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Basaltic Columns at Regla, Mexico.

RECREATIONS

IN

GEOLOGY.

BY ROSINA M. ZORNLIN,

AUTHORESS OF

RECREATIONS IN PHYSICAL GEOGRAPHY.

SECOND EDITION, WITH ADDITIONS.

LONDON:

JOHN W. PARKER, WEST STRAND

M.DCCC.XLI

LONDON:
HARRISON AND CO., PRINTERS,
ST. MARTIN'S LANE.

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PREFACE.

Geology may be considered as one of the most attractive and popular sciences of the present day. The great progress made in this science within the last few years, and the extraordinary and important facts brought to light by recent investigations, render the subject deeply interesting to all who delight in the study of nature, as also to those who may be desirous of benefiting by the mineral treasures of the earth. But there is another numerous class, to whom Geology is particularly attractive—to such as, without much knowledge of science, and with no economical end in view, engage in the pursuit merely as a recreation. The search for fossil remains has so much in it that is fascinating; the delight of meeting with rare, or even with well-known organic remains is so great; the possibility (open to all) of discovering some new species,—some new link in nature's chain,—so full of hope and expectation, that this science possesses a zest to which few others can lay claim.

To the latter class of observers, as well as to those who have hitherto bestowed no attention on the subject, this little work is more especially addressed: it having been the object to present the leading features of Geology in a simple and concise form: embracing a systematic arrangement (as far as at present determined) of the rocks and strata of the earth's crust, and a general view of its fossil organic contents.

In treatises on Geology, the *descending* series, or commencing from the latest geological period, is very usually adopted: but the highly interesting views afforded by the successive introduction (in organic nature) of genera and species gradually drawing nearer and more near to existing races of creatures, as we approach the era of man's creation, have induced the writer to make choice of the *ascending* series; and to conclude with some account of the Recent Period.

In the Preliminary Discourse, an attempt has been made to call the reader's attention to the nature and advantages of Geology, with the view of rendering the subject more interesting to all; and in the hope that, should this little treatise fall into the hands of any who consider this science as trivial and unimportant, such may be led to regard it in a light more in accordance with its actual value.

It would have been highly satisfactory to have referred to the various authorities consulted in this work. It has, however, been deemed advisable to avoid the numerous references which this would necessarily have entailed. The Author, therefore, must rest contented with a general acknowledgment of the obligation due to the valuable works of Adolphe Brongniart, Buckland, Cuvier, Ehrenberg, Lyell, Mantell, Murchison, Phillips, Sedgwick, Whewell, &c.; as well as to numerous other authors who have made important communications to the Geological Society, Royal Society, British Association of Science; to the London and Edinburgh Philosophical Magazine, the Magazine of Popular Science, Geographical Journal, &c., &c.

In offering to the public a new edition of "RECREATIONS IN GEOLOGY," no further notice will be required, than a brief intimation that such additions have been made to the work, as recent discoveries, and the progressive state of the science, have appeared to demand.

R. M. Z.

January, 1841.

ILLUSTRATIONS.

PRELIMINARY DISCOURSE
ON THE NATURE AND ADVANTAGES OF GEOLOGY.

We not to explore the secrets ask
Of His eternal empire, but the more
To magnify His works, the more we know.—MILTON.

THE highest aim to which the human mind can be directed, is the investigation of truth; such may be considered as the proper object of all Science, more especially when applied to the study of the works of nature. And if, in this delightful pursuit, we regard nature as "a rich storehouse for the glory of the Creator," we shall be led to the perception not only of truth, but of Supreme Goodness: for "certain it is that truth and goodness differ but as the print and the seal; for truth prints goodness." An acquaintance, however small, with natural philosophy, must fill our minds with awe and admiration of the Divine Author of all things: an increased knowledge of the book of nature tends to the confirmation of every feeling of true devotion: and, as has been justly remarked, "in every age the evidences of revealed religion have advanced with the progress of sound knowledge; indeed, it cannot be otherwise, for the God of nature, whose operations it is the province of science to explore, is the God of the

Bible; and both systems of knowledge, thus emanating from the same source, must harmonize with each other*." Therefore,—to adopt the language of one, who, from his having been the first to lead to the interpretation of those laws which nature has received from the hands of her Creator, has been styled the *Father of Philosophy*,—"let none think or maintain that a man can search too far, or be too well studied in the book of God's word or the book of God's works; but rather let men endeavour an endless progress and proficiency in both;—only let them beware that they apply both to charity†."

"Curiosity," it has been well observed, "is one of the most distinctive faculties of the human mind; one of those which establish a marked separation between man, and the rest of the animal creation:"

> ——— For of all
> The inhabitants of earth, to man alone
> Creative Wisdom gave to lift his eye
> To truth's eternal measures.

But though curiosity, or the love of investigation, is one of man's best faculties when directed to an end really worthy of him, it is capable of being misdirected and misapplied. It becomes, therefore, of paramount importance that this principle, so active in all intelligent minds, should be guided into channels, where it may not only find free scope for

* Rev. J. Williams' *Missionary Enterprises*.
† Bacon's *Advancement of Learning*.

its exercise, but the most exalted ends for its ultimate object. Such are "the sacred paths of nature and of science." The grandest discoveries, and the inventions of the greatest use to mankind,—the sublime truths of astronomy, electro-magnetism, the steam-engine, the telescope, the microscope,—are all the result of long-continued research, ennobled by their object; and the same principle is still stimulating us to extend the range of our knowledge, and to fathom the hidden mysteries of nature.

In modern times, science appeared to have made such great progress, that we scarcely could have expected any new track would have been opened, equally rich in discoveries with those disclosed by the telescope or by the microscope. Yet the investigation of the ground we daily tread under foot, has, during the last half century, in the hands of Smith, Cuvier, and a host of other scientific men, become a science peculiarly fertile in novelties, not only deeply interesting to the geologist, but strikingly attractive to all who look with wonder and curiosity on the visible works of the Creator.

Geology, indeed, may be regarded as a science necessarily dependent on the advanced state of the natural sciences; for its conclusions have only been established by these means, and it can scarcely be said to have existed as a science, until chemistry, zoology, botany, and mechanics, were applied to the explanation of the phenomena it presents. A general acquaintance with science is, therefore, of the greatest possible advantage to the geological student. Yet, nevertheless, to those unpossessed of these acquirements, geology may form a highly engaging pursuit; for it is a science of observation, and is directed to objects immediately within our reach,—to the rocks and cliffs on the sea-shore; to the beds exposed to our view in the excavations of a road; to the very pebbles scattered in our path*,—all of which will derive an infinitely higher interest, if regarded with reference to the phenomena of geology, and to those changes which have been instrumental in imparting to them their actual form, or present arrangement.

Sir John Herschel tells us, that "geology, in the magnitude and sublimity of the objects of which it treats, undoubtedly ranks in the scale of the sciences next to astronomy." To those who are in some measure acquainted with the immensity of the field into which astronomy guides her votaries, but to whom geology is as yet "a sealed book," this assertion may appear to assign too exalted a station to the latter science. The distances treated of in astronomy are so immense, and the time required for the completion of some of the celestial cycles so vast, that they elude the grasp of our comprehension: "What, then, is there in geology," may such in-

* The Author has, not unfrequently, met with well preserved fossils among the pebbles of a garden gravel walk.

quire, "to compete with the myriads of years to which astronomy directs our attention?" To this the geologist will reply, that by careful researches into the rocks and beds of the earth, we learn that periods approaching to, if not equalling, the myriads of years of the astronomer, have apparently been required for the accomplishment of all the changes on the surface of the globe. And if geology may yield to astronomy in the vastness of the space over which it ranges, and in the former science our views are confined to the observation of only a limited portion of one small planet, the indications it displays of the Mighty Hand that rules the universe, are scarcely less striking, and perhaps fully as impressive, from their capability of being brought more immediately under our own inspection.

The difference between the sciences of astronomy and geology may be compared to that of the discoveries effected by the telescope and the microscope:—the one reveals to us objects of vast magnitude concealed from us by their immense distance; the other discloses objects hidden from us by their almost incomprehensible minuteness. Thus whilst astronomy leads us to the contemplation of

——— An infinite of space,
With infinite of lucid orbs replete:
* * * * *
In motion all, yet what profound repose!
What fervid action, yet no noise! as awed
To silence by the presence of their God:—

whilst astronomy speaks of boundless space and boundless time, and geology describes a comparatively circumscribed area, telling us of change and mutability:—yet the one, no less than the other, displays the wisdom, power, and goodness of

Nature's Controller, Author, Guide, and End.

Geology shows us that "the configuration of the earth's surface has been re-modelled again and again; mountain chains have been raised or sunk; valleys have been formed, again filled up, and then re-excavated; sea and land have changed places. Yet throughout all these revolutions, animal and vegetable life has been sustained: these changes in the condition of the earth, having been accompanied by corresponding changes in organic bodies, adapting them to those altered conditions;—the succession of living beings having been continued by the introduction into the earth from time to time of new plants and animals, evidently admirably adapted for successive states of the globe. Had it been otherwise, had they been less fitted for each new condition of things, they would not have increased and endured for indefinite periods of time; a fact proved by the myriads of fossil remains preserved in strata of all ages*."

It being, then, an ascertained fact, that we

* Lyell's *Anniversary Address to the Geological Society*, 1837.

repeatedly see the commencement of new races, we are obliged again and again to have recourse to a supreme Intelligence and a creative power. "If we examine the marine remains of the strata, we find that whole genera of shells, which in the present seas are most abundant in species, were not in existence till after the chalk was deposited. Other genera again originated about the middle of the series, and soon became extinct, being represented by no species in the Tertiary strata, that is, the strata above the chalk. These new creations supplied the place of other races which perished; for some genera are peculiar to the lower groups of rocks, not a single species of them occurring higher in the series than the coal-measures. There are a few, and but a few, genera, which, commencing in the lowest fossiliferous strata, have endured through all the changes to which the earth has been subject, and have species existing in the present seas. The changes which occurred in the organization of fishes appear to have been greater and more rapid, and exhibit a wider difference between those found above and below the chalk, than is observable in the case of molluscs.

"The same proofs of organic changes are afforded by the study of fossil botany. The formations containing vegetable remains may be arranged, according to Professor Henslow, in four groups, representing epochs, during any one of which no very marked difference is observable in the general character of the vegetation: but between any two of these groups the change is striking and decided, most of the genera being different, and none of the species alike. The character of the fossil vegetation of the earlier epochs is also such as to warrant the conclusion, that the plants of that epoch grew under a climate both hotter and moister than that of any part of the earth at present.

"We can scarcely be said, at present, to have sufficient data for determining what were the animals inhabiting the land while the earlier strata were being deposited at the bottom of the sea. It is evident that some of our oldest rocks have been derived from the waste of pre-existing land; and, as that land appears to have been clothed with its appropriate vegetation, we have no right to suppose that it was destitute of its appropriate animals. A great ocean like the Pacific, interspersed, like it, with small islands, appears to have prevailed, during the formation of the older strata, over that part of the Northern Hemisphere in which are situated those countries whose geology has been most explored. Small oceanic islands do not, at the present day, contain many mammalia, while they are wholly destitute of the larger kinds; and the discovery of such remains, in an oceanic sediment, after its conversion into dry land, must be an event of very rare occurrence; for, however abundant mammalia might be on some distant continent, by the rivers of which their carcases would be drifted down, yet before they could be floated out far to sea, they would be almost certain to be devoured by the carnivorous monsters of the deep; and even supposing them to escape this fate, the chances are very much against the discovery of the spot where these rare remains are concealed, after the bed of the ocean shall be laid dry.

"But whether mammalia existed during the earliest epochs of the world of which we possess geological monuments, and were contemporary with those marine animals imbedded in the lower strata, though, for the reasons above stated, their remains have not yet been discovered; or whether they were not created till a later period, though still before the deposition of the chalk, it is certain that during the tertiary era, when their remains were abundantly entombed in the strata, we can trace the introduction of new races even of those animals. The remains of the land quadrupeds imbedded in the olden tertiary strata, are chiefly those of extinct *genera.* In the deposits of a more recent period we meet, in these northern latitudes, with the remains of extinct *species* of genera now existing, but existing only in warm climates, such as the elephant, rhinoceros, hippopotamus, &c. And at length we come to peat bogs and alluvial deposits, in which human remains occur, mixed with those of animals now living

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in the countries where the remains are found, together with a few which have become locally extinct, within the historic period. The animals that have become locally extinct in Britain are, the wolf, the beaver, and the wild boar.

"But if the earth's crust furnishes us with evidence, that great and repeated changes have taken place in the organic and inorganic world, it furnishes us with proofs no less clear, that great epochs of time elapsed while these changes were in progress,—epochs so great, that we are tempted to connect them with the secular periods of astronomy to which we have before alluded. There is, however, this difference between the phenomena of astronomy and geology; that in the former, we have a series of events recurring, in a fixed order, after the lapse of fixed intervals of time, whereas in geology, (if we except the interchange between land and sea, and the recurrence of volcanic action after long intervals of repose,) we have no evidence of the repetition of a single phenomenon; much less have we evidence of geological cycles, in which the same events are repeated, again and again, in a stated order, and at stated intervals. Thus, whole orders of fishes, characteristic of the older strata, become extinct, and are succeeded by new races, which in their turn give place to others; and this class of vertebrated animals affords an unbroken record, from the earliest to the most recent geological epoch; the changes which occur in it being more rapid than those which take place among invertebrate animals; but as we ascend in the series of strata, we meet with no instance of the revival of any of the extinct genera or species.

"When the Copernican system of astronomy was established, and the earth, no longer regarded as the centre of the universe, was proved to be one of a system of bodies revolving round the sun, the question naturally arose, were the other bodies of that system habitable and inhabited; and, reasoning from analogy, astronomers were disposed to answer the question in the affirmative. It was true, that as regards the distribution of light and heat, and the intensity of gravitation, a very different state of things must prevail in most of those planets from what obtains on the earth; but since every part of this earth was crowded with sentient beings, possessing an organization so adapted to the conditions of existence assigned them, as to render that existence a state of enjoyment, it appeared highly improbable that all the variety here displayed should be limited to one planet, and that all the others should be mere blanks, made only to be gazed at by us, and destitute of beings suited to their respective states. And when the modern researches of astronomy extended to the fixed stars, showed them to be suns, like that which forms the centre of our system, and it was found that they were arranged in groups circling round each other,—the argument from analogy was carried further, and the probability was inferred that each of these suns might be attended by its system of planets, with their satellites, the whole teeming with life under a countless variety of forms, and under a countless variety of conditions. Geology comes in aid of these conjectures, by showing that this our planet has existed under a different distribution, of land and sea, of heat, and perhaps of light, from that which it at present enjoys; and that, under these different circumstances, it was not a mere blank, but was as much crowded as now, with living beings adapted to the then state of things.

