five minutes, or of twelve hundred or more in the course of an hour, as we saw them; yet this was only a part of the sublime spectacle before us.

"On emerging from the darkness, occasioned by the small crater being hidden by the large one, as we passed round to the other side of the mountain, we found the whole scene illuminated by the river of lava, which gushed out of the valley formed by the craters, and the hill on which we now stood. The fiery current was narrow at its source, apparently not more than eighteen inches in breadth, but it quickly widened, and soon divided into two streams, one of which was at least forty feet wide, and the other somewhat less; between them was a sort of island, before which they reunited into one broad river, which was at length lost sight of in the deep windings and ravines of the mountain."

In an eruption witnessed by Sir W. Hamilton, jets of liquid lava, mingled with stones and scoriæ, were thrown up to the height of ten thousand feet. The streams of lava issue with great velocity, and in a state of perfect fusion; but as they cool on the surface, they crack, and the matter becomes vesicular or porous; at a considerable distance from their source, they resemble a heap of scoriæ, or cinders from an iron-foundry, rolling slowly along, and falling, with a rattling noise, one over the other.

Etna. — This volcanic cone, which is entirely composed of lavas, rises majestically to an altitude of nearly two miles, the circumference of its base being nearly one hundred and eighty miles. Compared with this prodigious mass of igneous products, Vesuvius sinks into insignificance; for, while the lava-streams of the latter do not exceed seven miles, those of Etna are from fifteen to thirty miles in length, five in breadth, and from fifty to one hundred feet in thickness. The grand feature of Etna is the *Val del Bove*, a vast plain, partially encircled by subordinate volcanic mountains, some of which are covered with forests, while others are bare and arid, like those of Auvergne. This plain, which is five miles in diameter, has been repeatedly deluged by streams of lava, and presents a surface more uneven and rugged than that of the most tempestuous sea; it is inclosed on three sides by precipitous rocks, from two to three thousand feet high. The face of these precipices is broken by vertical walls of lava, which stand out in relief, are exceedingly picturesque, and of immense altitude. The base of Etna, for an extent of twelve miles upwards, is richly cultivated, and abounds in vineyards and pastures, with towns, monasteries, and villages. The middle region is woody, being covered with forests of oak and chestnut, and a luxuriant vegetation. From about a mile below the summit, all is sterility and desolation, and the highest point is covered with eternal snow. The crater, from which a volume of vapor constantly escapes, is about a quarter of a mile high, and three quarters of a mile in circumference. The varied and picturesque scenery of this extraordinary mountain, the physical changes now in progress, as well as those which have taken place in periods far beyond all human history or tradition, but of which natural records still remain, are sketched by Mr. Lyell with the vigor and fidelity which characterize all the productions of his pen.

THE LIPARI ISLANDS, between Naples and Sicily, lying as it were midway between Vesuvius and Etna, are replete with the highest interest. The crater of one of the islands, Stromboli, has been in constant activity from the earliest historical period. It always contains melted lava, in constant motion, which at uncertain intervals suddenly rises, and large bubbles appear, which, upon reaching to the brim of the crater, explode with a sound resembling thunder, and masses of lava, with dust and smoke, are thrown into the air; the incandescent mass then sinks down to its former level. The cliffs of St. Calogero, which are about two hundred feet high, extend four or five miles along the coast, and consist of horizontal beds of volcanic tuff. From the perennial emanation of sulphurous vapor, the rocks are decomposed; alum, gypsum, and other sulphuric salts are formed, as well as muriate of ammonia, and silky crystals of boracic acid. The dark clays have become yellow white, red, pink, checkered, and marked with stripes of various colors. Veins of chalcedony and opal occur, and pumice-stone and obsidian are abundant. Dikes and veins of trachyte intersect the tuff in every direction, and bear a striking resemblance to the intrusions of trap into the secondary strata.

Hawaii, one of the Sandwich Islands, which is about seventy miles in length, and covers an area of four thousand square miles, is a complete mass of volcanic matter, perforated by innumerable craters. It is, in fact, a hollow cone, rising to an altitude of sixteen thousand feet, having numerous vents, over a vast incandescent mass, which doubtless extends beneath the bed of the ocean; the island forming a pyramidal funnel from the furnace beneath to the atmosphere. The following account of a visit to the crater affords a striking picture of the splendid, but awful, spectacle which this volcano presents.

"After travelling over extensive plains, and climbing rugged steeps, all bearing testimony of volcanic origin, the crater of Kirauea suddenly burst upon our view. We found ourselves on the edge of a precipice, with a vast plain before us, fifteen or sixteen miles in circumference, and sunk from two to four hundred feet below its original level. The surface of this plain was uneven, and strewed over with large stones and volcanic rocks; and in the centre of it was the great crater, at the distance of a mile and a half from the precipice on which we were standing. We proceeded to the north end of the ridge, where, the precipice being less steep, a descent to the plain below seemed practicable; but it required the greatest caution, as the stones and fragments of rock frequently gave way under our feet, and rolled down from above.

"The steep which we had descended was formed of volcanic matter, apparently of light red and gray vesicular lava, lying in horizontal strata varying in thickness from one to forty feet. In a few places, the different masses were rent in perpendicular and oblique directions from top to bottom, either by earthquakes, or by other violent convulsions of the ground, connected with the action of the adjacent volcano.

"After walking some distance over the plain, which in several places sounded hollow under our feet, we came to the edge of the great crater. Before us yawned an immense gulf, in the form of a crescent, about two miles in length, from northeast to southwest, one mile in width, and eight hundred feet deep. The bottom was covered with lava, and the southwest and northern parts were one vast flood of burning matter. Fifty-one conical islands, of varied forms and size, containing as many craters, rose either round the edge or from the surface of the burning lake. Twenty-two constantly emitted columns of gray smoke, or pyramids of brilliant flame, and, at the same time, vomited from their ignited mouths streams of lava, which rolled in blazing torrents down their black, indented sides into the boiling mass below.

"The existence of these conical craters led us to conclude that the boiling caldron of lava did not form the focus of the volcano; that this mass of lava was comparatively shallow; and that the basin which contained it was separated by a stratum of solid matter from the great volcanic abyss, which constantly poured out its melted contents, through these numerous craters, into this upper reservoir. We were farther inclined to this opinion from the vast columns of vapor continually ascending from the chasms in the vicinity of the sulphur banks and pools of water, for they must have been produced by other fire than that which caused the ebullition in the lava, at the bottom of the great crater; and also by noticing a number of small craters in vigorous action, high up the sides of the great gulf, and apparently quite detached from it.

"The streams of lava which they emitted rolled down into the lake, and mingled with the melted mass, which, though thrown up by different apertures, had perhaps been originally fused in one vast furnace. The sides of the gulf before us, although composed of different strata of ancient lava, were perpendicular for about four hundred feet, and rose from a wide, horizontal ledge of solid black lava, of irregular width, but extending completely round. Beneath this ledge, the sides sloped gradually towards the burning lake, which was, as nearly as we could judge, three or four hundred feet lower. It was evident that the large crater had been recently filled with liquid lava up to this black ledge, and had, by some subterranean canal, emptied itself into the sea, or upon the low land on the shore; and, in all probability, this evacuation had caused the inundation of the Kapapala coast, which took place, as we afterwards learned, about three weeks prior to our visit. The gray, and in some places apparently calcined, sides of the great crater before us; the fissures which intersected the surface of the plain on which we were standing; the long banks of sulphur on the opposite sides of the abyss; the vigorous action of the numerous small craters on its borders; the dense columns of vapor and smoke that rose out of it, at the north and south ends of the plain; together with the ridge of steep rocks by which it was surrounded, rising three or four hundred feet in perpendicular height, presented an immense volcanic panorama, the effect of which was greatly augmented by the constant roaring of the vast furnaces below."

In June, 1825, Mr. Stewart, accompanied by Lord Byron, and a party from the Blonde frigate, went to Kirauea, and descended to the bottom of the crater. In his account of the scene, Mr. Stewart says, "The general aspect of the crater may be compared to that which the Otsego Lake would present, if the ice with which it is covered in winter were suddenly broken up by a heavy storm, and as suddenly frozen again, while large slabs and blocks were still toppling and dashing and heaping against each other with the motion of the waves. At midnight, the volcano suddenly began roaring and laboring with redoubled activity, and the confusion of noises was prodigiously great. The sounds were not fixed or confined to one place, but rolled from one end of the crater to the other; sometimes seeming to be immediately under us, when a sensible tremor of the ground on which we stood took place; and then again rushing on to the farthest end with incalculable velocity. Almost at the same instant, a dense column of heavy, black smoke was seen rising from the crater directly in front, the subterranean struggle ceased, and immediately after, flames burst from a large cone, near which we had been in the morning, and which then appeared to have been long inactive.