"If we apply ourselves to the task of classifying organized bodies now existing, arranging them in groups as they differ from or resemble each other in their structure, we find that those forms of each group which are most dissimilar, are connected by a series of gradations, separated from each other by the most minute distinctions, and that the groups, whether we regard the larger or the subordinate divisions, are again connected by forms possessing some of the characteristics of two groups. There are, however, cases in which the transitions are more abrupt; and when these cases occur, we frequently recover, among the extinct forms of an ancient state of nature, those connecting links which are wanting in the existing creation. As instances, we may mention the ichthyosauri, as combining some of the characters of a lizard with those of a fish, and occupying among saurians the place of the whale and seal among mammalia; and the pterodactyles, which bore the same analogy to lizards, that the bat now bears to mammalia. The pachydermatous* order of mammalia, as existing at present, consists of but few genera,—the elephant, rhinoceros, hippopotamus, horse, hog, and tapir, genera possessing but slight resemblance to each other, and singularly poor in species. The tertiary strata of the Paris basin abounds, however, in remains of extinct animals of this order, supplying gradations between some of the above genera, and connecting this order with others. Similar instances might be adduced from other divisions of the animal kingdom; and others are afforded by a comparison of fossil and recent vegetation†."

A very close analogy is thus found to exist between extinct and recent species, so as to leave no doubt on the mind, that the same harmony of parts and beauty of contrivance which we admire in the living creature, has also characterized the organic world at remote periods.

For all are equally
A link of Nature's chain
Formed by the Hand that formed me,
Which formeth nought in vain.

"The geologist, therefore, can bring new and original arguments to bear upon those parts of natural theology which impress us with exalted conceptions

* Thick-skinned. † *Magazine of Popular Science.*

of the intelligence, power, wisdom, and unity of design, manifested in the creation.

"That the most perfect unity of plan can be traced in the fossil world, through all the modifications it has undergone, is admitted by all geologists; and also that we can distinctly carry back our researches to times antecedent to the existence of the human species. It can be proved that man had a beginning, and that all the species now contemporary with man, and many others which preceded these races, had also a beginning. And thus, as we increase our knowledge of the inexhaustible variety displayed in living nature, and admire the wisdom and power which it displays, geology will incalculably increase our admiration of the works of creation, by suggesting the reflection that the present order of things is only the last of a great series, of which we cannot estimate the number or the limit in the past ages of the world*."

Form of the Globe.

The terrestrial globe, it is well known, has the form of a spheroid, a little flattened at the poles, the *radius* of which, or the distance from the external surface to the centre, is about 3950 miles. Most persons, perhaps, who have at all reflected on the subject, have felt some curiosity to know whether the earth is similarly constituted throughout the

* Lyell's *Anniversary Address*, 1837.

whole extent of its depth; whether rocks and strata, analogous to those on its surface, still continue to occur; or whether at a certain depth, one uniform substance occupies the whole of the interior. This inquiry, in former times, led to various fanciful hypotheses, some geologists having supposed the interior of the earth to be filled with water, others with gas, others with enormous masses of loadstone, and others with metals in a solid or a liquid state. The utter impossibility of penetrating to these enormous depths, renders personal observation wholly out of the question. How then can information be obtained? Here astronomy and general physics come to our aid, furnishing us with data by which we are enabled to form some general conclusions regarding the figure and density of the earth.

The earth, it appears, has acquired its present figure under the joint influence of gravitation to its present centre, and rotation on its present axis. If the whole mass of the globe were *solid*, no accommodation or change of form could take place; but if the globe was formerly, or is at present, either wholly, or in great measure, fluid in the interior, the spheroidal form would necessarily result: we must therefore suppose that some of its parts are or have been yielding or fluid. If, then, the mass of the globe were "internally fluid and externally solid, the crust or solid part might, upon such change, yield in various directions, and produce local irregularity of land and water, and the surface becoming subsequently hardened, the form, once acquired, might be almost invariably preserved*."

By direct experiments, the mean density of our planet has been inferred to be about five times that of water; and it thus appears that the interior parts of the globe must be heavier than that of the exterior rocks, the density of which is about two and a half times that of water. We might therefore at first be led hastily to conclude that the interior of the earth could not be in a fluid state. But by the laws of compression or pressure, as observed at the surface of the earth, we find that without some counteracting cause, the weight or density of metals, rocks, fluids, and gases would be immensely increased at great depths in the interior of the earth. Thus in the centre of the earth, steel would be compressed to one-fourth, and stone to one-eighth of its bulk; water, at the depth of three hundred and sixty-two miles, would be as heavy as quicksilver; and air at that of thirty-two miles, would be as heavy as water. What, then, is this mighty counteracting cause? There is every reason to believe that it is the expansive force of HEAT.

HEAT OF THE GLOBE.

The solar rays are the principal source of heat on the surface of the globe, the temperature varying in

* PHILLIPS' *Treatise on Geology.*

relation to the amount of these rays, and consequently decreasing from the equator to the poles. The temperature also varies with day and night, and with the seasons of the year. At a certain depth below the surface, nowhere exceeding one hundred feet, these variations become insensible, and the temperature is constant, or fixed, being nearly the same as the mean temperature at the surface.

If from this point of equable temperature, we find a gradual *decrease* of heat as we dig deep into the earth, we must necessarily conclude that the interior parts are colder than the surface, and that there is no reason to imagine the earth to have any other heat than that derived from the solar rays. But if, on the contrary, it be found that as we descend into the earth, an *increase* of temperature occurs, we cannot but admit that the earth has a proper or inherent temperature derived from internal sources. Experiment proves the latter to be the case.

These trials to determine the internal heat of the earth have been made at various depths, and under different circumstances—in artesian wells, salt-pits, coal-works, and mines of different metals; and it appears to be fully ascertained, that in situations far removed from volcanic action, and in different kinds of strata, water, air, and rocks continually grow warmer as we descend in the earth. Without a single exception, the interior of the globe has been found to be warmer than the surface; and the heat augments constantly with the depth; the mean, or average increase, being one degree of Fahrenheit in forty-five English feet. Indeed, the heat in some deep mines becomes so oppressive, that the miners can, with difficulty, pursue their labours.

Such being the case, it will be evident, if the same ratio of increase continue, that the heat at considerable depths in the interior of the earth must be most intense, acting as the mighty counteracting cause before alluded to, which prevents the compression of the materials in the interior of the earth. The notion of an incandescent mass in the interior of the earth is startling to many, and not without discomfort to some; but so far from finding in this any cause of alarm, a further consideration of the subject will declare to us, that the preservation of the world in its existing state is probably dependent on this powerful agent.

> Thus, in thy world external, Mighty Mind,
> Not that alone which solaces and shines,
> The rough and gloomy too demands our praise.
> The winter is as needful as the spring,
> The thunder as the sun.

The temperature at the surface is, as has already been observed, dependent on solar radiation; and the rocks in the upper strata of the earth are such bad conductors of heat, that no sensible effect appears to be produced at the surface by this internal heat. It may, and probably has, sufficient influence, to prevent the refrigeration or cooling of the earth beyond the present temperature at the surface, and thus may act its part in adapting the earth for the present races of organized beings. But we must remember that this intensely heated mass in the interior of the globe is no new condition of things, but that if it exist, it must have existed for many centuries, probably from the era of man's creation. For it appears, there is no reason to conclude that any change has taken place in the climates of the earth since the earliest historical records; and astronomy informs us that the general temperature of the mass of the globe has not varied one-tenth part of a degree for the last two thousand years. This is proved by calculations of the moon's motion. All solid rocks, except clay, expand when heated, and were the heat of the globe increased, its diameter would be augmented and its motion retarded. If, on the other hand, the heat of the globe were diminished, this motion would be accelerated; and thus we may be led to the conclusion that so far from being an element of destruction, the very continuation of the earth in its present state may be dependent on this internal intensely heated mass, ordained for this purpose by an all-preserving God.

It has, however, been supposed that the internal temperature of the earth may have been considerably greater in ancient geological eras; and that by the greater heat thus at those periods communicated to the surface, even the frozen regions of the present day may have been capable of sustaining races of organic beings, found in those parts in a fossil state, but whose modern representatives only inhabit the hottest regions of the globe.

General Arrangement of Strata.

On examining into the structure of the earth's crust, (as that small portion of the exterior of the globe accessible to man's observation is termed,) we discover in all parts a series of mineral masses evidently not scattered and mixed at random, but arranged in much order, and frequently spread over areas of considerable extent. And though, in some cases, we find that the original position of these mineral masses has undergone great subsequent disturbance, proofs of the order that once prevailed may be distinctly observed.

The greater part of these mineral masses, which constitute the rocks and beds or strata of the earth, are evidently composed of matter deposited by, or accumulated under water, formed in a manner similar to that which is constantly in progress at the present day, in the beds of rivers, lakes, and in the ocean. In most instances the water carries down sand, clay, and other sedimentary matter, which sinks to the bottom, and banks and shoals are formed. These, at least such as come under our observation, are usually of small extent; whilst the different groups of strata of the ancient world are mostly on a scale of great magnitude. Thus we find masses of limestone several hundred feet in thickness, and in other places vast beds of sand or of clay. An examination of sandstone rocks leaves no doubt that they have experienced the agitation of water; such are called sedimentary deposits. Some limestones yield evidence of similar agitation, but others appear to be *aggregates* or *aggregations* of particles of carbonate of lime, slowly deposited from water holding that substance in solution.

It will be evident that if we find a series of horizontal strata of sedimentary origin, the uppermost bed must be of later formation than those which are beneath; some instances occur, indeed, where by convulsions of extraordinary violence, the original position of the strata has been actually reversed; but such instances are rare, though it is by no means uncommon to meet with strata thrown into an inclined position.

These strata are all characterized by their peculiar fossils, the greater part being full of the remains of marine exuviæ, exactly as we might expect to find the bed of the ocean at this day filled with the exuviæ of now existing or lately perished animals. In each system of strata lie entombed the remains of different races of beings, all successively buried in marine or fresh-water sediments, (the latter being of much rarer occurrence,) on the same area or surface, forming "a series of monuments" which mark the numerous changes of organic and inorganic nature*.

It appears, therefore, that the greater part of the present continents at some former period existed in a sedimentary form at the bottom of the sea. But to have become so consolidated as they are at present, these formations must have been subjected to some other condition, some other agent must have been at work. This agent is supposed to be subterranean heat, acting upon the various substances of which the rocks are composed, either whilst under the pressure of super-incumbent or overlying rocks, or that of a deep ocean†.

These sedimentary rocks, though apparently modified by heat, are evidently of *aqueous* origin, or formed by water; but there is another class of rocks which appear to be of *igneous* origin, or formed by fire, or heat. Among these rocks are granite, trap, lava, &c. All these igneous rocks present the ap-

* The introduction of the important doctrines, that during the formation of the successive stratified rocks which compose the crust of the earth, the races of animals and plants were often and completely changed, is due to Mr. William Smith. This distinguished geologist, who commenced his career as a surveyor of land, was justly the first to whom the Geological Society of London awarded the gold medal for geological services, bequeathed by Dr. Wollaston. Mr. Smith commenced his geological observations in 1790, and received this medal in 1831.

† The application of this principle is due to Dr. Hutton.

pearance of having been in a state of fusion, and as they all either form the lowest of the series of rocks, or have apparently been ejected from an unknown depth below, in a melted state, as is the case with existing volcanoes, they corroborate the opinion of great central heat.

These various formations occur in all parts of the globe, though they have hitherto been principally studied in Europe and in North America. Great Britain is singularly prolific in an extensive range of geological formations, and it has been prettily said, "As if nature wished to imitate our geological maps, she has placed in the corner of Europe, our island, containing an *index series* of European formations in full detail*." Indeed, the series of British strata represent very well the succession of stratified rocks not only in Europe, but also in part of Africa, Asia, and North America, the agreement being very close in those parts which are nearest to the British islands, and being vague and indefinite as the distance increases. The greater number of recognized stratified rocks occur in this island, and though volcanos are unknown, igneous rocks belonging to the granite and trap formations are met with in some parts; and few districts of such comparatively small area, perhaps, present so complete an assemblage of the successive geological groups. This is a fact of much interest to the British student of geology, who thus

* WHEWELL'S *Anniversary Address*, 1839.

may have it in his power to study all these formations in his native land. They do not, however, occur equally in all parts of the island, and should our attention be confined to a limited district, we might very possibly find the number of strata exceedingly limited.

It has been amusingly remarked, that "If a stranger were to land in Cornwall, and after traversing the whole extent of that county and of North Devon, and crossing over to St. David's, were to make the tour of North Wales, and from thence passing by the Isle of Man, through Cumberland, to the south-western shores of Scotland, should proceed either through the border counties, or along the range of the Grampians to the German Ocean, he would conclude from such a journey of many hundred miles, that Britain was a thinly peopled, sterile region, whose principal inhabitants were miners and mountaineers.

"Another foreigner, arriving on the coast of Devon, and crossing the midland counties, from the mouth of the Exe to that of the Tyne, would find a succession of fertile hills and valleys, thickly overspread with towns and cities, and in many parts crowded with a manufacturing population, whose industry is maintained by the coal with which the strata of these districts are abundantly interspersed.

"A third foreigner might travel from the coast of Dorset to the coast of Yorkshire, over elevated plains of oolitic limestone, or of chalk, without a single mountain, or mine, or coal-pit, or any important manufactory, and occupied by a population almost exclusively agricultural.

"Let us suppose these three strangers to meet at the termination of their journeys, and to compare their respective observations: how widely different then would be the results to which each would have arrived respecting the actual condition of Great Britain* !"

These differences would have arisen from the peculiar geological structure of the different parts of our island. And in a similar manner, the student in geology, if he would become acquainted by personal observation with the various strata, must direct his course with due consideration, and not expect to meet with the whole series in a limited district, but only to accomplish it by extensive and judicious travel and research.

To this arrangement of the strata, perhaps the prosperity of Great Britain may, in a great measure, be attributed, for the three principal sources of national wealth,—mining, manufactures, and agriculture,—are thus combined in the small compass of this island,

> . . . . . . which stands
> As Neptune's park, ribbed and paled in
> With rocks unscaleable, and roaring waters,
> With sands that will not bear her enemy's boats,
> But suck them to the top-mast.

* Dr. Buckland's *Bridgewater Treatise*.

Geological Nomenclature.

By geological nomenclature is meant a system of names, that is, the adoption of technical and constant names for rocks and strata. Geology was long considered as only forming a branch of mineralogy, and many of the names bestowed upon rocks are arbitrary terms, at that period in use among mineralogists for special minerals. Such are the names of syenite, serpentine, porphyry, and granite. Others are words in use among miners, (introduced in Germany by Werner,) such as gneiss, grauwacké, zechstein, &c.