"Red-hot stones, cinders, and ashes were also propelled to a great height with immense violence; and shortly after, the molten lava came boiling up, and flowed down the sides of the cone, and over the surrounding scoriæ, in the most beautiful curved streams, glittering with a brilliancy quite indescribable. At the same time, a whole lake of fire opened in a more distant part. This could not have been less than two miles in circumference, and its action was more horribly sublime than any thing I ever imagined to exist, even in the ideal visions of unearthly things. Its surface had all the agitation of an ocean; billow after billow tossed its monstrous bosom in the air; and occasionally those from different directions burst with such violence, as, in the concussion, to dash the fiery spray forty or fifty feet high. It was at once the most splendid and fearful of spectacles."

The following account of this volcano, and of the eruption in October, 1840, is contained in a letter to Professor Silliman. "It is an immense pit, one thousand feet deep and six miles in circuit, with perpendicular walls, except at one point where it is reached by a steep descent; and the whole of this vast caldron, full of boiling, bubbling, and spouting lava. The surface at one moment black as ink, and the next exhibiting rivers and pools, and jets of a hideous blood-red fluid, that was sometimes thrown up to a height of fifty or sixty feet, and fell back with a sudden plashing that was indescribably awful. The aspect of the whole was *hellish*, — no other term can express it. By night, it was grand beyond description. The frequent lightings up, the hissings and deep muttering explosions, reminded me of some great city in flames, where were magazines of gunpowder or mines continually exploding. Vesuvius is a fool to it. Just previous to my visit, the lava had burst out at a new place, about six miles northeast of the crater, and flowed down to the sea in a stream forty miles in length by from one to seven in breadth. I saw the light one hundred miles off. It reached the sea in five days, threw up three hills of from twenty to two hundred and fifty feet high, gained two thousand feet seaward from the old line of coast, by three fourths of a mile in width, and heated the water for fifteen miles either side to such an extent, that the fishes were heaped up in myriads on shore, scalded to death. Its falling into the sea was accompanied with tremendous hissings, and detonations like constant discharges of heavy artillery, distinctly heard at Helo, twenty miles distant."

As to the amount of force exerted in volcanoes, we can form some estimate from the quantity of lava ejected, and the distance to which rocks have been thrown; also, by computing the force requisite to raise lava to the tops of the existing craters from their bases. Professor Hitchcock furnishes the following data under these different heads.

Vesuvius, more than three thousand feet high, has launched scoriæ four thousand feet above the summit. Cotopaxi, nearly eighteen thousand feet high, has projected matter six thousand feet above its summit; and once it threw a stone of one hundred and nine cubic yards in volume, the distance of nine miles. Taking the specific gravity of lava at 2.8, the following table shows the force requisite to cause it to flow over the tops of the several volcanoes, whose height above the sea is given; the velocity produced at the outset of such a force, called its initial velocity, is also given.

Name.	Height in feet.	Force exerted upon the lava in atmospheres.	Initial velocity per second in feet.
Stromboli (highest peak)	2,168	176	371
Vesuvius . .	3,874	314	496
Jorullo (Mexico) . .	3,942	319	502
Hecla (Iceland) .	5,106	413	570
Etna	10,892	882	832
Teneriffe . .	12,464	1009	896
Mouna Kea (Sandwich Isles)	14,700	1191	966
Popocatepetl (Mexico)	17,712	1435	1062
Mount Elias . .	18,079	1465	1072
Cotopaxi (Quito) .	18,869	1492	1104

There can be but little doubt that the chimney of a volcano extends generally as much below the level of the sea as it does above, and often, probably, fifty times as deep; so that the actual force pressing upon the lava in its reservoir may be far greater than the second column of the preceding table represents, and the initial velocity much greater than in the third column.

It is estimated that the amount of melted matter thrown out by Vesuvius, in the eruption of 1737, was eleven million eight hundred and thirty-nine thousand one hundred and sixty-eight cubic yards, and in that of 1794, twenty-two million four hundred and thirty-five thousand five hundred and twenty cubic yards. But these quantities are small, compared with what Etna has sometimes disgorged. In 1669, the amount of lava was twenty times greater than the whole mass of the mountain; and in 1660, when seventy-seven thousand persons were destroyed, the lava covered eighty-four square miles. The greatest eruption of modern times, however, is said to have been that of Skaptar Jokul, in Iceland, in 1783.*

New Islands formed by the Agency of Volcanoes. — There are numerous examples of this phenomenon. The celebrated islands of Delos, Rhodes, and the Cyclades, in the Grecian Archipelago, are described by the ancient writers as having had such an origin. Livy, the Roman historian, mentions a similar event about the time of the death of Hannibal; and the Roman people were so affrighted by it and its attendant phenomena, that they decreed a supplication to the gods to avert the displeasure of Heaven, which they thought to be indicated by these prodigies.

In 1831, a volcanic island arose in the Mediterranean, about thirty miles off the southwest coast of Sicily, where previous soundings had ascertained the depth of the sea to be six hundred feet. It was preceded by a fountain of steam and water, and at length a small island gradually appeared, having a crater on the summit, which ejected scoriæ, ashes, and volumes of vapor; the sea around was covered with floating cinders and dead fish. The scoriæ were of a grayish black color. The crater reached an elevation of nearly two hundred feet, with a circumference of about three miles, having a circular basin full of boiling water of a dingy color. It continued in activity for three weeks, and then grad-

* For an account of this, see "Glance at the Sciences," article, *Geology*.

ually disappeared. In 1838, two years after its destruction, a dangerous reef remained eleven feet under the water, in the centre of which was a black volcanic rock, — probably the remains of the solid lava ejected during the eruption, — surrounded by shoals of scoriæ and sand. From these facts it appears that a hill eight hundred feet high was here formed by a submarine volcanic vent in the course of a few weeks.

In the Azores, a small island, called Sabrina, rose up in 1811, which was three hundred feet high and a mile in circumference; after six months, it disappeared. It is also recorded, that in the year 1720 a similar island arose, which was six miles in circumference. In 1707, the island called Isola Nuova was thrown up near Santorini, and still remains. Just before the great eruption of Skaptar Jokul, in Iceland, in 1783, a new island is stated to have appeared off the coast, which afterwards vanished. In 1796, a new island, three hundred and fifty feet in height and two miles in circumference, rose up in the Aleutian group, east of Kamtschatka, and still remains. Others, yet larger, are also mentioned. In the same archipelago, another peak arose in 1814, which is said to have been three thousand feet high.

In 1538, Monte Nuovo, in the Bay of Baiæ, in Italy, was thrown up in a day and a night, and remained permanently elevated, the height being four hundred and forty feet above the level of the sea. Its base is about a mile and a half in circumference. Many large islands, which have all existed from the earliest known records, also appear to be wholly, or mainly, the effect of volcanic agency. The Sandwich Islands, containing four thousand square miles, and one point of which rises eighteen thousand feet above the ocean; Teneriffe, the peak of which is thirteen thousand feet high; probably Iceland, Sicily, Bourbon, St. Helena, Tristan d'Acunha, the Madeira, Faroe, and Azore islands; a great part of Java, Sumatra, Celebes, and Japan; — all were, for the most part, lifted from the ocean, by the agency of volcanic fires.

The lava which is thrown forth from volcanoes, being a non-conductor of heat, is often very long in cooling. It is stated, that in the case of Jorullo, in Mexico, a heap of lava, sixteen hundred feet high, thrown out nearly two hundred years since, is not yet cooled. The lava thrown out by Etna in 1819 was moving at the rate of a yard in a day, nine months after the eruption; and the lava from the same volcano, at a previous eruption, was in motion ten years afterward.