The nomenclature introduced by Smith was founded on English provincial terms of very barbarous aspect, as cornbrash, lias, gault, clunch clay, coral rag, &c. Yet these terms were widely diffused when his classification was generally accepted, and many of them at present form part of the geological language of the whole civilized world.

Another kind of names which has been very prevalent among geologists is that borrowed from places. Thus we meet with the terms Alpine limestone and Jura limestone, Wealden clay, Purbeck marble, and Portland stone. These names can only be advantageously adopted when the peculiar formations to which the terms are applied, form exclusively the rocks in that particular locality.

In other instances descriptive names have been adopted. But the great variety occurring in the structure of rocks which belong to the same formation, renders this in most cases very indefinite, and descriptive names are only really useful in geology when they are applied without any scrupulous regard to the correctness of the description. Thus *red sandstone* may be either limestone or sandstone, it may be black, yellow, or gray, as well as red; *green sand* may be white, brown or red; *mountain limestone* may occur only in valleys, and oolite may have no roe-like structure. And yet these may be excellent names, if applied as mere terms to designate formations belonging to any particular geological division, and used as aids to the memory.

Mr. Lyell has given to the divisions of the tertiary strata the appellations *eocene*, *miocene*, and *pliocene*, according as they contain a small proportion of recent species of shells, a minority of such species, or a majority of living species. These terms are designed to express the relative ages of the groups, the pliocene being immediately antecedent to the *recent* or present period. And though the exact amount of the shells belonging to recent species found in all eocene, miocene, or pliocene formations, may not be the same, they constitute very useful divisions, on account of their being expressive of the interesting fact of the gradual approach, in this class of animals, to the existing order of things.

Many of the above terms, as we have already observed, have been adopted in the geological world.

But, though nothing can be more desirable than the establishment of a universal scientific nomenclature, there is some difficulty attending this adoption in the case of geology; especially in the more recent strata. For, although various formations which, (on account of certain coincidences, and from their bearing the appearance of having been the results of a similar series of events,) must be considered as geologically identical, are found to extend over large regions, the construction of these strata usually is not precisely similar; and "we may with more propriety consider them as two corresponding series, of which the members of the one may be treated as the *representatives* or *equivalents* of the members of the other*." As an instance we may mention that the term *cretaceous*, (derived from *creta*, chalk,) has been universally adopted as the designation of the latest secondary group; but though its equivalents occur in North America, no true chalk has been discovered in that region.

The divisions among stratified rocks, expressed by the terms *primary*, *secondary*, and *tertiary*, are capable of more universal application, if we consider the absence of organic bodies to constitute the separation of the primary from the secondary; and the presence of some species of recent shells to mark the commencement of the tertiary. The term *transition* is more vague, and probably, when further

* Whewell's *History of the Inductive Sciences.*

researches have been made in the rocks included in this class, it will be altogether exploded, and give place to additional subdivisions of the secondary period.

Other geological terms, such as *dykes*, *crop out*, *faults*, &c., are mostly derived from miners' language, and though there may be some uncouthness in these terms, they are perhaps less forbidding than some of the appellations conferred by modern science. The latter, however, are never adopted without having some reference to the construction of the body, organic or inorganic; and a great part of the apparent difficulty of such terms vanishes, when we become acquainted with the signification of the words of which they are formed. Thus the term ichthyosaurus, may, to the uninitiated, present a somewhat formidable appearance, if only regarded as so many letters strung together; but if we consider it as derived from *ichthus*, a fish, and *saurus*, a lizard; and as indicative of the nature of this remarkable creature, intermediate between a fish and a lizard,—the term becomes at once, not only simplified, but we acknowledge its utility. Some distinctive names must be bestowed on all newly discovered bodies; and though it may be highly desirable to avoid giving appellations which present a forbidding aspect, this is by no means an easy task, when it is the object, as it always should be, to express some peculiarity of the species or genus described.

THE UTILITY OF GEOLOGY.

The day is perhaps almost past, for questions to be mooted as to the utility of general science: its practical application has been of such importance, so available to various economical purposes, within the last half century, that on this subject we shall scarcely meet with a dissentient voice. The value of geology, however, on account of its comparative newness, and its being therefore less generally known, is, perhaps, less acknowledged than it merits. This has in great measure arisen from ignorance of its capabilities, in consequence of which a certain opprobrium was at one time cast upon it, as a science more calculated to amuse the speculative and curious, than to be applied to any practical purpose.

It has, however, risen superior to the calumnious assertions of its opponents, and fully vindicated its rights, and its utility begins now to be very generally admitted. It may be interesting to adduce a few special instances of its practical application; and in attempting this, we cannot do better than adopt the language of an eminent geologist, from whose writings we have already made some extracts.

"The geologist," he observes, "can confer on mankind benefits of no mean order; can assist the farmer to fertilize the surface of the earth, so that two blades of grass shall grow where one grew before; and can impart system to the labours of the miner, so that, no longer groping his way in the dark, he may prosecute with confidence and with an approach to certainty, those costly operations which are necessary, in order to extract from the earth the treasures which have been there stored up for our use.

"The mineral wealth of the earth has not been distributed through it at random; but each formation, (as geologists call a group of strata,) is, over extensive areas at least, the peculiar receptacle of certain minerals.

"In the present state of our knowledge, it is too much to affirm that these general rules prevail over the whole earth; but they hold good over extensive portions of the earth's surface, though, even within those areas, there are exceptions to the rule; and the study of the rule and the exception is alike profitable.

"Let us take for example the case of coal. Deposits of vegetable matter occur in formations of all ages, but they occur only in thin seams, and in small quantities. The great coal-deposit lies between two formations known by the names of the old and the new red sandstones, closely resembling each other in mineral composition, though very different in their zoological characters. The coal-fields of Brora, in Scotland, and of Whitby, in Yorkshire, can scarcely be called exceptions, though they are situated in a newer group of rocks, called the oölitic. For they afford an inferior kind of non-bituminous coal, worked only to supply a local demand. In communicating these facts we are obliged to anticipate the knowledge of our readers as to the order in which the strata succeed each other,—

Things by their names we call, though yet unnamed,

and therefore, perhaps, they can scarcely perceive the full import of these remarks. In that case, we must request them to return to the subject when they shall have become familiar with the names of the formations, and with their order of superposition.

"Now, the practical results to be derived from a knowledge of this general rule and its exceptions, are these: That searches for coal ought only to be undertaken with the greatest caution, and under peculiar circumstances, in strata beyond the limits of the regular coal-strata; though the working of them may sometimes be attended with success in districts which are ill supplied with coal from the coal-measures properly so called. The same remark applies to the lignite, or wood-coal, of the tertiary strata, which is wood partially carbonized, affording a very inferior fuel, which would never be used where the produce of the coal-fields of Newcastle, or Staffordshire, or South Wales, could be easily obtained. In England, which is so abundantly supplied with coal of the best description, lignite occurs but sparingly; but on the Continent it is sometimes largely developed, and extensively worked.

"Copper is not generally met with in strata more recent than the old red sandstone; but there are in England some exceptions to this rule:—the celebrated Ecton mine, in Staffordshire, and the Llandidno, or Orme's Head mine, in Caernarvonshire, being situated in the carboniferous limestone. On the Continent, the ore of this metal is worked in a formation even still more recent, the copper-slate of Thuringia being a portion of the new red sandstone series. The advantages to be derived by the practical miner from a knowledge of these facts are obvious. On the one hand, the general rule will prevent a waste of capital, in fruitless searches for certain minerals in strata where they rarely occur; and, on the other hand, the exceptions will prevent that slavish adherence to the general rule, which would prohibit all attempts to work them in those strata, when the indications are in other respects favourable; and Geology furnishes us with means for discriminating the different strata, and teaches us their order of succession; so that having ascertained to what part of the series a given rock belongs, we know what other rocks we may expect to find above and below it.

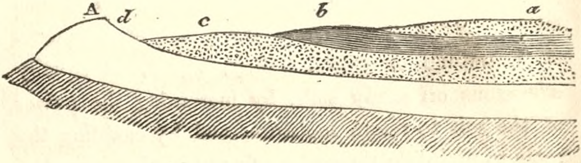
"Mineral veins, again, are not equally productive through all parts of their course, but masses, or 'bunches,' as they are called, of ore, are locally distributed through the vein, being connected by thin strings of ore, or by barren portions of the vein-stone, which are only useful as guiding the miner to the richer deposits. His object, therefore, is to arrive at the productive portions of the vein, with the expenditure of the least possible labour; and this object he attains by observing the circumstances under which these bunches occur in those particular veins on which he is employed, till, by repeated observations, he discovers the laws which they follow, and knows those parts of a vein which are likely to be most productive. But these laws are not the same in all mineral districts. If, therefore, we remove from any one of our most celebrated mining-counties one of its most experienced practical miners, and if we place him in another, where different laws for the distribution of ore in veins prevail, and where, though minerals may be abundant, those laws are not yet known by experience, because no mines have yet been worked; all his practical knowledge acquired from observations in his native district will avail him nothing, perhaps will become absolutely injurious, because it will be likely to prevent his paying attention to the suggestions of those who have studied mineral veins on a more general scale. This study forms one department of Geology, and the mine-agent who possesses most of it, is most likely to conduct mining operations with success. A person of this kind is too often branded by the ignorant with the epithet, 'theoretical,' whereas, he is in fact the really practical man, because he concentrates and combines in himself the knowledge derived from the observations of all practical miners in every part of the world.

"The benefits which Geology can confer on agriculture are neither few nor trifling. Our limits will not permit us to point out in detail how the nature of a soil depends on that of the rocks from the disintegration of which it was derived, nor to show how particular plants affect particular soils,—in which, in a state of nature, they exclusively flourish, and in which they flourish most in a state of cultivation; so that, by consulting a good geological map of a given district, we may predict, before we enter it, the species of crops which will be found most extensively cultivated there, and which experience has proved to be best adapted to it.

"A due mixture of the earths in a soil is essential to its fertility. The most productive districts of England have been made so by nature, and owe their fertility to this mixture; and it is by copying nature that we must proceed in our endeavours to improve those that are barren. Neither pure clay, sand, nor chalk, afford productive soils. Those are the best which contain a mixture of the three earths, silica, alumina, and lime, with a portion of decomposed animal and vegetable matter. These are the soils, so much coveted by the farmer, which will bear repeated cropping without manure. The principal ends proposed in agricultural improvement are, to render wet soils dry, and dry soils sufficiently moist; to render adhesive soils loose, and loose soils sufficiently adhesive; and the proportion in which the earths above mentioned should be mixed for these ends, must depend upon the climate and the substratum. Aluminous, or clayey, soils retain too much moisture, and siliceous, or sandy, soils part with it too rapidly; and a soil, good in itself, may be rendered unproductive by resting on too retentive or too porous a substratum. Draining or irrigation are in such cases the remedy. When one of the earths prevails in a soil to the exclusion of the others, great improvement may be effected by the addition of that which is deficient; and it is astonishing, as M. De la Beche has remarked, that the superior fertility observable along the line of junction of two rocks, occasioned by the mixture of their component parts, has not oftener induced agriculturists to have recourse to various artificial mixtures of the materials of rocks adjacent to each other. There are districts in which such mixtures have been practised with the greatest success; but, in general, farmers rely too exclusively on farm-yard manure. Clay, sand, and limestone, are, nevertheless, mineral manures of the greatest value, and have changed the face of whole districts that were before comparatively barren. By such mixtures the constitution of the soil has been improved,—causing the animal and vegetable manure afterwards applied to be more efficacious.

"The clayey lands of Essex have been greatly improved by the use of chalk. This acts upon the land in several ways. It decomposes any free acids, and some acids in combination, naturally existing in the soil, and which are prejudicial to vegetation; and it acts mechanically, by rendering the soil more pervious to moisture, and affording greater facilities for the roots of plants to expand. When chalk is not at hand, a dressing of sand or fine gravel will produce some of these results, particularly if it contains calcareous matter, in the shape of fragments of limestone or shells. Clay, again, is equally efficacious on sandy soils, by increasing the power of the soil to retain moisture, and by enabling the roots to maintain themselves firmly in the ground.

"In Norfolk and Suffolk, vast tracts of land which were before incapable of bearing corn, have, by the application of clay, been made to produce good crops of wheat, barley, clover, and turnips. Thus a greater number of cattle are kept upon a given area, and the quantity of animal and vegetable matter returned to the soil is proportionably increased. The mineral manures are, in general, too much neglected, with the exception of lime (the injudicious use of which too often runs into the abuse), and even in those districts where they are applied, they are frequently brought from a distance, when, though not visible on the surface, they exist at a small depth below it, sometimes under the very field for the improvement of which they are required. Now, who, we would ask, is most likely to discover them,—he who never looks deeper into the earth than the bottom of his ditches, or he who studies the position of rocks, with respect to each other, and for this purpose examines every natural section by which they are exposed to view in cliffs and ravines, and every artificial section laid open by mines, wells, and other excavations.



"Let A B, in the annexed diagram, represent the surface of a district, composed, like some of the eastern parts of England, of strata of sand, clay, and gravel, resting upon chalk, all the strata having a slight inclination to the eastward, or towards B: a farmer cultivating the sandy soil at *a*, knows, for he observes it in riding to market, that at a certain distance from his own farm he shall cross a tract of clay, *b*, and that, after leaving that, he shall meet with sand and gravel again at *c*, and that at *d* he shall quit the plain and reach hills of chalk. But he does not know, and he would probably laugh at the person who communicated the information, that all the strata *b*, *c*, and *d*, are to be found under his own land at *a*, at a depth proportioned to the thickness and inclination of the strata, so that a bed which in one part of an estate will be at a considerable depth, may rise in another very near the surface. But these are points to the determination of which the geologist applies himself, and having ascertained, from the nature of the embedded fossils, that the stratum *a* is the crag, and *b* the London clay,—he knows that by proceeding in a direction contrary to that in which the strata dip, he shall meet with the sands and gravels of the plastic clay, as well as with the chalk, rising successively to the surface.

"A knowledge of the stratification of a country will also prove valuable to those engaged in agricultural improvements, by enabling them to drain their land more effectually, and at less expense, than by the ordinary methods. A good soil, as was before observed, may be rendered unproductive by resting on a bed of clay, which holds up the water, and there may be a porous bed again beneath the clay. Now, if the thickness of the clay is not too great, such land may be freed from excessive moisture by perforating the bed of clay, and leading the surface-water into the perforations.