As an evidence of the non-conducting power of lava, a circumstance of a very extraordinary nature is mentioned by Mr. Lyell, — that of the preservation, for ages, of a glacier, or bed of ice, from having been covered and protected by a flood of red-hot lava. The intense heat experienced in the South of Europe, during the summer and autumn of 1828, caused the usual supplies of ice entirely to fail. Great distress was consequently felt for want of a commodity regarded in those countries rather as an article of necessity than luxury. Etna was, therefore, carefully explored, in the hope of discovering some crevice or natural grotto on the mountain, where drift snow was still preserved. Nor was the search unsuccessful; for a small mass of perennial ice, at the foot of the highest cone, was found to be part of a large, continuous glacier, covered by a lava current. The ice was quarried, and the super-position of the lava ascertained to continue for several hundred yards. Unfortunately, the ice was so extremely hard, and the removal of it so expensive, that there is no probability of the operation's being renewed. Mr. Lyell explains this apparently paradoxical fact, by supposing that a deep mass of drift snow was covered by a stream of volcanic sand, which is an extremely bad conductor of heat; and thus the subsequent liquid lava might have flowed over the whole without affecting the ice beneath, which, at such a height, — ten thousand feet above the level of the sea, — would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from above.

There are some volcanoes which are incessantly active. Of this class is Stromboli, one of the Lipari Islands. For at least two thousand years, this has never ceased its fiery labors. The lava is said never to flow over the top of the crater; though it is sometimes discharged through a fissure into the sea, killing the fish, which are thrown on the shore ready cooked. It is said to be more active in stormy than in fair weather, also in winter than in summer, — which fact is explained by the different degrees of pressure exerted by the air on the lava at different times. Thus, when the air is light, the internal force predominates; but when heavy, it restrains the energy of the volcano.

The volcano of Popocatepetl, in Mexico, which is eighteen thousand feet high, is continually pouring forth smoke. Another of the same class also exists in Lake Nicaragua. The same is the case with the terrific volcano of Kirauea, the grand appearance of which has already been described.

EXTINCT VOLCANOES. — There is, as has already been suggested, a class of volcanoes called *extinct*. These are of very different ages; some were active, as is evident from their appearance, in the tertiary, and others in the glacial period; there are others, still, which were in action at a later date. The extinct volcanoes of Auvergne and the South of France have been an object of much interest to geologists, and have been described by Bakewell, Daubeny, Lyell, Scrope, Murchison, &c. The following account is furnished by Mantell, being, in part, borrowed from Scrope's "Geology of Central France."

The country which is the site of these extinct volcanoes may be described as a vast plain, situated in the old province of Auvergne; it is so remarkable for its fertility, that it is called the Garden of France, — a quality attributable to the *detritus* of volcanic rocks, which enters into the composition of the soil. It is inclosed on the east and west by two parallel ranges of gneiss and granite. Its average breadth is twenty miles; its length, between forty and fifty; and its altitude, about twelve hundred feet above the level of the sea. The surface of this plain is formed of alluvial deposits, composed of granite and basaltic pebbles and bowlders, reposing on a substratum of limestone. Hills of various elevations, composed of calcareous rocks, are scattered over the plain; and the River Allier flows through the district over beds of limestone or sandstone, except where it has excavated a channel to the foundation rock of granite. The hills, composed of calcareous, alluvial deposits, are the remains of a series of beds which once constituted an ancient plain, at a higher elevation than the present. Many are surmounted by a crest or capping of basalt, to which their preservation is probably attributable. Others have escaped destruction by being protected by horizontal layers of a durable limestone. We have, then, as the ground-plan of the district, an extensive plain, checkered with low hills of fresh-water limestone, which are capped with compact lava; the boundaries of the plain being formed of ranges of primary rocks, three thousand feet in altitude.

To the westward the limestone disappears, and a plateau of granite rises to a height of about sixteen hundred feet above the valley of Clermont, being three thousand feet above the level of the sea. This supports a chain of volcanic cones and dome-shaped mountains, about seventy in number, varying in altitude from five hundred to one thousand feet above their bases, and forming an irregular range nearly twenty miles in length, and two in breadth. The highest point in this range is the Puy de Dôme, which is four thousand feet above the level of the sea, and is composed entirely of volcanic matter; it possesses a regular crater, three hundred feet deep, and nearly one thousand feet in circumference. Many of these cones retain the form of well defined craters, and their lava currents may be traced as readily as those of Vesuvius.

One of the most remarkable cones is the Puy de

Côme, which rises from the plain to the height of nine hundred feet; its sides are covered with trees, and its summits present two distinct craters, one of which is two hundred and fifty feet in depth. A stream of lava may be seen to have issued out from the base of the mountain, which, at a short distance, from having been obstructed by a mass of granite, has separated into two branches; these can be traced along the gigantic platforms, and down the side of a hill into the adjacent valley, where they have dispossessed a river of its bed, and constrained it to work out a fresh channel between the lava and the granite of the opposite bank.

Another cone rises to the height of one thousand feet above the plain, having a crater nearly six hundred feet in vertical depth, and a lava current which first falls down a steep declivity, and then rolls over the plain in hilly waves of black and scorified rocks. In one part of this volcanic group is a circular system of cones, apparently the produce of several rapidly succeeding eruptions. The extraordinary character of this scene impresses it for ever on the memory; for there is, perhaps, no spot, even among the Phlegræan fields of Italy, which more strikingly displays the character of volcanic desolation. Although the cones are partially covered with wood and herbage, yet the sides of many are still naked; and the interior of their broken craters, ragged, black, and scorified, and the rocky floods of lava with which they have loaded the plain, have a freshness of aspect, such as the products of fire alone could have so long preserved, and offer a striking picture of the operation of this element in all its most terrible energy.

HERCULANEUM AND POMPEII. — But all these phenomena are far surpassed in interest by the wonderful preservation of the relics of the cities which were overwhelmed by the first recorded eruption of Vesuvius. In the words of an eloquent writer, "After nearly seventeen centuries had rolled away, the city of Pompeii was disinterred from its silent tombs, all vivid with undimmed hues; its walls fresh as if painted yesterday; not a tint faded on the rich mosaic of its floors; in its forum, the half-finished columns, as left by the workman's hand; before the trees in its gardens, the sacrificial tripod; in its halls, the chest of treasure; in its baths, the strigil; in its theatres, the counter of admission; in its saloons, the furniture and lamps; in its triclinia, the fragments of the last feast; in its cubicula, the perfumes and the rouge of faded beauty; and everywhere, the skeletons of those who once moved the springs of that minute, yet gorgeous, machine of luxury and life.

"The cities of Herculaneum, Pompeii, and Stabiæ were buried beneath an accumulation of ashes and scoriæ to a depth of from sixty to one hundred and twenty feet. No traces have been perceived of lava currents, or of melted matter; showers of sand, cinders, and scoriæ, with loose fragments of rocks, were the agents of desolation. The various utensils and works of art, which may be observed in the lamps, vases, beads, and instruments in the British Museum, exhibit no appearance of having suffered by the action of fire. Even the delicate papyri appear to have sustained more injury from the effects of moisture, and exposure to the air, than from heat; for they contain matter soluble in naphtha, and are, in fact, peat, in which bitumenization has commenced. In Pompeii, the sand and stones are loose and unconsolidated; but in Herculaneum, the houses and works of art are imbedded in solid tuff, which must have originated either from a torrent of mud, or from ashes moistened by water. Hence, statues are found unchanged, although surrounded by hard tuff, bearing the impressions of the minutest lines.

"The beams of the houses have undergone but little alteration, except that they are invested with a black crust. Linen and fishing-nets, loaves of bread with the impress of the baker's name, even fruits, as walnuts, almonds, and chestnuts, are still distinctly recognizable. The remarkable preservation, for nearly two thousand years, of whole cities, with their houses, furniture, and even the most perishable substances, beneath beds of volcanic rocks, may be compared to those geological changes, by which the forests of an earlier world, and the remains of the colossal dragon-forms which inhabited the ancient land and waters, have been perpetuated."

Various other countries exhibit examples similar to those we have described. Thus, in the valley of the Jordan, in Palestine, especially around Lake Tiberias, and extending as far northwest as Safed, volcanic rocks are found. The region occupied by the Dead Sea has doubtless been the seat of volcanic action, at some former, though distant, period. The evidences of this are found in the fact, that the lake is highly charged with saline matter; that it produces vast quantities of bitumen; that cliffs of rock-salt and masses of sulphur are found upon its margin; and that its surface is depressed more than five hundred feet below the level of the Mediterranean Sea. And it has been usually supposed, that the five ancient cities, Sodom, Gomorrah, Admah, Zeboiim, and Zoar, which undoubtedly occupied what is now the southern part of the Dead Sea, were destroyed by a volcanic eruption; but this theory is now rejected by the best geologists.

Mount Ararat, in Armenia, is also said to be an extinct volcano. To the same class, likewise, belong many of the lofty peaks of the Andes and the Cordilleras, and the region between the Rocky Mountains and the Pacific Ocean.

The size of these extinct volcanoes, and the extent of their craters, are often immense. In the middle and southern parts of France, they cover several thousand square miles. Between Naples and Cuma, in the space of two hundred miles, there are sixty slumbering craters, some of them larger than that of Vesuvius. The city of Cuma has stood three thousand years in a crater of one of these volcanoes. Vesuvius and the Peak of Teneriffe both stand in the midst of craters of ancient volcanoes; the latter of which is one hundred and eight square miles in extent. Humboldt says, that all the mountainous region of Quito, embracing six thousand three hundred square miles, may be considered as an immense volcano, which occasionally finds vent through some one of the elevated peaks in that region, and which formerly must have been active to have produced the results which remain. The great volcano of Kirauea is said also to be surrounded by two circular walls, one fifteen and the other twenty miles in circuit, and which must be considered as the boundaries of ancient craters.

Some geologists have inferred from these facts, that ancient volcanoes, now extinct, must have exerted a more powerful agency than existing ones; but Mr. Lyell conceives this view to be incorrect, and appeals to the immense amount of matter thrown out by the eruption of Skaptar Jokul, in 1783, which he thinks must have equalled any of those in the olden time.

EARTHQUAKES.

Closely connected with the subject of volcanoes is that of earthquakes. These are almost always experienced before an eruption, and cease to be felt when the lava has found some means of bursting forth. One striking peculiarity of earthquakes is the extent of country which is often affected by them. The shock of the earthquake of Chili, in 1822, was felt simultaneously throughout a space of twelve hundred miles, from north to south. An earthquake, which occurred lately at Cutch, was felt at Ahmedabad, and also slightly at Poonah, which is four hundred miles farther. And during one of the earthquakes in Calabria, toward the end of the last century, the surface over which the shocks acted so forcibly as to excite terror and alarm amounted to five hundred square miles. The agitations also affect the sea, as well as the land. The town of Sorcino was destroyed by the waves of the ocean, during an earthquake in 1780. During the earthquake at Lisbon, the waves mounted to a greater height than they had ever been known to do in the most violent storms; and at Cadiz, the swell rose eighty feet, breaking down the mole which joins the town to the continent. The effect of the shocks on vessels at sea has been described as similar to the concussion that is felt when a ship strikes violently upon a sandbank.

Of the powerful influence of earthquakes in modifying the surface of the land perhaps as striking an instance as can be adduced is that which occurred on the coast of Chili, in 1822, and to which we have already alluded. When the district around Valparaiso was examined, after the shock, it was found that the whole line of coast, for the distance of more than a hundred miles, was raised nearly four feet above its former level; and the muscles, oysters, and other shell-fish, which were thus exposed, were all dead, and exhaling most offensive effluvia. The rise of the inland country was even greater than that of the sea-coast. The area thus convulsed and permanently altered is believed to have extended to a hundred thousand square miles.

In 1812, a violent earthquake occurred in Caraccas. The surface undulated like a boiling liquid; terrific sounds were heard under ground; and the whole city, with its splendid churches, was in an instant a heap of ruins, under which ten thousand of the inhabitants were buried. Enormous rocks were detached from the mountains, and Silla lost about three hundred and fifty feet of its height, by subsidence. In 1797, the district around the volcano of Tunguragua, in Quito, for forty leagues from north to south, experienced an undulating movement which lasted four minutes. Every town was levelled to the ground; and Riobamba, Quero, and other places, were buried under masses detached from the mountains. At the foot of Tunguragua the earth was rent open, and streams of water and fetid mud poured out, overflowing and wasting every thing. In valleys one thousand feet broad, the water of these floods reached to the height of six hundred feet, barring up the course of the river, and forming immense lakes. The surface of the district thus affected was entirely changed.

The earthquakes which occurred in Calabria present a frightful picture of the desolating power of this tremendous agent. The shocks began in February, 1783, and lasted for nearly four years. The ground was rent and cracked in all directions. Chasms were formed a mile in length, and hundreds of feet deep. Cities and villages were overthrown, and many houses, and even streets, were altogether ingulfed. Trees, supported by their trunks, sometimes bent during the shocks to the earth, and touched it with their tops. The quay at Messina was sunk down below the level of the sea; and at Terranuova, a stone well was driven upward out of the earth, so as to form a tower, eight or nine feet in height. Many land-slips also occurred. In other words, immense portions of land, sometimes forming the sides of mountains, were separated from the parent mass, and precipitated into the valleys, obstructing the river-courses, and causing lakes and floods. Two portions of land of this kind, about a mile long, and half a mile broad, were carried for a mile down a valley; and a thatched cottage, together with large olive and mulberry trees, most of which remained erect, were carried uninjured to this extraordinary distance.

The number of persons who perished during the earthquakes is reckoned at forty thousand; and twenty thousand more died of epidemics caused by insufficient nourishment, and by malaria arising from the new stagnant lakes and pools. Many of the victims who were buried in the ruins of the houses might have been rescued, but no person could be procured to remove the superincumbent rubbish. The peasantry either had fled, or had enough to do with their own misfortunes; and neither entreaties nor rewards could induce them to lend the necessary aid. At Terranuova, four monks, who had taken refuge in a vaulted sacristy, the arch of which continued to support an immense pile of ruins, made their cries heard for the space of four days. One only of the brethren of the whole convent was saved, but, unassisted, he could lend them no aid. He heard their voices die away gradually; and when afterward their four corpses were disinterred, they were found clasped in each other's arms.

Professor Hitchcock presents us with the following cases of cities and places, wholly or in part deluged by the ocean, in consequence of earthquakes. In the year 876, Mount Acraces is said to have fallen into the sea; in 541, Pompeiopolis was half swallowed up; in 1692, a part of Port Royal in the West Indies was sunk; in 1755, a part of Lisbon; in 1812, a part of Caraccas. About the same time, numerous earthquakes agitated the valley of the Mississippi, for an extent of three hundred miles, from the mouth of the Ohio to that of the St. Francis, whereby numerous tracts were sunk down and others raised, lakes and islands were formed, and the bed of the Mississippi was exceedingly altered. In 1819, the bed of the Indus, at its mouth, was sunk eighteen feet, and the village and port of Sindree submerged. At the same time, a tract of the delta of the Indus, fifty miles long and sixteen broad, was elevated about ten feet. In Caraccas, in 1790, a forest was sunk, over a space of eight hundred yards in diameter, to the depth of eighty or one hundred yards.

The Rev. Mr. Parker has described a remarkable subsidence, twenty miles in length, and a mile in width, just above the falls in Columbia River, and which has been before adverted to. Through this whole distance, the trees are standing in the bottom of the stream, at an average depth of twenty feet; only that part of them above high-water mark being broken off. He could discover no evidence that this tract had separated from the bank of the river; but the whole region appears to be one of extinct volcanoes, and the river passes through hills and walls of basalt, and most probably this is a case of subsidence from an earthquake. The banks are too high and rocky to admit of the explanation, that a lake has been formed by the river cutting through its *levée*, and overflowing the adjacent low ground, by which means, along the Mississippi, a lake with trees standing in it is sometimes produced.

ELEVATIONS AND DEPRESSIONS WITHOUT EARTHQUAKES.

As earthquakes sometimes occur without immediate relation to volcanoes, so there are instances where large tracts of land have been elevated or depressed, by a gradual progressive movement, not occasioned directly by either of these causes, or at least without any apparent evidence of their action, exhibited in the usual manner at the surface. For instance, it has been clearly ascertained that a great part of the coast of Sweden, upon the Baltic and the Gulf of Bothnia, is slowly but continually rising; and the same phenomenon has been observed upon the western coast of Sweden, particularly near Uddevalla, and the neighbouring coast. Into the proofs of this rise our limits do not permit us to enter; but they are clear beyond a doubt. This rising of land in Scandinavia, together with depressions which are known to occur in Greenland and other places, is not improbably connected with subterranean volcanic agency, although the country has been from time immemorial free from volcanoes and violent earthquakes.

CAUSES OF VOLCANOES AND EARTHQUAKES.

This has been a fruitful subject of dispute among geologists; but as an investigation of all that has been advanced on the subject would lead us far beyond our present limits, we shall merely take a cursory glance at the more important theories.