"The dip or inclination, and also the 'faults' or dislocations of the strata of the district, ought to be studied with the same view. These faults are fissures which traverse the strata, and produce two opposite effects with respect to drainage, according to the nature of the substances with which they are filled. Sometimes they are pervious to water, and then they act as natural main drains, into which subordinate drains may be turned. In other cases they are filled with clay, and then they act as natural dams, holding up the water in the strata to a higher level on one side of the fault than on the other. A fault so filled is often traceable on the surface, by the land-springs which break out along its course, arising from the pent-up water struggling to escape wherever there is the least resistance; and cases will occur in which, by piercing through the fault, vent may be given to the water which before burst out at several smaller openings, and the land may thus be laid dry at a cheaper rate than by contending with each spring individually. This water, which was injurious in one place, will sometimes be in sufficient quantity, when thus collected into one channel, to improve another part of the estate, by being employed in irrigation, or by being made to drive an overshot wheel. Artesian wells have been bored, to obtain a supply of water for both these purposes.

"The nature of a country is sometimes such that it is destitute of rivers and surface-springs, and then the population are dependent for a supply of water upon that which can be obtained by means of very deep wells, or upon that which falls from the atmosphere, and is collected in ponds or tanks. The water derived from the former source is obtained at a great expense; that derived from the latter is by no means wholesome, and is liable to fail in dry summers. In such seasons, we have seen the population of an extensive parish almost fighting for the green unwholesome water of a muddy pond; and cases have occurred, in which it has been necessary to drive the cattle so far to drink, that by the time they returned, they were as thirsty as when they started. Few greater benefits could be conferred on a district so circumstanced, than the establishment in it of Artesian wells.

"Artesian wells are nothing more than perforations a few inches in diameter, made through the strata with the ordinary boring-tools, and their action arises from the natural tendency of water to find its level. It is only under certain conditions of geological structure, however, that they can succeed; and the structure of the district in which it is proposed to introduce them, ought to be thoroughly investigated before any borings are attempted, because, though one of these wells may be made for one-third of the cost of an ordinary well of the same depth, yet it will be perfectly useless, though a water-bearing stratum should be penetrated, if the water will not rise to the surface, the orifice being too small to admit of its being raised by mechanical means.

"There are few persons conversant with rural affairs, who are not aware how much good roads improve the value of property, by facilitating the conveyance of the produce of the land to a market; and either for the improvement of old, or the formation of new roads, a knowledge of the strata over which they are formed, is of the utmost importance. The durability of a road depends, in a great measure, upon the materials employed, and upon the solidity of its foundation. These points are, in general, too much neglected by those to whom the formation of roads is intrusted, the chief objects of attention being the shortening of distance, and the reduction of acclivity; and to obtain these, a road is often carried over strata affording an unstable base, and liable to frequent land-slips. Soft and bad stone is also frequently employed, because it is near at hand, when better materials might be brought from a distance by means of canals and railways, at a small extra expense, which would be in the end more economical, because of their greater durability, and because, when used, they afford a good, instead of a bad road. On the other hand, stone of inferior quality is often brought from a distance of several miles, when better exists much nearer; not quarried, it is true, nor visible on the surface, but easily discoverable by the eye of the geologist. Hardness is not the only essential in a stone employed for the repair of roads. It is required not only to resist friction, but also the crushing force of heavy carriages, moving with considerable velocity. Hence a certain degree of toughness is necessary to durability. Yet when hard and tough materials are both at hand, the latter is often neglected for the former.

"There are situations in which flints from the chalk, and chert from the green sand, might be obtained for the roads at the same cost. The chert, as the toughest, is the best; yet surveyors of roads, looking only to hardness, or perhaps merely adhering to established custom, almost invariably prefer the flints. Masses of greenstone, again, are of frequent occurrence in the midst of granitic districts. Granite is reduced to powder under the crushing action of wheels much sooner than greenstone, owing to the superior toughness of the latter, which arises from the presence of the mineral called hornblende. This mineral enters largely into the composition of most of the trappean rocks,—a numerous family, which, though differing much in external aspects, all possess, in a greater or less degree, the toughness essential to a good material for roads. We will illustrate this subject by one or two examples.

"The improvement which has taken place of late in the roads in the neighbourhood of London, must be well known to most of our readers. Much of this has been effected by reducing the surface to a better form, and by applying the materials used, in

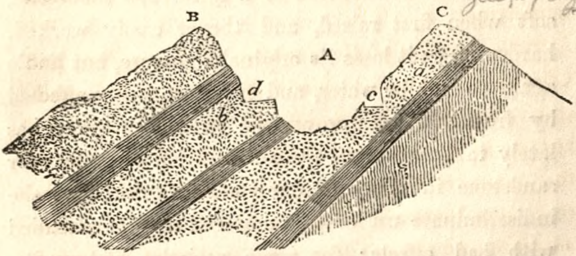
Quarry [illegible], gun-flint, [illegible] a more judicious manner; but much has also arisen from the selection of better materials.

"Under the old system, these consisted exclusively of gravel raised in the neighbourhood, much mixed with sand and clay, from which it was difficult effectually to clear it. In mineral composition, it consisted chiefly of flint, but the pebbles being for the most part round, could never form so solid a mass as a layer of angular pieces of stone. The first improvement was, to substitute for this gravel broken flints from Kent, brought up the river Thames. Possessing hardness only, without toughness, their brittleness was found to be an objection against them, and granite was substituted. This was found more durable than flint, but less so than a hornblende-rock from Mount Soar Hill, in Leicestershire, which is now chiefly employed, and with manifest advantage.

"The surface of the counties of Lancashire and Cheshire is occupied chiefly by the new red sandstone formation, which affords no road materials, but stone of the most friable kind. The roads of this extensive district are now supplied with a trap-rock from Penmaen Mawr on the coast of Caernarvonshire, and the quantity used is so great, that even at the low price at which it is supplied, the persons who have taken a lease of these rocks are realizing large profits. Stone of the same kind occurs in many parts of the Snowdonian chain, but nowhere so near the sea, except in Caernarvon Bay. Whoever, therefore, shall succeed in discovering, within the district thus supplied, a mass of trappean rock, so situated as to be easily quarried, may be assured that he has made a valuable discovery. Mr. Murchison has shown, that in a part of Shropshire, trappean rocks have burst through the red sandstone, and it is by no means improbable that the action may have been prolonged into Cheshire.

"Attention to the direction in which the strata dip, will frequently save considerable expense, both in the first construction, and future maintenance of a road, when it is carried along the side of a hill through a stratified country.

"Let A represent a valley between the hills B and C, composed of many alternations of shale



and sandstone, having a steep dip; so that had the beds of B not been removed, they would have covered those of the hill C. Let *a* and *b*, moreover, be two beds of loose sandstone, on opposite sides of the valley, with beds of clay or shale beneath them. If a road be cut at *c*, the water percolating through the sandstone, and prevented from descending by the retentive bed below, will have a constant tendency to throw down upon the road portions of the rock above; but no such effect will be produced, if the road be cut at nearly the same height on the opposite side of the valley, at *d*, where the strata dip *into* the hill instead of *out* of it.

"Every architect and civil-engineer ought to be a geologist, for the study of the structure of rocks, and of the situations in which they occur, would frequently enable them to select more durable stones for building than those usually employed. Some of the finest public buildings in London, less than two centuries old, are hastening rapidly to decay, from having been constructed of a calcareous sandstone, soft when first raised, and thence easily worked, hardening as it loses its original moisture, but liable again to imbibe water, and therefore easily affected by frosts. An improvement in this respect has lately taken place in the substitution of granite for sandstone in many of our public works; but the indiscriminate use of this material may be attended with bad effects; for some varieties of granite, though hard and difficult to work when first raised, afford a bad building-material, from the rapidity with which they decompose.

"We have now taken a rapid glance at some of the practical advantages resulting from the study of geology. The subject is by no means exhausted, but the limits of a work like this will not admit of further details. It remains to speak of other benefits arising from the cultivation of the science, less direct, it is true, and, to some minds, less obvious, but not the less important, because they cannot be made to enter into a calculation of pecuniary profit. As an employment for the mind, and an exercise of the reasoning powers, Geology may be placed in the first rank, second only to the exact sciences, and in some respects superior to them, because it requires the exercise of those faculties, and employs that kind of reasoning, for which we have daily need in the conduct of human affairs. We observe the changes taking place around us in the organic and inorganic world, and we trace effects up to their causes; and then comparing like things with like, we infer that similar effects were produced by similar causes in the ages that are past. In this investigation we have often to weigh the conflicting evidence of apparently irreconcileable phenomena, we are perpetually seeking analogies, or detecting differences, or combining and generalizing scattered facts with which observation has furnished us. Occasionally, too, we find ourselves obliged to retrace our steps, compelled by new facts to abandon generalizations, founded on imperfect induction. Surely all this must tend to produce habits of acute observation, patient investigation, and salutary caution, in suspending our judgment in the absence of complete and satisfactory evidence; habits, these, of the greatest value in the affairs of life; and we must be most unapt scholars if we do not also learn from it this great moral lesson—that it is possible to acknowledge ourselves to have been in error, without either compromise of dignity or loss of strength.

"Geology possesses this advantage over most other sciences, that with discipline for the mind, it combines exercise for the body. The geologist breathes the purest air of heaven, amidst the loveliest and the sublimest scenery of nature, whilst exploring those mountain-recesses, where her mysteries are best revealed; hardy, active, and enterprising, he ranges through all the realms of Europe—now on the summit of Ben Nevis—now in the caves of Staffa—now among the wilds of Connemara—and now in the valley of the Arno.

"Geology can only be thus studied by those who are gifted with leisure and affluence, or by those who follow it as a profession; but, on a less extended scale, it is available to the man of business and the man of humble income. The rich and the unemployed will find in it a substitute for many pursuits to which they are driven as a resource against *ennui*, and he who is engaged in active pursuits, may resort to it as a relaxation from toil and care. If a state of total inactivity is unsuitable for man, so likewise is a state of unremitting labour. Rest and recreation we all require: change of employment is often equal to repose; and where can we find employment or recreation so refreshing and invigorating, both to mind and body, as this?

"Geology has fields of research suited to every labourer, and to every capacity. On some of its investigations, the highest intellectual powers, and the greatest acquirements in abstract science, may be brought to bear, while many of its problems may be solved by any one who has eyes and will make use of them. Extensive travel is requisite to afford comprehensive views of the structure of the earth, and to prevent our generalizing from too limited an induction; but he whose travels are confined within his native country, or within a circle of twenty miles round his own house, may add much to our knowledge. Nor is this class of observers by any means the least useful. He who makes a hasty excursion into a district, can give but a general outline of its structure, leaving many important points of detail to be filled up by resident observers. If we visit the same cliff, or the same quarry daily, for years, we shall, at every visit, be rewarded with something new; and there are few districts barren in objects of geological interest, however deficient they may be in the beauties of picturesque scenery*."

The above remarks distinctly show the great

* *Magazine of Popular Science.*

advantages which may result from an acquaintance with geology: and we have much satisfaction in finding, that Her Majesty's government, aware of the importance of this subject in a practical point of view, has recently established a Museum of Economic Geology. This new institution, which is to be freely accessible to the public at stated periods, is designed for the express object of displaying the practical application of geology to the useful purposes of life. In this museum specimens will be exhibited of marbles, building-stones, slates, porcelain and pottery clays, and minerals of every kind produced in this country, which are of pecuniary value, and applicable to the arts. It will be evident that information upon such subjects, thus readily and gratuitously accessible, will be of the utmost practical importance to the miner and the mechanic, the builder and the architect, the engineer, the whole mining interest, and all landed proprietors.

The analysis of metallic ores, and of other minerals, will also be carried on at this museum; and an opportunity will thus be afforded to those who may discover indications of various minerals on their estates, of ascertaining their actual value. Improvements in agriculture will likewise form a leading object in this establishment; and all persons who wish for an analysis of any sterile soil, for the purpose of giving it fertility by the artificial addition of ingredients with which it had not been supplied by nature, may there obtain (at a moderate cost) an exact knowledge of its composition, and thus ascertain the corrective additions which it requires: and thus, observes Dr. Buckland, "the Museum of Economic Geology may shortly enable us to realize at least some share of the success that attended Lavoisier's application of chemistry to agriculture in France*."

Records are also to be preserved in this national museum, of the state of mines and coal-works in which mining operations have been abandoned, with the view of affording useful information at future periods, when further proceedings may be re-commenced in these mines or their vicinity.

"A museum of economic geology," says Dr. Buckland, "comprehending institutions of this kind, demonstrates, even to the unlearned, the advantages that result from science in its application to the extraction of the treasures which Providence has laid up in the rich storehouses in the interior of the earth; and, by exhibiting the results obtained from the elaboration of these materials, by the industry of man, in the workshop and the forge, will afford a full and satisfactory reply to the question so often

* It was said of Lavoisier, that in ten years he doubled the produce of his land in grain, while he quintupled the number of his flocks. No doubt this report is much exaggerated.

raised by persons to whom the value of the truths of pure science and philosophy, pursued for their own sake, are unintelligible—and by whom everything is appreciated merely according to its immediate subserviency to the acquisition of wealth, or its ministration to the daily necessities or conveniences of human life*."

As an instance of the advantages likely to accrue from such an elaborate inquiry into the nature of minerals, we may mention that of building-stone. Thus, some kinds of *magnesian limestone* are remarkable for their durability, whilst others fall to decay. Of the former, the Norman part of the church of Southwell, in Nottinghamshire, which was built in the twelfth century, affords a striking example. The magnesian limestone of which this church is built, combines strength and durability with applicability to ornamental carved work, in a degree surpassing all other kinds of stone that have been employed in the most ancient fabrics of this country; the sharpest of the mouldings and carved enrichments of that church, being throughout in as perfect a state as when first executed. York Cathedral, on the other hand, though also built of magnesian limestone, is, in its mouldings and architectural decorations, far advanced in decay. Chemical analysis, however, explains and accounts for

* Dr. Buckland's *Anniversary Address to the Geological Society,* 1840.

this difference in the durability of these varieties of magnesian limestone; it being found that the stone resists decomposition in proportion as it is more perfectly crystalline: a result, the cause of which is further illustrated by the experiments of Professor Daniell, which show, that the nearer the composition of the magnesian limestone approaches to *equivalent* proportions of carbonate of lime and carbonate of magnesia, the more crystalline is its structure.

By the aid of chemical analysis, valuable properties may be discovered in substances hitherto considered worthless. As an instance of this, we may mention, that previously to the last four or five years, it had been the practice to import chalk flints at a great expense into Staffordshire, for the use of the earthenware manufacture. It has lately been found that the *millstone-grit* of the pottery district will answer the same purpose; and it is now quarried to the extent of many hundred tons annually. It is found to be a perfect substitute for flint, with the advantage of not requiring calcination previously to being ground. The material for the pottery is compounded of about equal parts of millstone-grit, Dorsetshire and Cornwall clay, and the ware produced is found to possess the qualities of whiteness and compactness in a very high degree. Chemical analysis shows that the best specimens of millstone-grit are those which contain about three parts of silica, and one of alumina, and which are free from iron.