The common cause of volcanoes and earthquakes is on all hands admitted to be connected with the passage of heated matter, which we find ejected from the interior to the surface of the earth. The question, then, is, Where does this heat come from? It is the opinion of some very profound geologists, that the earth was originally in a state of igneous fusion, and that, as this heated mass began gradually to cool, an exterior crust was formed, first very thin, and afterward increasing, by degrees, until it attained its present thickness, which they calculate as amounting to sixty miles. During this process of gradual refrigeration, some portions of the crust cooled more rapidly than others; and the pressure on the interior igneous mass being unequal, the heated matter, or lava, burst through the thinner parts, and caused high peaked mountains, such as we at present see in the moon. The same cause, they allege, produces volcanoes still. According to this theory, we live upon a thin crust, inclosing matter in a state of intense heat, which in particular districts agitates the earth in its pressure to escape, thus causing earthquakes; or occasionally bursting forth and producing volcanoes. The arguments adduced for this doctrine are plausible. The first is the form of the earth,—that of a spheroid of rotation,—being just that form which an igneous *liquid* mass would assume, if thrown into an orbit with a motion similar to that of the earth. Again, they appeal to the fact, that it is found, by experiments in mines, that the heat increases with the depth, and that hot-springs and mineral waters are found in all countries. They likewise argue, that the peculiar appearance of *lavas*, all over the world, indicates that they proceed from a common source. And lastly, they contend, that on no other hypothesis can we account for the vigorous growth of sigillaria, arborescent ferns, and other plants found fossil in northern regions,—plants which could have been produced only under circumstances of high temperature and moisture,—meaning, of course, that the heat which assisted the growth of this luxuriant flora must have proceeded, not from above, but from beneath the soil.

This doctrine, nevertheless, is opposed by Mr. Lyell. The spheroidal figure of the earth, he says, may have been caused by the gradual operation of the centrifugal force, acting on the materials brought successively within its action by aqueous and igneous causes. And besides, he adds, it is a gratuitous supposition, that the original figure of our planet was strictly spherical. He maintains, moreover, that, according to the laws which regulate the circulation of heat through fluid bodies, the crust of the earth, instead of increasing in thickness, would be altogether melted. And finally, he attempts to account satisfactorily, by changes on the surface of the earth, for the growth of the gigantic plants found in cold regions.

Mr. Lyell refers the heat of the interior to chemical changes constantly going on in the earth's crust; forming particular combinations which evolve heat and electricity, and which again, in their turn, become sources of new chemical changes. He suggests, that subterranean electric currents may exert a slow decomposing power, like that of the voltaic pile, and thus become a constant source of chemical action, and consequently of volcanic heat; that the metals of the earth and alkalies may exist in an unoxidized state in the subterranean regions, so that the occasional contact of water with those metals must produce intense heat; that the hydrogen evolved during the process of saturation may, on coming afterward in contact with the heated metallic oxides, reduce them again to metals; and that this circle of action may be one of the principal means by which internal heat, and the stability of the volcanic energy, are preserved.

The sudden fracture of solid strata, by any of the causes mentioned, would produce a vibratory jar, which, being propagated in undulations through a mass of rock several thousand feet thick, (for the crust of the earth is extremely elastic,) would give rise to superficial waves, and so cause earthquakes. Or, as Michell supposes, large districts may rest on fluid lava, which, when disturbed, will produce a similar undulatory motion; and when this pent-up heated matter finds a means of egress, it will rush out, for days or weeks, through the orifice, with an explosive power, accompanied by smoke and flame, and the other peculiarities of volcanic eruptions. The rocks shattered by such subterranean convulsions may assume and retain an arched form; or the gases may drive before them masses of liquid lava, which may thus be injected into newly opened fissures. In either case, the country above may remain permanently elevated. There is reason to believe that in some such way the mighty

Andes have been upheaved from the bottom of the ocean, and, indeed, most of the present dry land on the face of the globe; for geological phenomena plainly indicate that each region of the earth has at one time or other been a great theatre of subterranean convulsions.

CHANGE OF CLIMATES UPON THE GLOBE.

THIS is a highly interesting topic in geology, and it is one of the most difficult to explain. It is a fact now fully admitted, that the climate of the northern hemisphere was, at a former period of the earth's history, much hotter than it is at present. The proofs of this are abundant. Shells and corals, discovered fossil in the secondary rocks, are found intimately connected, by generic affinity, with species now living in warmer latitudes. Turtles, tortoises, and lizards appear in great abundance in European formations; and plants have been found in situations where they could not possibly have grown under the present temperature. Thus, in the superficial deposits of sand, gravel, and loam, strewn over all parts of Europe, remains of extinct mammalia are discovered, among which are those of the elephant, rhinoceros, hippopotamus, bear, hyena, lion, tiger, and others, consisting in a great measure of species now confined to warmer regions.

In the elevated land of Europe, the rocks called secondary contain assemblages of organized fossils, all of unknown species, and many of them referable to genera now abundant between the tropics. Among these, as we have seen, are gigantic reptiles, some of them herbivorous, others carnivorous, far exceeding in size any now known, even in the torrid zone. The genera are for the most part extinct; but some of them, as the crocodile and monitor, still have representatives in the warmer parts of the earth. Coral reefs were evidently numerous in the seas of the same periods, and composed of species belonging to genera now characteristic of a tropical climate. In the ancient coal-deposits the proofs are still more striking, for there we find equiseta upward of ten feet in height, arborescent ferns fifty feet high, and lycopodiaceæ from sixty to seventy feet; and these not only in Europe, but in North America and Greenland. These, together with the corals and chambered univalves which have been found at Melville Island and other high latitudes, prove, that, during the carboniferous period, there was an elevated temperature, even in regions bordering on the Arctic Circle. The approximation to a climate similar to that now prevalent in these latitudes does not commence till the era of the tertiary formations, which, it will be recollected, are the latest formed of the stratified rocks.

To account for the change of climate thus indicated, some have argued for a derangement in the position of the earth's axis of rotation; but astronomers satisfactorily prove to us that this is impossible. Another theory we have already noticed, in treating of volcanoes, namely, the former thinness of the earth's crust, and the consequently greater amount of heat transmitted to the surface. Another theory is, that the high temperature in northern regions was the result of an arrangement of the land and sea, different from, and, indeed, the reverse of, what now appears on the face of the globe.

Wherever there are large tracts of land, with mountainous districts rising into the colder regions of the atmosphere, there will ice and snow be found to prevail and accumulate. But the ocean has a tendency everywhere to preserve a mean temperature, which it communicates to the adjoining land, so that it tempers the climate, moderating alike an excess of heat or cold. Accordingly, we find that the climate of islands is much more equable than that of continents. Their summers may be more cool, but their winters are warmer. If, therefore, the present relative positions of land and water were reversed, we may suppose, that, in the islands, which would then occupy the polar regions, the temperature might be somewhat raised by the prevailing mean temperature of the ocean, — by currents flowing from the tropical regions, — and by other favorable circumstances, — so as, possibly, to render them fit for the support both of animals and plants which could not exist in a climate such as is found at present in those quarters of the world.

That such a distribution of land and sea has occurred is not only possible, but highly probable; and the agents at present operating a change on the earth's surface are quite competent to produce it again. "The imagination is apt to take alarm," says Mr. Lyell, whose theory is here presented, "when called upon to admit the formation of such irregularities on the crust of the earth, after it had once become the habitation of living creatures. But if time be allowed, the operation need not subvert the ordinary repose of nature; and the result is, in a general view, insignificant, if we consider how slightly the highest mountain-chains cause our globe to differ from a perfect sphere. Chimborazo, though it rises to more than twenty-one thousand feet above the sea, would be represented on a globe, six feet in diameter, by a grain of sand, less than one twentieth of an inch in thickness."

It is claimed, that the appearance of the whole system of stratified rocks supports the theory which has been stated; but we shall only allude to the more recent series,—the tertiary. In this formation, we find a gradual increase of animals and plants fitted to our present climates, in proportion as the strata which we examine are more modern; and it is an ascertained fact, that, during all these successive tertiary periods, there has been a great increase of land in European latitudes. In fact, two thirds of the present lands in Europe have emerged since the deposition of the earliest of these tertiary groups. Large portions of Sweden, Finland, Lapland, Turkey, France, and Austria, the greater part of Prussia and Poland, the whole of Denmark, almost the whole of Russia, with part of England, have been elevated from beneath the ocean, during the period in question. The proofs of submergence are unequivocal, for the area described is now covered by deposits containing the fossil remains of animals which could only have lived under water. The species, moreover, of the marine testacea found in the oldest of these formations cannot be deemed very remote, geologically speaking; for a proportion of more than three in a hundred of the fossils has been identified with species now living. The elevation, too, of the extensive districts mentioned was by no means sudden. Evidence has been obtained which renders it probable that there have been at least twelve different periods of elevation, affecting the strata of Europe.

We shall not undertake to decide between the several theories adopted to explain the obvious fact of a change of the climates of the earth; and need only remark, that a combination of these systems may, perhaps, furnish us with the true hypothesis.

GENERAL VIEW.

LET us now briefly review the ground over which we have passed, and consider the results at which we have arrived. Instead of regarding this earth as brought suddenly into existence some six thousand years ago, by one creative act of God, we must carry the mind back into the remote depths of eternity, and suppose, that, in the formation of our earth, the same process was adopted as that which the astronomer now sees going on in the boundless regions of space. Notwithstanding Mr. Lyell's theory, recited in a previous chapter, we incline to that hypothesis which supposes that the sun was once the nucleus or centre of a nebulous mass, revolving on its axis; that this became condensed, and the planets were successively thrown off from the central body. At first, we suppose the earth to have been in a gaseous state, similar to the comets. By degrees, its heat was dispersed and radiated into space; in consequence of which, the particles became condensed, yet still in a state of fusion. The process of cooling went on, until the external crust of the globe became hardened into the solid materials of which we see it now composed, yet, perhaps, leaving the central mass in a state of incandescence.

At what period this process began, or how long a time has elapsed since the work was thus far completed, we have not the means of knowing; but we have reason to believe that it was myriads of years ago, and that the imagination of man is incompetent to measure the ages which have rolled away since our earth began its career as a planetary body. From the time that the earth had thus assumed its present form, we suppose that the great agencies which we now see at work in changing the surface of the earth have been in operation, and that these have been the instruments by which a series of revolutions and mutations have been effected.

The precise order of these changes we cannot trace, yet their general character and tendency we are at no loss to discover. At first, in the process of cooling, the crust of the globe was, perhaps, broken and torn, thus presenting the rugged aspect which the telescope now unfolds to view in the moon. The pent-up fires within would seek vent, the volcanoes would disgorge their contents, and the earthquake would shake and dislocate the land and the sea. The rain and the tempest now began their work; particles of earth were disengaged from the mountains, and borne by the floods to the valleys; and a soil was formed for vegetation. But, in a world which had sprung from a molten mass of matter, there was no seed, — no principle of vegetable or animal life. A creative act of God was now necessary to commence the organic kingdoms. That act was put forth; seeds were created and cast into the soil which had been preparing for them. These sprang up at the bidding of the Almighty. At first, they were the *fuci* and *algæ*, —the rank weeds which grow on the margin of the sea. These flourish and decay, and their successive generations contribute to form a rich mould which shall give sustenance to higher forms of vegetation yet to be created.

At an early period, and perhaps immediately after the commencement of vegetable life, the lowest forms of animal existence were brought into being. The zoophytes were seen to swarm in the waters, and shell-fish began to abound; crustaceous animals were multiplied; myriads of trilobites sported in the sea; fishes of the sauroid and shark form succeeded; — and while these steps of creation were advancing in the waters, the land began to put forth its blossoming flowers. Such is the Silurian or Cambrian Period.

But a change comes over the scene. Continents and islands sink beneath the ocean, and new continents arise from the bosom of the deep. The old creations are in fact swept away. A new earth appears, and new beings are created to inhabit it. Fishes of new forms are seen to glide in the waters; scorpions, spiders, and various insects are seen upon the land and the sea. The fresh-waters now begin to teem with shell-fish, and the land becomes clothed with a gigantic vegetation. The pine-tree rises, with its lofty branches, into the air. The stately palm broods in forests over hill and valley; and flowering plants and shrubs appear, in diversified forms and hues, on every hand.

At this age of the world, the climate differs from that of the present period. The torrid zone seems to overspread the earth; and even in the polar regions, where animal and vegetable life can now hardly exist, the tropical plants seem to luxuriate, and animals now confined to the torrid regions sport in the tepid waters around the poles. This was the Carboniferous Period; and it was during this prolific age that the mighty masses of vegetable matter were produced and buried in the earth, to constitute those inexhaustible beds of coal, which ages after were to contribute to the civilization of man, to drive the whirling spindles of the factory, to work the sledge of the iron-mill, to impel the steamboat through the wave, and urge the locomotive on its track.

Another change comes over the scene. A new distribution of land and water is made. Myriads of organized existences become extinct, and new ones succeed. Reading the record of this age, as written upon the enduring leaves of red-sandstone, we see that gigantic frogs and birds of amazing stature now dwell upon the earth. The ichthyosaurus, the plesiosaurus, and other strange yet stupendous reptiles, wonderfully combining the powers of distinct genera, dwell in the waters or along their margin, and at the same time new forms of vegetable life are scattered over the landscape.

Still another change appears, and now the marsupial animals are seen; the crocodile, the gavial, and the tortoise are created. New fishes, new insects, and new animals of the crustaceous kind are discovered; and plants, also, of new forms, spring up from the soil. This is the Oölitic Period.

And now we come to the Wealden Period, the age of the iguanodon, that stupendous reptile, whose very existence had never been imagined until a recent period, and to which the words of Milton have been fitly applied: —

> "With head uplift above the waves, and eyes
> That sparkling blazed, his other parts besides
> Borne on the flood, extended long and large,
> Lay floating many a rood, in bulk as huge
> As whom the fables name of monstrous size,
> Titanian, or earth-born, that warred on Jove, —
> Briareus, or Typhon, whom the den
> By ancient Tarsus held, — or that sea-beast
> Leviathan, which God of all his works
> Created hugest that swim the ocean stream."

The imagination, in turning back to this period, pictures to itself this mighty reptile rioting in the waters where the solid earth of the British islands now stands, and, in place of the human habitations, the ox, the horse, the oak, and the chestnut, — which now appear in the scene, — discovers flying reptiles in the air, crocodiles and turtles sporting in the fens, and lizards and fishes, now blotted out of existence, making the waters boil with their gambols.

Another change takes place, and the Cretaceous Period appears. Again new forms of organized existence occupy the earth. The mososaurus and other reptiles are found. New insects, fishes, and crustacea are seen, with many that have before existed. The vegetable world displays also some new plants, amid varieties that have belonged to other ages.

We now come to the Tertiary Period, which is far more prolific in organic remains than those that have gone before. A multitude of new animals and plants appear to have entered upon their career. Many species that are now extinct — such as the palæotherium, lophiodon, and dinotherium — are found, with a multitude of animals still in existence. The bones of creatures now unknown occur confusedly mixed with those of the bat, wolf, fox, raccoon, squirrel, owl, whale, elephant, ox, deer, &c. Many extinct species of genera still existing are discovered. Multitudes of extinct shell-fish are found with others that still remain, and, amid the relics of vegetable races which have vanished from the earth, we find the fossil remains of poplars, willows, sycamores, and elms. Thus, the old and the new, — the past and the present, — the races that are annihilated, and the races that remain, — are found huddled together in one common tomb, formed in that age of the earth to which we give the title of the Tertiary Period.

But as yet no traces of man appear. Hitherto the world has performed its revolutions, and ages have rolled away; change has followed change; myriads of animals have lived and perished; the seasons have come and gone; the elements have performed their work, and all unwitnessed by human beings. Geology tells us of the volcano and the earthquake; of the iguanodon and the plesiosaurus; of ages that have fled, and races that have perished; — it opens a new and wonderful volume of history, and reveals events which would otherwise have slept in oblivion for ever; but it tells us nothing of our own species. Man's history is recent; his existence, as compared with the age of the earth, is as an handbreadth. We do not find his bones imbedded in the ancient rocks; these hoary archives have not preserved a relic of the race. It is only in the alluvial period that we find the traces of man, and within a date compatible alike with the records of sacred and profane history.

"Such," says Dr. Mantell, in view of the geology of the British isles, "is a plain annunciation of the results of our investigations; but I will embody these inductions in a more impressive form, by employing the metaphor of an Arabian writer, and imagining some higher intelligence from another sphere to describe the physical mutations of which he may be supposed to have taken cognizance, from the period when the forests of Portland were flourishing, to the present time. Countless ages ere man was created, he might say, — I visited these regions of the earth, I beheld a beautiful country of vast extent, diversified by hill and dale, with its rivulets, streams, and mighty rivers, flowing through fertile plains. Groves of palms and ferns, and forests of coniferous trees, clothed its surface; and I saw monsters of the reptile tribe, so huge that nothing among the existing races can compare with them, basking on the banks and roaming through its forests; while in its fens and marshes were sporting thousands of crocodiles and turtles. Winged reptiles of strange forms shared with birds the dominion of the air, and the waters teemed with fishes, shells, and crustacea.