We have seen that geology has very great practical advantages, and that it is also conducive to the improvement of our minds. Nor does it stop here; it takes a yet more exalted stand; this science is at the same time "the efficient auxiliary and handmaid of religion." Wherever we direct our researches in the natural world, we meet with distinct traces of a controlling Intelligence, and thus this employment of our intellectual faculties leads us to the contemplation of the great First Cause. And though, without the aid of Revelation, we may not be able to discern the moral government of the world, by "the exercise of our reason we discover abundant evidences of the existence, and of some of the attributes, of a Supreme Creator, and apprehend the operations of many of the second causes or instrumental agents, by which He upholds the mechanism of the material world*;"

> Where order, wisdom, goodness, providence,
> Their endless miracles of love display.

Geology does not attempt, and indeed is "incapable of giving, any distinct and satisfactory account of the origin of the universe, or of its parts. We need not wonder then at any particular instance of this incapacity; as, for example, that of the impos-

* Dr. Buckland's *Bridgewater Treatise.*

sibility of accounting, by any natural means, for the production of all the successive tribes of plants and animals which have peopled the world in the various stages of its progress, as geology teaches us. That they were, like our own animal and vegetable contemporaries, profoundly adapted to the condition in which they were placed, we have ample reason to believe, but when we inquire whence they came into this our world, geology is silent. The mystery of creation is not within the range of her legitimate territory; she says nothing, but she points upwards*."

Great as is the progress that within the last few years has been made in geology, and replete with interest as are the discoveries recently brought to light, this science is still far from complete—much, very much, yet remains to be accomplished. A very large portion of the globe is still geologically unexplored, and a true theory of the earth can scarcely be formed, without a much more extended acquaintance with the strata and their organic contents in all parts of the globe; and even then any hypothesis will be imperfect, unless we can obtain, from adequate facts, the laws of change of the organic and inorganic creation. "And we have yet to learn," observes Mr. Whewell, "whether man's past duration upon the earth—whether even that which is still destined to him—is such as to allow

* Whewell's *History of the Inductive Sciences.*

him to philosophize with success on such matters; whether man, placed for a few centuries on the earth as in a school-room, have time to strip the wall of its coating and count its stones, before his PARENT removes him to some other destination*."

* *Anniversary Address to the Geological Society*, 1839.

GEOLOGY.

CHAPTER I.

THE EARTH'S CRUST.

The whole heavens are the Lord's: the earth hath He given to the children of men.—*Psalm* cxv. 16.

The more science is investigated, the more does it become evident that each branch lends its aid in elucidating every other, and that a close union exists between the whole. Without the assistance of astronomy, we should be in utter ignorance of the density of the terrestrial globe; without that of chemistry, we could acquire no knowledge of the composition of rocks; and without botany, conchology, zoology, geological researches would be divested of their supreme interest. For, without the latter sciences, we might, instead of regarding the fossil relics of former ages as evidences of Creative Wisdom and Goodness, have followed in the footsteps of some of our ancestors, and considered them as mere stones, which had accidentally assumed particular forms. The rocks on the earth's surface, however, in fact teem with the remains of organized beings; and these are found to be equally distinguished with the present occupants of the earth's surface, for the variety and singularity, as well as beauty, of their forms, and their adaptation to the circumstances in which they were placed. And the whole presents evidences of being one great design, guided by one unerring Hand.

As inhabitants of the earth, some particulars of the ground on which we tread, and of its natural productions, cannot be devoid of interest. In an extended point of view, this would embrace a vast range in the circle of the sciences; but we may here consider it as including GEOLOGY, or the earth in its former condition, and PHYSICAL GEOGRAPHY, or the earth as it is. On the present occasion, we will confine our attention to the former subject.

"In the beginning God created the heavens and the earth." When that "beginning" was, we are not informed, nor does it belong to the Geologist to inquire; it is enough for him to know that God created the earth: he attempts not to pry into its origin, but simply extends his researches to the investigation of those changes which have taken place in that portion of the globe to which the term, the *earth's crust*, has been applied. For, that changes of great magnitude have taken place, we meet with the most decided proofs; and geology must not be considered as a mere acquaintance with the names of a few rocks or of a few fossils, but rather as a science whose object it is to present us with the history of these mighty revolutions, and with the indications of order and design which pervade the whole.

An examination of the *crust*, or surface of the earth, shows us that it is formed of numerous horizontally-disposed layers, or *strata* of rocks, the greater part of which contain *organic remains*, that is, the remains of animals and plants, which have become converted into a mineral substance, and are termed *fossils*. Among these, the most abundant are marine productions; in some instances, indeed, shells and corals are so numerous as to constitute the principal portion of the beds; and they are occasionally found in so perfect a state, that their most delicate parts are completely preserved. These remains are met with in situations very far above the present level of the sea; and since every part of the earth,—every continent, every island, exhibits similar or nearly similar formations, it appears that the ocean must at some period, not only have covered all our highest lands, but have remained there for a considerable length of time, in a state of tranquillity.

These strata are not, however, always found in a horizontal position; for it appears that, in some cases, this ancient bed of the ocean had, subsequent to its tranquil formation and consolidation, been broken, lifted up, and disturbed in various ways: by which means some of the more ancient strata have been thrown into a highly inclined, and occasionally an almost vertical position. Upon these dislocated beds, more recent formations have again accumulated; and thus, in some parts, horizontal strata are found resting upon the older inclined or vertical strata. The rocks which form these various beds are not only of different composition, but contain the remains of distinct races of animals and plants, the shells and other fossils of the more ancient rocks differing from those found in the newer, and all (with a few exceptions, which will hereafter be mentioned) differing from those now known to be in existence.

The successive changes which the earth's surface has undergone, and the influence these changes have exercised in bringing the earth to its present condition, will form the primary object of our inquiry. That portion of the science to which the term *Palæontology* has been applied, and which includes "the beautiful monuments of ancient life, the fossil remains of animals and plants," will not only assist us as chronological data, but will render the subject peculiarly attractive, and also strikingly display the beneficence of the Creator.

The *earth's crust* includes such parts of the earth as are accessible to man's observation. This, however, forms a very small portion of the globe, for the inequalities on the earth's surface, arising from mountains and valleys, have been well likened to the roughness on the rind of an orange, as compared with the general mass. The earth is a spheroid, (that is, of a round figure, slightly flattened at the poles,) whose diameter at the equator is 7,926 miles, nearly; and from pole to pole about 7,899 miles. Now, as the highest known mountain scarcely exceeds five miles, which is little more than the sixteen hundredth part of the earth's diameter, and the deepest mine scarcely penetrates above half a mile below the surface, it will be evident that very little can be known of the whole earth, and that the term the "earth's crust" is highly appropriate, and expressive of the narrow limits to which geological researches can extend.

The earth's crust is composed of rocks, and of earthy substances. When mineral substances are found in hardened masses, they are termed *rocks*. Some rocks are *simple*, that is, composed of one mineral substance, as limestone; others *compound*, or composed of two or more kinds of minerals, as granite. *Earthy formations* include such loose materials as, combined with decayed animal and vegetable matter, or *humus*, constitute the soil of meadow and arable lands, and, generally speaking, all beds that are not consolidated; and which, in great part, consist of particles of rocks reduced to fine dust.

But though simple rocks, of which limestone forms an instance, are composed of only one mineral substance, limestone, or *carbonate of lime*, is not itself a simple substance, but a compound body, composed of three elementary substances,—namely, oxygen, carbon, and the metal called calcium. Such inquiries, however, belong to chemistry rather than to geology, and the subject is merely alluded to, that the term *simple*, as applied to rocks, may not lead to erroneous conclusions regarding their constitution.

About fifty-four substances are known to chemists which have never been proved to be compound, and which therefore are at present ranked as elementary forms of matter. The most abundant in nature, and those with which on that account the student in geology should be in some degree acquainted,, on account of their entering largely into the composition of rocks, are *silicium*, which forms the base of flint; *calcium*, which forms that of lime; and *aluminum*, which forms the base of clay. Besides these, we meet with *magnesium*, *sodium*, *potassium*, *sulphur*, *carbon*, *oxygen*, &c.

Oxygen forms a constituent part of atmospheric air, and readily enters into combination with a large number of substances with which it comes in contact, and by this means the nature of these substances is changed. Thus, if iron be exposed to the air, it becomes rusty, or more correctly speaking *oxidized*,—that is, the oxygen enters into combination with the iron, and a new mineral substance, called oxide of iron, is formed; if the *metal* silicium come in contact with oxygen, it is converted into the *earth* called silica. Oxygen in its simple state is a light invisible gas, but, when combined with metals it becomes consolidated, and sometimes forms little less than half of some species of rocks*.

The most abundant *earths* are silica, lime, alumina, and magnesia.

Silica, *silex*, or *quartz*, is an exceedingly abundant earth, and very universally diffused. It is found in nearly a pure state in *rock-crystal*, *flint*, *agate*, *opal*, *chalcedony*, and in the *siliceous* or *flinty sand* of the sea-shore. It also enters into combination with many other substances, forming rocky masses and minerals, as also some precious gems; such as the *garnet*, *amethyst*, &c. Silica is very useful in the arts, and a mixture of silica and soda forms glass.

The art of making glass is said to have been accidentally discovered by some Phœnician mariners, who were boiling a kettle near the mouth of the river Belus. As soda is obtained from sea-weed, the

* It may not be out of place to remark that the neuter termination *um*, as in silic*ium*, alumin*um*, &c., has been adopted to designate the *metal* which forms the base of an earth or other substance; whilst the plural termination *a*, as in silic*a*, alumin*a*, &c., indicates that the metal is in a state of combination with oxygen, and that it is not an elementary substance, but an *earth*, or a *salt*.

probability appears, that this article may have been mixed with the silica, or sand, in such proportions as to form glass, and that these substances were fused or melted by the fire the mariners had kindled. The sand of those shores seems to have been considered as possessing peculiar virtues for forming glass, for we are informed that not only the manufactories of Sidon, but those of all other places, were for ages supplied from thence with materials for that purpose. And even as late as the seventeenth century, this sand was still imported into Italy, for the glass-houses of Venice and Genoa. But it is now well known, that not only the sand on the shores of the Belus, but all fine silica or flint sand, is adapted for this exceedingly useful and beautiful manufacture.

Water passes freely through sand; sand therefore dries so rapidly that no vegetation can thrive in it, when unmixed; a circumstance which renders sandy tracts barren and destitute of vegetable productions, unless they are maintained in a constant state of irrigation.

Lime is also one of the most abundant and widely distributed earths; but is usually found in the form of carbonate of lime. As *marble*, or *granular*, *foliate* and *compact limestone*, and also in the form of *marl*, *oolite*, *chalk*, and *lucullite*, it constitutes beds, hills, mountains, and even ranges of mountains. The purest form of carbonate of lime is *calcareous* *spar*, which occurs in every formation, from the most ancient to the newest member of the secondary series. England and Scotland abound in interesting varieties of calcareous spar, and the mountains, hills, and valleys of Great Britain, afford numerous instances of the different kinds of carbonate of lime; whilst its caves and caverns, and its calcareous springs, exhibit varied forms of *calc-sinter* and *calc-tuff;* which are mineral substances formed by deposits from water, holding carbonate of lime in solution. The beautiful substance called Derbyshire spar, is *fluate of lime.* A distinguishing feature of carbonate of lime is its solubility, or capability of being dissolved in acids, which it neutralizes. Lime enters largely into the composition of animal bodies, forming a constituent part of the bones of animals, and also of numerous shells.

Alumina, or *clay*, called also *argil*, is likewise a very abundant earth, and of great importance to mankind. It is rarely found pure in nature, but enters largely into the composition of rocks; its most usual form is that of *felspar*, which is a compound of alumina and silica, with a small portion of lime, of potassa, and of oxide of iron. In its purest form, alumina is the principal ingredient of some of the most beautiful gems; such as the *topaz*, *sapphire*, &c. But it is by no means in this form that alumina is most useful, its great importance arising from its peculiar property of not permitting water to pass through its substance; a circumstance which renders it of inestimable value as a lining to canals and basins of water; and also in forming natural reservoirs of that all-important material in the interior of the earth. Alumina is also of great utility on account of its property of combining readily with greasy substances, which renders it of the first importance in scouring cloth; *Fullers' earth*, which is alumina mixed with very fine silica, was in olden times considered so valuable for the woollen manufactories of this country, that its exportation, even to Scotland or Ireland, was made felony by an Act of Parliament: and an old geological writer speaks of it as "a precious commodity of much higher advantage, and bringing in a much higher revenue, than the delves of diamonds in Golconda, the silver mines of Potosi, or the gold of Brazil*." Alumina, or clay, is likewise of great value for making bricks and tiles, as well as all kinds of pottery and earthenware. The finest sort of porcelain earth, or *kaolin*, is a compound of silica and alumina, generally combined with a small portion of magnesia. The great proportion of kaolin used in the English manufactories is supplied from Cornwall.

Magnesia is by no means so abundant in nature as silica, lime, or alumina; it enters into combination with other earths, and also with acids. Most

* Woodward.

minerals containing magnesia have a soapy feel; among these may be mentioned *talc* and *soapstone.* Combined with lime it forms *magnesian limestone.* Both lime and magnesia are used in bleaching, in the form of chloride.

Besides these principal earths, there are some salts which are very abundantly diffused: these are *potassa*, or *potash*, and *soda.* They are found in combination with the different earths, and form part of various rocks. These salts are readily dissolved in water, and thus, those rocks into the composition of which they enter, are liable to be acted on by rain, and by the moisture contained in the atmosphere, and to crumble away, or be *disintegrated.*

Potassa forms an ingredient of sea-water; into the composition of which soda also enters in great abundance, in the form of *muriate of soda*, or *common salt.* Muriate of soda is also found in marine plants; in salt springs; and in a concrete or consolidated state in extensive masses, when it is known under the name of rock-salt: it is met with in this form in salt-mines, and frequently occurs in beds of vast magnitude. There are some very celebrated mines in Poland, which employ five hundred men, and have been worked ever since the middle of the thirteenth century: the quality of the salt in these mines, does not, however, equal that obtained from those of our own country, the principal of which are situated in Cheshire. But the purest salt known to exist is perhaps that found at Cardona, in Spain, where the rock-salt is so free from admixture with other substances, that it has only to be ground in mills similar to our corn-mills, to render it fit for use. This salt is not situated in a mine, but on the surface of the ground, in a valley, which is nine miles in circumference, on one side of which rises a vast cliff of salt four hundred feet in height, standing on a floor of salt; and the quantity is supposed to be sufficient to supply the whole of Spain for two thousand years.

Sulphur is met with in masses, in powder, and in crystals. It is usually divided into two kinds, *common*, and *volcanic*, in reference to the situation in which it is found. Volcanic sulphur occurs in the vicinity of active volcanos, and also in that of some which are no longer in a state of activity. The remarkable sulphur-bed on the summit of Mount Demavend presents an instance of the latter. Common sulphur is generally met with in beds of clay, and often in combination with silver, copper, lead, antimony, and iron.

Carbon is a non-metallic elementary body, which is widely diffused through nature, and acts a considerable part in the mineral constitution of the earth. The purest, and, at the same time, the rarest form in which it occurs, is that of the *diamond*, which is pure carbon. Another well-known substance in which carbon is found nearly pure, is *graphite*, called also *black lead*, and *plumbago*. Another form of carbon, though not so unmixed as the preceding, is *charcoal*, which is obtained from the decomposition of wood by heat. *Anthracite*, *culm*, or *stone coal*, is a black, light, mineral substance, and consists almost entirely of carbon in the black state in which it exists in charcoal. Anthracite is sometimes called *blind coal*, because it burns slowly and without flame; and also *glance coal*, because it frequently presents a shining surface. The best kinds of coal, such as the Newcastle coal, &c., also contain a large proportion of carbon, in combination with bitumen, which is a very inflammable substance, and is the cause of the bright flame that cheers our apartments in winter. The various kinds of *bitumen*, indeed, themselves contain carbon: the chief constituent principles of *naphtha*, *petroleum*, *elaterite*, or *elastic mineral pitch*, and *asphaltum*, being carbon and hydrogen, combined with certain proportions of oxygen and nitrogen. The principal difference in these substances, appears to consist in their fluidity or hardness. The yellowish transparent liquid called naphtha, or mineral oil, if exposed to the air, thickens, becomes brown, and seems to pass into petroleum, by which name the blackish brown liquid varieties are known. Petroleum, again, if exposed to the air, becomes consolidated, and forms a mineral pitch resembling asphaltum, which is a solid substance, of a pitch black colour, and possessing a splendent shining lustre. Naphtha and petroleum flow from rocks of the limestone and coal formations. United with oxygen, carbon forms *carbonic acid*, and in this state it combines with various bases, forming *carbonates*, of which, carbonate of lime, or limestone, is an instance.

These elementary substances, however, rarely occur on the earth's surface in a simple or uncombined state: for, before the earth became fitted for the habitation of man, it appears that vast and important changes had taken place, effected partly by the agency of heat, partly by the action of water, and partly by that of the atmosphere. So that, as far as our limited capacities enable us to judge, we find that the earth's crust has undergone a great alteration, and differs widely in its present from its original constitution; apparently in its ancient condition not having been suited to sustain the particular description of organic beings which at present occupy its surface. It further appears that the all-wise Author of nature has employed those changes which it is the object of geology to investigate, as the most efficient means of rendering the earth a suitable habitation for man, and for that race of animals and plants which appear to have been placed on the earth contemporaneously with him. And thus, whilst contemplating the ancient history of the earth, we shall perceive that the Creator, being all-bountiful as well as all-wise, and possessing, in a super-eminent degree, that attribute of goodness which delights in promoting happiness, instead of exercising His omnipotence, and issuing the decree, "Let the earth be fit for man's abode,"—placed on the globe organic beings susceptible of enjoyment, and suited to its condition at the particular period in which they were created, at the same time causing these creatures of His hand, as well as others of the vegetable kingdom, to be instrumental in adapting the earth for man's reception.

It has been observed, that the Bible gives us no account of these changes, which so evidently appear to have occurred antecedent to the creation of the human species. But in fact, such explanations would have been foreign to the design of Holy Writ. We find two special objects kept in view in the Old Testament—the one, to turn men from idolatry; the other, to direct their attention to the promised Messiah:—to neither of these points would a description of the revolutions of the globe in any way have tended. For these purposes, it sufficed to declare that God was the Creator of all things. And if we investigate the subject, we shall perceive that, in the Mosaic account of the Creation, those creatures are more especially alluded to, which formed objects of idolatrous worship with the nations among whom the Israelites dwelt. In this catalogue, the sun and moon held a conspicuous place; and accordingly, we find "the greater and lesser lights" particularly specified: though we may conclude, that these luminaries (at least the sun) had an existence prior to the *fourth* day; the first Divine command recorded being, "Let there be light:" and we also find that evening and morning, which are dependent on the sun, are mentioned as having already occurred three times. It appears probable, therefore, that God may not have created the sun, and moon, and stars at that period, but that He *then* appointed them for signs and for seasons, when an intelligent being, capable of observing those signs and seasons, was about to be placed on the earth.

As we proceed, we shall take occasion to notice some particulars, in which the conclusions of the geologist are remarkably confirmed by the Sacred Writings. And we shall also, whilst pursuing this subject, be led to regard with gratitude and admiration, the beneficent providence of the Creator, who, amid all the changes which have taken place, appears ever to have kept in view the benefit of man, His "master-work," a creature capable of being

> Magnanimous to correspond with heaven,
> But grateful to acknowledge whence his good.

CHAPTER II.

UNSTRATIFIED ROCKS. PLUTONIC ROCKS. TRAP ROCKS. VOLCANIC ROCKS. FAULTS AND DISTURBANCES.

To describe the depth
Of all the universe, is no emprize
To jest with, and demands a tongue not used
To infant babbling.—DANTE, *Carey's Translation.*

THE rocks which form the crust of the earth, are divided into *stratified*, and *unstratified*.

Stratified rocks are such as bear evidence of having been formed by successive deposits of sediment in water; all stratified rocks being considered of *aqueous* origin. They are called stratified, because the materials of which they are composed appear to have been strewed or deposited in successive layers; and *aqueous*, because this has been effected by the agency of water. These include sandstones, clays, limestones, &c.

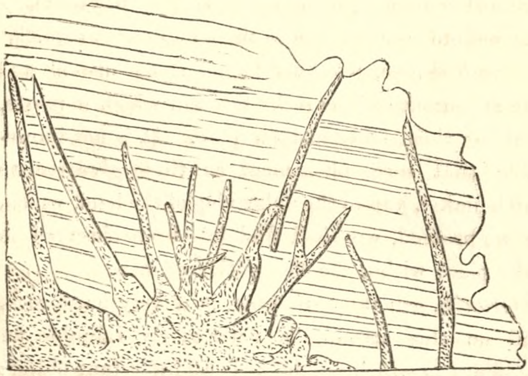
Unstratified rocks are such as appear to be of *igneous* origin. They consist of a variety of *crystallized*, and some uncrystallized minerals, many of which are very similar to artificial products, formed by the heat of a furnace. They are called *unstratified*, because they appear to have been formed by fusion of the mass of which they are composed, and not, like stratified rocks, in successive layers; and *igneous*, because this has been effected by the action of fire, or heat. These include granite, basalt, lava, &c.

In some instances we find that both aqueous and igneous agency have been instrumental in the formation of a rock: that is, a rock has been originally formed in strata or layers, but subsequently, by the action of heat, has acquired a crystalline texture. Mr. Lyell has proposed to call this description of rocks, *metamorphic*, or altered rocks.

Unstratified rocks may be divided into three classes:—Plutonic; Trap; and Volcanic.

Plutonic rocks, (so named from Pluto, the fabulous god of the infernal regions,) are rocks which present the appearance of having been formed by intense heat, at a great depth in the interior of the earth, and of having cooled under the pressure of *super-incumbent*, or *over-lying rocks*. The principal rock belonging to this class is granite, which is a very universally diffused rock, generally forming the base of all the stratified rocks in every part of the globe. Until within a recent period, all granitic formations were supposed to be more ancient than any of the stratified rocks, and to have become consolidated previously to the creation of any animals or plants on the surface of the earth; but it is now ascertained that *all* granitic rocks are not of so ancient a date, but that they have been formed at different eras: for granite veins have forced their way through masses of other granite, and also through stratified rocks containing fossils. From this circumstance, it appears, that the newer granite must have existed in a liquid state in the interior of the earth, and intruded itself into some crevice or chasm in the older granite with which it came in contact.

This diagram is a representation of some granite veins passing through a stratified rock in Cornwall; in the district in which this formation occurs, the most ancient rocks being the slates, and the granites the most recent.



Stratified rocks, however, as before observed, belong to the class of rocks formed by the agency of water, and are neither so hard nor so compact as granite; it therefore usually happens, when granite veins pass through stratified formations, that the intensely heated melted granite, has either wholly or partially dissolved these rocks, where it has come in contact with them, and they have become *metamorphic*, or altered rocks. Under such circumstances, the rock called sandstone, has been observed to be transformed into quartz; limestone, into crystalline marble, &c. A remarkable instance of an intruding mass of granite passing through stratified rocks, occurs near Christiana, in Norway, which place was visited by Mr. Lyell, in 1837. This newer granite has forced its way through some rocks, (belonging to the Silurian group,) containing fossil shells and zoophytes; and has not only sent veins into these rocks, but actually, in some degree, overtops them: it has also altered the appearance of the rocks through which it passes, making them truly metamorphic. It is not impossible that such phenomena as these give rise to earthquakes, and to the upheaving of the land, which, as we proceed, we shall find has been observed to take place within the observation of man.

Granite, generally speaking, is a very hard rock, and on this account is particularly valuable for buildings in which durability is an important object: Waterloo and London bridges are built of granite. Some kinds of granite, however, owing to the difference in their composition, are apt to crumble away when exposed to the action of the atmosphere. Granite has received its name from the *granular* appearance it presents: but, owing to the difference of its composition, it varies very much in colour. The substances of which it is composed are, quartz, felspar, mica, and hornblende: the most usual combination is quartz, felspar, and mica. The latter is a mineral presenting a shining silvery surface, and capable of being split into very thin elastic leaves or scales; the brilliant grains occurring in granite are particles of mica. Hornblende is of a deep greenish gray or black colour: it is found in masses or in crystals. Only two of these minerals are present in some kinds of granite; whilst others contain the whole number. A variety of granite, called syenite, (which name it received because it was first brought from Syene in Egypt,) is a compound of felspar, quartz, and hornblende.

Another variety of granite is called *porphyry*. The particular rock to which this name was originally given by the Greeks, was of a red colour, with small angular pieces of crystallized felspar diffused through it. The term is, however, applied by modern geologists to any rock of granitic formation through which crystals of felspar are diffused, though the colour and composition may differ from the Egyptian porphyry.

Greenstone is another unstratified rock; it is composed of hornblende and felspar, and is of a dark green, or grayish colour. *Serpentine* is a beautiful rock, and derives its name from presenting changeable colours like the skin of a serpent. It contains much magnesian earth, and has a soapy feel. It is found in Cornwall, and in the north of Scotland. The three latter rocks are, by some geologists, referred to the next class we shall consider, or Trap rocks.

Trap rocks are formations which appear to be the products of volcanos long extinct; and are supposed to have cooled under the pressure of *water*, probably of a profound ocean. They bear a considerable resemblance to the substances ejected by existing volcanos, but are usually harder and more compact: many of them appear to have been originally porous like lava, but to have had the cavities or cells subsequently filled up with silica, carbonate of lime, and other ingredients. *Amygdaloid* is a rock of this description, and has received its name from the word *amugdalea*, "almond," because, in this rock, agates and other minerals appear scattered like almonds in a cake.

Basalt is another rock belonging to the trap formation, and is one of the most remarkable, as well as most common species of trap rock. It is of a dark green or blackish colour, very compact in texture, and very hard. Basalt is sometimes found in tabular masses, but it is also frequently met with in regular columns, which are usually called basaltic columns. The Giants' Causeway, in the north of Ireland, is a remarkable instance of a formation of this kind. Numerous specimens of basaltic columns occur in various parts of the globe; perhaps among the grandest is that at Regla*, in Mexico, which is described as one of the most picturesque spots in the world.

The other most remarkable rocks belonging to the trap formation, are *clinkstone*, called also *phonolite*†, which names it has received because it sounds or clinks when struck with a hammer; *trachyte*, which is composed of glassy felspar, and often greatly resembles porphyry in structure;—this rock has a peculiar rough feel; *dolorite*, which much resembles trachyte; and *zeolite*, which includes stilbite, mesotype, analcime, and some other rocks;—the name zeolite has been given because some of the varieties of this rock boil up or swell, when exposed to the blowpipe. soldering-pipe = soudoi

The greater number of these formations are also found among the matter ejected by active volcanos.

Volcanic rocks, so named from Vulcan, in Grecian fable represented as the framer of Jove's thunderbolts, (evidently a poetical allusion to the phenomena of volcanos,) are igneous rocks, which appear to have cooled in the *open air*. The lava, or melted

* See Frontispiece.

† The word *lithos*, "stone," rendered *lite*, forms a very general termination to the names of rocks.

matter ejected by volcanos, is not always similar in its composition, greatly varying in different localities; but felspar and augite are almost invariably present: the latter is a mineral of a dark green, or black colour.

Among the principal volcanic rocks, we may mention *Tufa*, or tuff; which is of an earthy texture, seldom very compact, and composed of an agglutination of cinders and loose matter ejected from a volcano. *Stone tufa* is of a reddish brown colour, and is of sufficient hardness to be employed in building. *Granular tufa* is of a blackish brown hue, and so slightly cemented together, that it crumbles to dust when exposed to the action of the atmosphere. *Obsidian*, another volcanic production, is a species of lava, bearing a strong resemblance to common green bottle-glass: it is semi-transparent in thin fragments, but almost black in large masses. *Pumice-stone* is obsidian, in a frothy state: it varies in colour from white to brown and black. *Pitch-stone* is a rock of uniform texture, and has an unctuous appearance, like indurated or hardened pitch. *Leucite*, which is a mineral of a white colour, and *olivine*, of an olive colour, and semi-transparent, are also met with in volcanic formations.

Besides these rocks, loose sand, *scoriæ*, or cinders, and ashes, are ejected from the crater of volcanos. The scoriæ and dust are frequently collected, by means of water, into sedimentary deposits, by which tuff, conglomerate, and pozzuolana are formed. It is this description of accumulation which covers Herculaneum; but Pompeii appears to have been buried in loose dust and ashes. *Pozzuolana* is used as mortar in buildings, and has received its name from Pozzuoli, a town in the Bay of Naples, from whence it is shipped in large quantities to all parts of the Mediterranean. It is similar in nature to the substance in this country known as Roman cement.