"And after the lapse of many ages, I again visited the earth; and the country, with its innumerable dragon-forms, and its tropical forests, all had disappeared, and an ocean had usurped their place, and its waters teemed with nautili, ammonites, and other cephalopoda, of races now extinct, and innumerable fishes and marine reptiles. And thousands of centuries rolled by, and I returned, and lo! the ocean was gone, and dry land had again appeared, and it was covered with groves and forests; but these were wholly different in character from those of the vanished country of the iguanodon. And I beheld, quietly browsing, herds of deer of enormous size, and groups of elephants, mastodons, and other herbivorous animals, of colossal magnitude. And I saw in its rivers and marshes the hippopotamus, tapir, and rhinoceros; and I heard the roar of the lion and the tiger, and the yell of the hyena and the bear.

"And another epoch passed away, and I came again to the scene of my former contemplations; and all the mighty forms which I had left had disappeared, the face of the country no longer presented the same aspect; it was broken into islands, and the bottom of the sea had become dry land, and what before was dry land had sunk beneath the waves. Herds of deer were still to be seen on the plains, with swine and horses and oxen, and wolves in the woods and forests; and I beheld human beings, clad in the skins of animals, and armed with clubs and spears; and they had formed themselves habitations in caves, constructed huts for shelter, inclosed pastures for cattle, and were endeavouring to cultivate the soil.

"And a thousand years elapsed, and I revisited the country, and a village had been built upon the seashore, and its inhabitants supported themselves by fishing; and they had erected a temple on the neighbouring hill, and dedicated it to their patron saint. And the adjacent country was studded with towns and villages, and the downs were covered with flocks, and the valleys with herds, and the corn-fields and pastures were in a high state of cultivation, denoting an industrious and peaceful community.

"And lastly, after an interval of many centuries, I arrived once more, and the village was swept away, and its site covered by the waves; but in the valley, and on the hills above the cliffs, a beautiful city appeared, with its palaces, its temples, and its thousand edifices, and its streets teeming with a busy population in the highest state of civilization, — the resort of the nobles of the land, the residence of the monarch of a mighty empire. And I perceived many of its intelligent inhabitants gathering together the vestiges of the beings which had lived and died, and whose very forms were now obliterated from the face of the earth, and endeavouring, by these natural memorials, to trace the succession of those events of which I had been the witness, and which had preceded the history of their race."

INFERENCES.

Marks of Design in the Geological Changes of the Earth's Surface. — There are some plain and obvious inferences to be drawn from the views which we have presented, and which it may be well to notice. In the first place, it may be remarked, that there are proofs of design, of the use of means adapted to an end, in the whole course of events presented by the geological history of the earth. We have already adverted to the process by which a soil was first formed for the support of vegetable life, and the means thus provided for the sustenance of animal life. In the outset, only the mineral kingdom existed; as yet there was no such thing as organized matter; there was nothing fit for the support of animal life. The vegetable kingdom was devised and brought into being, and thus the means were provided for the support of the animal kingdom. Now we may fairly presume that this earth was destined to become the habitation of living, sentient beings; and we see that a series of events, all tending to fit it for such a purpose, actually took place. We here see an intelligent and desirable end in view, and means, extending through countless ages, and embracing an infinite variety of circumstances, all finally terminating in fulfilling that end.

We may also suppose that the earth was intended to be the abode of man; and geology teaches us that this end has been accomplished by a process bearing the evident marks of intelligent design. In the several stages of the world's progress, we have seen that the animals and vegetables were mutually adapted to each other, and to the state of things around them. When the air was heated and filled with moisture, the vegetation conformed to these circumstances; and the animals, consisting of huge reptiles, were fitted to breathe a fetid atmosphere, and to feed on coarse, rank herbage. But in tracing the geological changes, we observe a constant improvement, from one step to another. If we compare any one age with that which preceded it, we see that the earth always becomes more and more suited to the higher forms of animal life. At first, only zoöphytes, animals which seem to be on the verge of the vegetable world, are created; then shell-fishes appear; then insects, and, in succession, gigantic tortoises, frogs, reptiles, and lizards of many forms. These are swept away, and, after a succession of generations, man and his associate animal races occupy the earth. Here is a series of steps obviously leading to a plain result; — the mighty engines of fire and water, the energies of chemical combination and decomposition, have been in operation for countless ages; at length the earth is fitted to be the abode of man, and then, and not till then, man appears as the master of the organic kingdoms. Here again, we see the adaptation of means to ends, and the successful accomplishment of a desirable end by the intelligent use of instruments.

We might advert to the fact, that animal races are created, with the vegetable kingdom suited to sustain them, as a proof of design; but we can particularly notice one instance only, unfolded by geology, in which an adaptation to the uses of man is obvious and striking; — we allude to the production of coal, in connection with useful minerals. The distribution of beds of coal over the earth, and the placing them in basins so as to be easily wrought, must be regarded as one of the most beneficent dispensations of Providence. The utility of this mineral, as well for domestic as public purposes, is beyond calculation.

It has been calculated that in England about fifteen thousand steam-engines are daily at work. One of those in Cornwall is said to have the power of a thousand horses; the power of each horse, according to Mr. Wyatt, being equal to that of five and a half men. Supposing, then, the average power of each steam-engine to be that of twenty-five horses, we have a total of steam power equal to that of more than two millions of men. When we consider that a large proportion of this power is applied to move machinery, and that the work now done by machinery in England has been supposed to be equivalent to that of three or four millions of men by direct labor, we are almost astounded at the influence of coal and iron and steam upon the fate and fortunes of the human race. "It is on the river," says Mr. Webster, "and the boatman may repose upon his oars; it is on highways, and begins to exert itself along the courses of land conveyances; it is at the bottom of mines, a thousand feet below the earth's surface; it is in the mill, and in the workshop of the trader. It rows, it pumps, it excavates, it carries, it draws, it lifts, it hammers, it spins, it weaves, it prints."

It hardly increases our sense of the importance or power of coal to state that there is virtue in a bushel of coals, properly consumed, to raise seventy million pounds' weight a foot high. "The ascent of Mont Blanc from Chamouni," says Dr. Buckland, "is considered, and with justice, as the most toilsome feat that a strong man can execute in two days; yet the combustion of two pounds of coal would place him on the summit." If we consider these facts, and observe the mighty purposes which this mineral is actually fulfilling, in promoting the happiness of the human race, it is impossible to believe that it was created, and man himself brought into existence, but with a design that embraced the adaptation of the one to the uses of the other.

If this inference needed confirmation, it might be found in the fact, that in Pennsylvania, England, Scotland, and other countries, there are rich beds of iron ore found in near connection with the deposits of coal. If we consider the utility of this metal to man, we cannot doubt that it was designed for his use; and when we see it thus placed side by side with a material requisite for its reduction to the purposes of life, it becomes a matter of reasonable assurance, that these things were thus disposed by the care of a wise and benignant Providence for the benefit of man.

Nor will a full view of the disturbing forces on the face of the earth furnish less evident proofs of intelligence in the great Governor of the earth, than the topics we have just considered. Elevations and subsidences, inclinations and contortions, fractures and dislocations, are phenomena which at first sight present only the appearance of confusion and disorder; yet, when fairly understood, they demonstrate the existence of order, method, and design, even in the operation of those mighty physical forces which have affected the terraqueous globe. But our space does not enable us to go into a consideration of this subject.

Unity of Design. — Geology teaches us that amid all the diversities of creation, reaching through an incalculable series of ages, and embracing innumerable species of animals, the same general plan has been carefully observed. We have already stated, that, in every geological period, we observe the same classes of animals and vegetables, even when the genera were totally distinct from the present. As Paley has said in reference to other worlds, so we may say in respect to the past ages of this, as displayed by geology, "We never get amongst such originally or totally different modes of existence, as to indicate that we are come into the presence of a different Creator, or under the direction of a different Will." "Wherever we go, into the records of whatever period we look, it is," says Buckland, "the same handwriting we read, the same system and contrivance we trace, the same unity of object, and relation to final causes, which we see maintained throughout, and constantly proclaiming the unity of the great Divine Original."