Modern lava which has flowed down into water, and been consolidated under the pressure of that fluid, is found to be more condensed than lava which has hardened in air. Sudden cooling gives lava a glossy character, like obsidian; slow cooling causes it to exhibit a crystalline, granular, or earthy texture. Besides these mineral substances, some volcanos pour forth streams of muddy water; and they all emit volumes of gaseous matter and steam.

When the expressions "flame" and "smoke" are used in describing the phenomena of volcanos, they must not generally be understood as signifying flame and smoke in our ordinary acceptation of those terms. The clouds of apparent smoke usually consist of aqueous and other vapours, or of fine dust and powdered ashes; and the apparent flames are showers of incandescent, or red-hot fragments of lava, rendered doubly glowing by reflecting the vivid light emitted from the interior of the crater, where the melted materials are said to equal the solar light in splendour. The Latin word, *crater*, "a great cup," or "bowl," has been adopted for these circular cavities at the summit of volcanos, on account of the cup-like form they usually assume.

By a careful comparison of trap rocks with the products of modern volcanos, and from the evidence afforded of similar igneous action on both, the conclusion has been drawn, that they are similar in their origin, and that the chief difference arises from the manner in which they have cooled. Even within the historical period, that is, since such events have been recorded, some volcanos are known to have become extinct; and we infer from thence, that more ancient ones may also have had their periods of activity, and of extinction. In recent volcanos, we may sometimes observe that long after they have ceased to emit melted matter, they retain their form, and the lava is unchanged. Thus, in Asia Minor, some volcanos occur which must have been extinct for at least three thousand years; nevertheless their craters are still perfectly defined, and their streams of lava yet discernible, black, rugged, and barren. The form of volcanic mounds is usually conical, and some of them attain a remarkable height: that of Cotopaxi, in South America, which is a perfect cone, is 18,858 feet above the level of the sea.

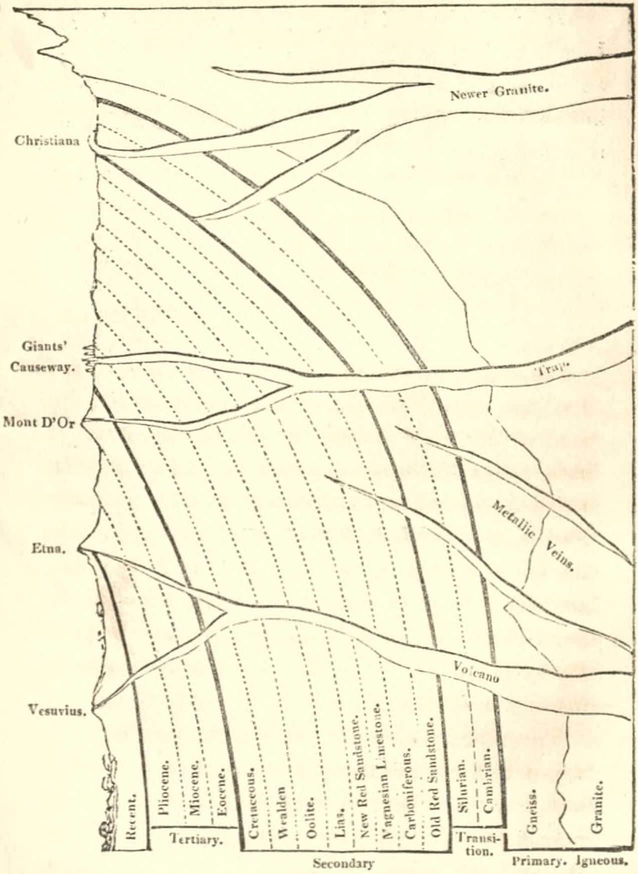
That some connexion exists between earthquakes and volcanos is generally admitted: indeed, volcanos have been termed the safety-valves of regions subject to such convulsions; for it not unfrequently happens, that earthquakes precede volcanic eruptions, and that the earth becomes stilled, when these commence. It thus appears that the melted matter being enlarged in its volume, or size, by the action of some unknown internal heat, attempts to force its way through the rocks which form the crust of the earth, and that this melted mass causes the rocks to be shaken, and perhaps shattered in pieces; unless it encounter a crack or fissure, in which case it forces its way through this opening, until it pours forth its streams as lava, &c., on the surface. Active volcanos may thus be considered as permanent channels for the escape of these subterranean streams of melted matter; whilst in those districts where they have become extinct, the melted mass has apparently reached its boundary, and, like the granite veins before alluded to, has cooled down into a solid rock. And, perhaps, under such circumstances, we may find one country has been upheaved, or raised to a higher level above the sea, and that another has sunk below its former level. Nor is it impossible that we may by such means account for another geological phenomenon;—that of *Faults* or *Dislocations*. Verwerfungen

crack, Ritz; Rissll
crag, Fels

It appears that in some districts, large masses, sometimes whole mountains, consisting of numerous strata, have been rent asunder, and without being thrown down, or shattered to pieces, have, by the depression of one portion, or the upheaving of the other, assumed a different relative elevation, so that the strata of rocks of one description, instead of forming a continuous line, are found at different heights. Thus, supposing we were digging for coal, and were to approach one of these *Faults*, we might find a sudden termination of the bed of coal; and, on examination, discover that the stratum was continued on the opposite side of the Fault, some hundred feet below its former level.

There is another description of *dislocation*, which perhaps may also be referred to the giving way of the ground at some depth below the surface, or to the upheaving of the outer crust of the earth:—this is the disruption by which in some places we find whole mountain-ranges thrown out of the perpendicular, and the strata consequently sloping at a considerable angle. These dislocations, of which we shall presently meet with some examples, appear to have taken place at various epochs, there being evidence of such disturbances having been repeated more than once in the same districts. To these we will direct our attention at the periods in which they are supposed to have occurred.

We shall also find that volcanos appear to have been in activity at various eras of geological history; an account of these will also be more interesting in the same order, and in their connexion with the stratified rocks.



SUPPOSED SECTION OF A BASIN.

CHAPTER III.

STRATIFIED ROCKS. THEIR DIVISION. PRIMARY PERIOD.

Time destroys them in its way,
Vicissitude and accident,
And busy change:
All bear the seeds of self-decay.

Spanish Romance.

STRATIFIED rocks are arranged in three grand divisions, called *Periods;* which divisions have reference to the order of time in which the strata, or beds, appear to have been formed. These divisions are distinguished as the *Primary Period*, *Secondary Period*, and *Tertiary Period:* the primary includes the oldest formations, and the tertiary those which are the newest in ancient geological history. To these divisions may be added the *Recent Period*, or the period which has elapsed since man became an inhabitant of the earth.

The primary stratified rocks all appear to rest on a granite floor; not an even surface, but one full of undulations, which in some instances attain the height of more than five miles above the level of the sea, and which, in others, are depressed to an unknown depth below the bed of the ocean. On this largely uneven base, the earliest stratified rocks have been formed; they do not, however, cover its whole surface, granite rocks frequently rising in bold and towering grandeur above all the stratified rocks, and forming the peaks of the highest mountains on the surface of the globe.

The principal rocks belonging to the *Primary Period* are,—

Gneiss.
Mica slate, or mica schist.
Primary limestone, or statuary marble.
Hornblende slate.
Clay slate, or roofing slate.
Quartz rock.

meta-morphic rocks

Gneiss, which is the principal rock belonging to this period, is composed of the same materials as granite, but usually contains a larger proportion of mica. It appears to have been formed by the *disintegration*, or crumbling, of the granite, and has a *laminated* structure, that is, it is capable of being divided into thin *laminæ*, or plates, in which respect it totally differs from granite. The gneiss has apparently accumulated in successive layers, or deposits, while the granite seems to have been formed at once, by fusion, or intense heat; and these two rocks present a good example of the difference between stratified and igneous rocks, composed of similar materials.

Mica slate is a compound of mica and quartz, and greatly resembles gneiss. *Primary limestone* includes some of the finest marbles used in sculpture. *Hornblende slate* is a species of slate, so called from the occurrence of hornblende in its composition, and may be distinguished by its dark colour. *Clay slate*, so named from being formed of alumina, or clay, is the best description of slate for roofing purposes. *Quartz rock* consists either of pure quartz, or of a mixture of quartz and felspar

In the formations of this period, all the rocks have a *crystalline* texture, that is, they consist of an assemblage of ill-defined small crystals, with a texture much resembling loaf-sugar. We meet with no sand, no clay, no chalk, no soft limestone: all the strata are indurated, or hardened, to a high degree, sandstone being converted into quartz, clay into slate or jasper, and limestone into crystalline marble. This has apparently been effected by the action of great heat, and these rocks may, perhaps, therefore, be classed among *metamorphic* rocks.

The primary stratified rocks are widely spread over the surface of the earth, scarcely any of the lofty mountain-ranges on the face of the globe being entirely devoid of these strata. They are, however, little met with in England and Wales; for Skiddaw and Snowdon are the only localities where they have been observed, these rocks being, in all probability, concealed from view by the superincumbent more recent formations. But in the Shetland or Zetland Isles, the Highlands of Scotland, the Western Isles, the Isle of Man, and in all the most mountainous parts of Ireland, they form the predominant class of rocks.

The uncertainty which still prevails regarding the formation of metallic veins, renders it rather doubtful in which division they ought to be placed: but as they are of most frequent occurrence in the primary stratified rocks, this will form a not unfitting place for some notice of these valuable products.

Metallic, or *mineral veins*, are fissures of indefinite length and depth, apparently caused by some dislocation, which have been filled with sparry or crystallized substances, and contain the metallic ores. In the formation of these cracks, or fissures, in the interior of the earth, there are signs of disturbance, which indicate a force of incredible magnitude, though slow and gradual in its effects; and it is interesting to remark, that there reigns a certain symmetry and order even in these disturbances; for it is a curious circumstance, that metallic veins almost invariably extend in one particular direction, namely, from east to west. In Cornwall, these are called *lodes*, and are usually productive. They are occasionally intersected by smaller veins, apparently of later formation, to which the name *cross courses* has been applied; but these are mostly unproductive. Metallic veins vary in width from less than an inch to thirty feet, or more; but the prevailing width is from one to three feet.

The manner in which these veins have been filled is a point that appears to be still undecided: some geologists supposing their contents to have accumulated, like stratified rocks, by aqueous deposits; others, that they have been filled from below, (like the granite veins before mentioned,) while the metallic ore was in a state of fusion; others, again, considering them to have been filled by sublimation, that is, by fumes or vapours rising from below; and others, that electro-magnetism has been the agent in their formation. Objections have, however, been raised against each of these hypotheses, or suppositions, and we shall therefore, for the present, content ourselves with briefly noticing metallic veins in their order of distribution in the earth's crust.

Iron and copper are sometimes found in masses, or beds, interposed between layers of rock; other metals not so frequently. Iron is also met with in *nodules*, or rounded masses, which are found strewed among some particular kinds of rocks. This metal, by far the most useful and important to mankind, is also greatly more abundant and easy of access than any of those termed the more precious. Metals, however, with the exception of gold and platinum, are very rarely met with in a pure state, being usually combined with oxygen and other substances, which causes them to present an earthy appearance. Gold, platinum, palladium, rhodium, osmium, and iridium, have been found in the sands of rivers.

Gold, iron, and other metals, have also been observed in volcanic formations.

Tin, copper, lead, and silver, are extensively worked in gneiss rocks, and also in clay slate, in both of which they are found in veins; but in mica schist they more frequently occur in beds and masses than in veins. Iron, copper, lead, silver, gold, arsenic, and cobalt, are abundantly found in this formation, with actynolite, garnet, and asbestus. Strathfillan

Igneous rocks are frequently interspersed among the primary stratified rocks; in many parts beds and veins of granite being found passing up into the gneiss and mica slate. Rocks belonging to the trap formation have also forced their way among these stratified rocks, appearing either as irregular masses of great extent, or as *dikes*, which are large veins or consolidated streams, and often resemble huge buttresses. Thus, porphyry, greenstone, basalt, serpentine, and other igneous rocks, are found intersecting the primary stratified rocks, in various parts of the Highlands and Western Isles; of these, the most frequent is porphyry, which forms a very large region in the vicinity of Ben Nevis and Glen Coe, and is also abundant in Ben Cruachan, both in great masses and in dikes, variously associated with granite veins.

No organic remains have hitherto been discovered in the primary rocks: and, in fact, it is the absence of any indication of the remains of the varied and beautiful forms, which subsequently adorned the face of the earth, that constitutes the grand line of separation between the primary and secondary periods. It has been supposed, that the action of intense heat on the primary strata may have destroyed all traces of animal and vegetable remains, if, indeed, organic beings had been called into existence at the time these rocks were deposited. This, however, is a point, which, in our present acquaintance with geological phenomena, we are unqualified to decide.

CHAPTER IV.

SECONDARY PERIOD. TRANSITION ROCKS. CAMBRIAN SYSTEM. SILURIAN SYSTEM.

O nature, all sufficient! over all!
Enrich me with the knowledge of thy works!
———————Through the disclosing deep
Light my blind way: the mineral strata there:—
Thrust blooming thence, the vegetable world:—
O'er that, the rising system more complex
Of animals. THOMSON.

THE secondary period is divided into various groups, which have been arranged according to the organic remains they contain. Had there been no fossils, we should have had no certain indications that all rocks were not of the same age; but in these illustrations of the volume of nature, we find the finger of God has traced in indelible characters, the history of the numerous revolutions which have occurred on the surface of our globe, before man was created to inhabit the earth.

But though the appearance, or the absence, of organic remains, seems to form the most distinct division between the primary and secondary periods, there is a class of rocks, containing organic remains, which, on account of the peculiarity of their structure, resembling that of the primary stratified rocks, appear to hold an intermediate place between the two formations; and, accordingly, some geologists arrange these rocks in the primary series, and others in the secondary: this division has been named the *Transition Period.* The circumstance of their containing fossils has been our motive for placing them with the secondary division, but it will be desirable to consider them separately, before entering upon the general subdivisions of the secondary period.

The Transition Period is divided into two groups:

1. The Cambrian.
2. The Silurian.

The *Cambrian* group, or system, (which is so called from Cambria, the ancient name for Wales, because these formations were first investigated in that country,) consists in great part of grauwacké, or greywacké, and greywacké slate, and of other rocks, bearing much resemblance to the slaty formations of the primary period: but distinguished from these by containing traces of organic remains, generally in the form of casts; that is, the impression remains, while the shell, or other substance, has disappeared. In some parts, these formations are of enormous, but unknown thickness. Other rocks belonging to the Cambrian group are red, green, purple, and other shales, and also limestones, which contain some organic remains.