PROOFS OF CREATION. — It has been conceived by some persons that the earth has existed from eternity; and in this mystery the atheist has generally intrenched himself. Geology affords the most satisfactory refutation of this fatal error. We see that the earth, from the commencement, has undergone an entire change, embracing a great variety of revolutions; — and that it has been, from time to time, the witness to a multitude of distinct acts of creation, by which all the races of animal and vegetable life have been successively brought into existence, is clearly demonstrated by geological researches. "We conceive it undeniable," says an able writer, "that we see, in the transition from an earth peopled by one set of animals to the same earth swarming with entirely new forms of organic life, a distinct manifestation of creative power, transcending the operation of known laws of nature; and it appears to us that geology has thus lighted a new lamp along the path of natural theology."

"If I understand geology aright," says Professor Hitchcock, "so far from teaching the eternity of the world, it proves more directly than any other science can, that its revolutions and races of inhabitants had a commencement, and that it contains within itself the chemical energies, which need only to be set at liberty, by the will of their Creator, to accomplish its destruction. Because this science teaches that the revolutions of nature have occupied immense periods of time, it does not, therefore, teach that they form an eternal series; it only enlarges our conceptions of the Deity."

GEOLOGY IN REFERENCE TO THE SCRIPTURE HISTORY OF THE CREATION. — We have already stated that geology calls upon us to reject the ancient chronology of the earth, founded, as has been supposed, upon the Mosaic record; but does it follow that the Bible itself falls to the ground? This is a question of deep interest, and deserves to be carefully considered.

When the discoveries of geology first began to be proclaimed, they were seized upon by infidels, and those who wished to discard the authority of a revelation from God, as instruments by which to impugn the veracity of the Scriptures. The account of the creation given by Moses, said they, cannot be true; for here are contradictory records of the earth's formation written in the very rocks of which our globe is composed. So bold a charge, and the seeming plausibility with which the arguments advanced were urged, made many a pious person look with prejudice on a science, which, it was claimed, struck so deadly a blow against the faith and dearest hopes of man. But in this case, as in every similar one, in the further prosecution of investigation, the defenders of revelation have been enabled to wrest from the hands of foes the weapons aimed at their shield, and to turn these against them. Cuvier, in his work on the revolutions upon the surface of the globe, clearly demonstrated the truth of the Bible, and boldly proclaimed it before the French *savans* who had ventured to attack it. Others have followed in his track, — as Buckland, J. P. Smith, Hitchcock, Silliman, &c., — sustaining the veracity of the Scripture account, and suggesting various methods by which the apparent discrepancies of the record with the facts discovered may be reconciled. We shall here give a brief summary of their views.

It may be laid down, as a general principle on which all reasoning on this subject must rest, that revelation does not profess to teach us the principles of science. The usual language of popular speech is employed; the Bible speaks, as we all do, of the sun's rising and setting, and of various things, which, viewed with strict philosophical accuracy, are altogether at variance with fact. No one, however, is deceived by this use of language.

There is, too, a general agreement between the Bible and geology, as to the agents employed to produce changes on our globe, — fire and water. They agree, also, in representing a primitive chaos, when the land was submerged and upheaved by the power of God; as well as in describing the work of creation to have been progressive; and that man was the last of the created inhabitants of the globe. They agree further in the fact, that the commencement of the existing races on the globe was at a comparatively recent period; not exceeding, it is probable, about six thousand years.

It deserves to be borne in mind here, that the object of the Bible is, to treat of subjects relating to the present race of man, and the creatures by which he is surrounded. In perfect consistency with such a design, there might have been many races previously; and if there are no other difficulties than on this score, these surely present no insurmountable obstacles.

But the supposed discrepancies deserve some consideration. They relate especially to the age of the world, and the period at which death was first introduced upon the globe. Immensely long periods, it is claimed, must have intervened; several successive systems must have preceded the present one; whereas the Mosaic account of the creation represents the matter of the globe to have been produced out of nothing in the course of only six natural days, and that all animals and plants were then brought into existence. If, however, methods can be suggested by which these difficulties can be obviated, they must be allowed to have no force, or to deserve no further regard.

In the first place, it is possible — though not, indeed, probable — that the rocks which contain fossils were not the result of slow deposition, but, with all their organic remains, were created just as we find them. It is also claimed — which, likewise, is improbable, though possible — that most of the changes discovered may be referred to the deluge of Noah. The shortness of the period that has elapsed since that event; the evidences of tumultuous action of the waves; as well as the existence of organic remains differing from those of present animals and plants, are considered as strongly militating against such an explanation. Similar remarks may apply to the hypothesis which refers the changes to the period between the creation and the deluge.

Others have attempted to show that the six days mentioned in the Mosaic account were not literal days, but periods of indefinite length, and may have been thousands of years. The turning of the earth on its axis is conceived by some to have been at first "inconceivably slow," and that the present rate was not obtained, till, at least, the fourth day. While it is admitted that the word *day* is sometimes used figuratively in the Scripture for an indefinite period of time, we must, however, say, there is no evidence that it is so used in the first chapter of Genesis. The description, there, is a simple, plain history, designed and adapted to uncultivated minds, and to give a view of events as they took place. The reference in the fourth commandment to the work of the creation in six days is one which deserves serious consideration, and is at variance with the hypothesis now under remark. The facts in the case are strongly opposed to such a view. If the Mosaic account include the fossil species, it does not the existing ones; and if it embrace the latter, it cannot the former.

Some very able writers have maintained, that the Mosaic account is rather intended as a pictorial representation of successive periods of the different parts of the creation, founded in the truth, but still not to be regarded as literally or exactly true. If admissible on other principles, this theory would afford a solution for the apparent discrepancy between geology and revelation, as it allows a sufficient period of time in the different epochs supposed.

The common method of explanation has been, however, to suppose, that in the first verse of Genesis Moses states the creation as having taken place *in the beginning*, without fixing the date, and then passing in silence over the intervening period, during which extinct animals might have lived and died, he describes the present creation, or rather reorganization, as it took place literally in six days. This would reconcile the apparent discrepancies, without doing violence to the language of the Scripture; and any seeming difficulty respecting the creation of the heavenly bodies is easily explained, on the supposition that Moses means nothing more than to describe the particular use of those bodies to our own globe, as designed for the residence of man, under the present system. Dr. John Pye Smith, in a recent able work "On the Relations between the Holy Scriptures and some Parts of Geological Science," has proposed a modified view of the last mentioned theory, which seems to have been well received by able geologists, as well as the Christian public.

His positions, as given by Professor Hitchcock, are as follows. 1. The first verse of Genesis describes the creation of the matter of the whole universe, probably in the state of mere elements, at some indefinite epoch in past eternity. 2. The term *earth*, as used in the subsequent verses of Genesis, describing the work of six days, was "designed to express the part of our world which God was adapting for the dwelling of man and the animals connected with him." 3. The narrative of the six days' work is "a description, in expressions adapted to the ideas and capacities of mankind in the earliest ages, of a series of operations, by which the Being of omnipotent wisdom and goodness adjusted and finished, not the earth generally, but, as the particular subject under consideration here, a *portion* of its surface for most glorious purposes. This portion of the earth I conceive to have been a large part of Asia, lying between the Caucasian ridge, the Caspian Sea, and Tartary, on the north, the Persian and Indian Seas on the south, and the high mountain ridges, which run at considerable distances, on the eastern and western flank. This region was first, by atmospheric and geological causes of previous operation under the will of the Almighty, brought into a condition of superficial ruin, or some kind of general disorder." Probably by volcanic agency it was submerged and covered with fogs and clouds; but was subsequently elevated, and the atmosphere, by the fourth day, rendered pellucid. 4. The sun, moon, and stars were not created on the fourth day; but then "made, constituted, or appointed, to be luminaries." 5. The Noachian deluge was limited to that part of the world occupied by the human race; and therefore we ought not to expect that any traces of it on the globe can now be distinguished from those of previous and canlogous deluges.

These positions Dr. Smith sustains with much powerful reasoning and accurate philology; and the view is conceived to correspond to many particular facts relating to the creation, which are mentioned in the Bible, as well as to others developed by geological research. It should likewise be remembered, that, in the further progress of discovery, the seeming difficulties may be further obviated, as others have already been, both as regards astronomy and other sciences, including geology itself.

The *second* difficulty alleged relates to the supposed statement in the Bible, that death did not exist in our world among inferior animals, till after the creation of man. The fact, however, is not so stated; for the reasoning of the Apostle, from which it is professedly drawn, relates to man, a moral being, by whom sin was introduced into the world. The wonders of the microscope have shown that the air, the water, every thing, teems with life; consequently, life must have been destroyed soon after the first existence of the various creatures; and without a constant miraculous interference with the laws of nature and the established course of Providence, death was unavoidable.

THE END.