Granites, syenites, porphyries, and greenstones, are usually associated with the slaty rocks of the Cambrian group, and in many cases the porphyritic beds appear to have been subjected to the same disturbances as the slates they intersect. Mineral veins are very numerous. Ores of copper, tin, lead, silver, cobalt, antimony, bismuth, &c., abound in the rich tract of Cornwall. The Cumberland, Snowdon, and Cardiganshire ranges, yield lead and copper ores.

The organic remains of the Cambrian group occur in greater abundance in the limestones which alternate with the slates, than in the latter formation, and consist principally of fuci, corals, and shells. Through wide tracts of country the slate series is entirely without fossils, but at Snowdon, and at Glider Fawr, encrinites, corals, and one or two species of bivalves, have been discovered in this formation.

The *Silurian* group, or system, (so named from the Silures, a tribe of ancient Britons, who, under Caractacus, made a noble stand against the Romans, and who inhabited that portion of Wales and the bordering counties of England where this formation was first studied,) is arranged in four divisions, which, in the ascending series, consist of,—

1. Llandeilo flags.
2. Caradoc sandstones.
3. Wenlock limestones.
4. Ludlow rocks.

The *Llandeilo* rocks, which are in some parts several thousand feet in thickness, consist of dark-coloured calcareous and shelly flagstones. The *Caradoc* rocks consist of limestone (almost wholly formed of shells), of freestone, and of sandstone. The *Wenlock* rocks include a particular kind of gray crystallized limestone, abounding in fossils. The *Ludlow* rocks consist of various shales and limestones. The rocks of the Silurian system are not so consolidated or hardened as those of the formations we have previously noticed, though the sandstones are still generally very compact; the argillaceous, or clayey beds, are shaly or slaty, and the limestones, some of which are almost wholly formed of coral, still present much of a crystalline texture.

Igneous rocks are associated with those of the Silurian system under circumstances of great interest. In some cases, the trap rocks are found piercing through sandstones, and converting them into quartz at the point of junction; in others, the igneous rocks are extended in layers between the strata of shale and other rocks; giving the idea that some ancient volcanic eruption may have spread its liquid streams for a considerable distance; and in others, the crumbled materials of igneous formations have, by the agency of water, been formed into rocks, to which Mr. Phillips has given the name of *volcanic sandstone.* Veins of lead-ore are of frequent occurrence in this system, especially where it is in conjunction with the igneous rocks; of this the Shelve district in Shropshire is an example.

Organic remains are numerous in this formation, though they all differ from any living species; but, notwithstanding so great a difference is observable between the creatures of that ancient period and those of the present day, some *species* have been met with belonging to each of the great divisions of the animal kingdom.

The animal kingdom has been arranged in four great divisions; which may be considered as four *forms*, on which all animals appear to have been modelled by their Almighty Maker. The subdivisions are only slight modifications, or alterations, caused by the developement, or addition, of some parts which do not produce any change in the grand general plan.

These four great branches of the animal world are *vertebrata*, or vertebrated animals; *mollusca*, or molluscous animals; *articulata*, or articulated animals; and *radiata*, or radiated animals. In this arrangement, there is no reference to the size of the animals, to their utility to man, to the knowledge we possess of them, whether extinct or existing, but solely to the peculiarity of their formation.

The *vertebrata*, or *vertebrated animals*, all possess a skull, and a back-bone, or spine, with lateral or side appendages. The name is derived from the bones of the neck, which are called *vertebræ*. Animals belonging to this division possess organs of sight, hearing, smell, and taste, and never have more than four limbs; it includes any animal possessing a bony skeleton. Among these are man, quadrupeds, birds, serpents, frogs, tortoises, crocodiles, and such fish as herrings, cod, &c.

This division is subdivided into four classes:—*Mammalia*, or animals which suckle their young, such as the cow, &c.; *Birds; Reptiles*, such as the crocodile; and *Fish*, that is, such as possess a backbone.

The *mollusca*, or *molluscous animals*, are so named from *mollis* (soft), because their bodies are soft, and devoid of a bony skeleton. In many molluscs stony plates, called shells, are secreted from their skin, which form a covering and defence to their soft bodies; the oyster, the whelk, &c. belong to this division,—these are called *testacea*. Other molluscs are without this external protection; such are the common garden slug, the sepia, or cuttle-fish, &c.

The *articulata*, or *articulated animals*, form the third great division of the animal world. The term articulated is derived from *articulus*, "a little joint," in allusion to the peculiar formation of the animals constituting this division, which consists of a head, and a number of successive portions of the body, *jointed* together. To this division belong the *crustacea*, that is, crabs, lobsters, &c.; the earthworm, spiders, beetles, flies, &c. The covering of the body in these animals is divided into a number of ring-like partitions, sometimes soft, as in the earthworm, sometimes hard, as in the lobster. Some have *articulated*, or jointed limbs attached to the side of the body. Of this description are the lobster, the fly, &c.

The *radiata*, or *radiated animals*, form the fourth great division of the animal world. In the three preceding divisions, the organs of motion and of sense are arranged on the two sides, so that the animal has a right and a left side; but in the radiata these organs are considered to *radiate* from a common centre, like the petals of an anemone. There are, however, some exceptions to this arrangement among radiated animals. This division includes the starfish, echinus, coral, sponge, and all those animals known by the name of Zoophytes: so called from *zo-on*, "life," and *phyton*, "a plant," because, though they are in fact living creatures, their structure bears a considerable resemblance to that of plants.

The radiata rank as the lowest in the order of the creation: the vertebrata, with man at their head, as the superior, or most perfect; and we shall find, as we proceed, that the more perfect animals increase in number as we approach the era of man's creation. But when an animal is spoken of as more perfect, it must not be understood that any creature has come out of its Maker's hands otherwise than perfectly adapted for the place assigned it in the universe; for, in that sense, every creature is perfect; not only good, but "very good;" and it is merely in reference to the complexity of their organization, and their supposed degree of importance and excellence, that animals are said to be inferior or superior.

The radiated animals are of very frequent occurrence in the rocks of the Silurian system. Some of the limestones of this period are supposed to consist of ancient coral reefs, which have been formed by polypes, animals nearly allied to the common actinia, or sea anemone, of our own shores. The gelatinous bodies of these polypes are furnished with the power of secreting carbonate of lime; which, becoming hardened, forms their case and habitation, as a shell does that of a mollusc; the polypes, however, like plants, are fixed to one spot, and attach themselves to some rock, or other object. The calcareous sheaths which have been thus formed are not so short-lived as the creatures which secreted them; but, unless removed by force, remain permanently fixed to the rock to which they were originally attached, and form the base on which succeeding polypes construct their habitations. The coral, thus formed, is nearly of the composition of limestone; and it appears that many of the limestone formations are almost entirely the work of these creatures, which, notwithstanding their apparent insignificance, have been greatly instrumental in

† to sécret, verheimlichen
to secrète, absondern

preparing the surface of the earth for man's reception.

Another description of radiated animals found in the Silurian rocks are the *encrinites*, which belong to the *Crinoideans*, (so named from *crinon*, a "lily," on account of their resemblance to that flower.) The most remarkable encrinites occurring in this formation, are the *apio-crinites*, or pear encrinite, and the *actino-crinites*, of which latter the annexed cut is a representation.

These remarkable animals might at first sight be mistaken for plants; but naturalists have discovered that encrinites, and all other zoophytes, are endowed with stomachs,—organs with which no plants are provided, but which are essential to the support of animal life. The frame of the actino-crinitis consists of a column composed of numerous joints, and supporting at its summit a cup-like body, in which this important organ is contained. From this cup proceed *arms*, or branches, which are again subdivided into thirty *fingers*, or feelers, surrounding the mouth, and evidently adapted to enable the animal to secure its prey. Fragments of the stems, or columns, of encrinites are dispersed through the transition rocks, and from their circular form*, they have received the name of *entrochi*, or wheelstones. They have been long known in the north of England, as St. Cuthbert's beads. There is a kind of marble called *entrochal marble*, belonging to this period, which is said to be "almost as entirely made up of the petrified remains of encrinites, as a corn-rick is composed of straws."

Among the molluscous animals, whose remains are found in the rocks of the Silurian group, are various species of the genera *bellerophon*, *orthoceras*, *euomphalus*, *spirifera*, *terebratula*, *producta*, and *orthis;* the latter of which may be considered as eminently characteristic of the Silurian system. Among the articulated animals we meet with an extinct family of crustacea, called *trilobites*, of which a considerable number of species have been observed, including the various genera *asaphus*, *calymene*, *cryptolithus*, *trinucleus*, &c. The vertebrated animals are less numerous, the only traces of this division of the animal kingdom consisting of some species of fishes, the bones and teeth of which, however, have been observed in great numbers in some formations of this period.

It is worthy of remark, that all the organic re-

* The columns of the encrinites are all of circular or elliptical form; and thus distinguished from the pentacrinites, another genus of crinoideans, whose stems are pentagonal.

mains above-mentioned are those of animals inhabiting the ocean: it also appears that the earliest vegetable productions hitherto discovered in a fossil state, consist of algæ, or sea-weed. Yet it is not improbable that, even at this remote period, islands may have existed covered with immense forests' which, as we shall find in the sequel, appear to have been designed to perform an important part in the economy of the earth's surface, and to have contributed in no small degree to the present benefit of man.

CHAPTER V.

SECONDARY PERIOD. ITS DIVISIONS. DEVONIAN, OR OLD RED SANDSTONE SYSTEM.

Then look who list, thy gazeful eyes to feed
With sight of that is fair, look on the frame
Of this wide universe, and therein read
The endless kind of creatures which by name
Thou canst not count, much less their natures aim;
All which are made with wondrous wise respect,
And all with admirable beauty deckt.—SPENSER.

BESIDES the systems to which the term Transition has been applied, the Secondary period is divided into several groups or systems, which, in the *ascending series*, or commencing from the most ancient in order of formation, are as follows:—

1. Devonian, or Old Red Sandstone*.
2. Carboniferous.
3. Magnesian Limestone.
4. New Red Sandstone, or Poikilitic.

* The term "Devonian" system has been proposed by Professor Sedgwick and Mr. Murchison, to express "all the great intermediate deposits between the Silurian and Carboniferous systems. The term being so far unexceptionable, that it may be applied without any contradiction of terms."—*Phil. Magazine*, April, 1839. It is named Devonian from its large occurrence in Devonshire.

Secondary

5. Lias.
6. Oolite, or Jura Limestone.
7. Wealden.
8. Cretaceous, or Chalk.

The *Devonian*, or *Old Red Sandstone* system, though consisting principally of sandstones, assumes a very different mineral aspect in different localities. In some tracts, (as in some parts of Scotland and Cumberland,) it is usually composed of coarse conglomerate, or pudding-stone*; in others, of the finest laminated sandstone; and in others, (as in Caithness and the Orkneys,) of black bituminous schist. In Herefordshire and Brecknockshire, variegated marls and concretionary limestones prevail: whilst in Pembrokeshire, the soft marls are replaced by a hard brownish-red rock; and large tracts are occupied by yellow and gray, hard, siliceous (or flinty) sandstones; and these again altogether differ from the slaty sandstones and limestones of Devonshire and Cornwall. It will be evident, therefore, that the formations belonging to this system cannot be distinguished by their *lithological*, or mineral structure; and, indeed, it is only by their characteristic organic remains, and by the intermediate position they

* Conglomerate has received the familar appellation of pudding-stone from its resemblance to a pudding with fruit scattered through it. It consists of pebbles or fragments of rocks rounded by the action of water, and cemented together by some mineral substance.

occupy between the Silurian and Carboniferous systems, that this has been determined.

The peculiar character observable in the red sandstone formations occurring in Devonshire and Cornwall, appears in great measure to be attributable to igneous action, that part of the country being said to "bristle with rocks of igneous origin," which are considered to belong to the same era, (perhaps to one fully as recent,) as the strata with which they are intermingled, and which they have altered into hardened rocks, thus causing them to differ from other formations of this group.

The organic remains of the Devonian or Old Red Sandstone group are, in their general character, intermediate between those of the Silurian and Carboniferous systems, though it possesses some remarkable forms peculiar to itself. In the lower rocks of this system the fossils are not numerous, but corals occur, among which is a species of *favosites*, which is also met with in the upper Silurian rocks: stems of encrinites, resembling those occurring in the latter group, are likewise found, as also some species of productæ, spiriferæ, and others. In the upper rocks of the Devonian system, however, these particular species disappear, and the fossils approach to those of the Carboniferous system. Thus, in the upper rocks, we meet with spined productæ and spiriferæ, which differ entirely from any found in the Silurian system, but closely resemble those found in the overlying strata, called mountain limestone. In the same rocks we also meet with new species of trilobites and of crinoidea. Fossil plants have been observed, considered undistinguishable from those of the Carboniferous system; and, indeed, as has been well remarked in reference to this group, "all true analogy would impel us to look for the presence of some species of plants common to the Carboniferous epoch;" and we have already seen that there is reason to suppose vast forests may have existed even at a more remote period. All the vegetable productions of this period do not, however, appear to be identical in species with those of the Carboniferous system; for casts of plants of considerable size have been found, which are considered distinct from any known remains in the coal-fields.

Among the most remarkable organic remains of this group, are, however, the various genera of fish. These fossils are met with in great abundance in the Old Red Sandstone formation in Scotland, and are, in some instances, associated with plants resembling *fuci*. The *ichthyolite*, or fish beds, in the neighbourhood of Cromarty, are very extensive, and the bold cliffs of the Moray Frith present sections of these rocks, including the fish beds. Some of the finest fish are often of a plum-blue colour; these specimens are found enclosed in large nodules of soft reddish brown schist. Among the fish met with in this group, are species belonging to the genera *dipterus*, *diplopterus*, *cheiracanthus*, *cheirolepis*, *osteolepis coccosteus*, *holoptychus*, &c.; besides the very singular genus *pterichthys*, of which some species have recently been discovered. One of these, (which has been named *pterichthys Milleri*, in honour of its discoverer,) is a winged fish, so nearly resembling crustacea, as to be with great difficulty distinguished from an insect. It is about an inch, or little more, in length, and the wings are upon the shoulders, nearly in the same position as in the dragon-fly. Other species resemble beetles.

Fossilized impressions of the footsteps of animals, known only by these traces, have been observed in the Old Red Sandstone, or Devonian formations in Wales.

CHAPTER VI.

CARBONIFEROUS SYSTEM. MOUNTAIN LIMESTONE. COAL MEASURES. — Coal-measures

Thus studied, used and consecrated thus,
On earth what is, seems formed indeed for us:
Not as the plaything of a froward child,
Fretful unless diverted and beguiled;
But as a scale, by which the soul ascends
From mighty means, to more important ends,
Securely, though by steps but rarely trod,
Mounts from inferior beings up to God;
And sees, by no fallacious light or dim,
Earth made for man, and man himself for Him.

COWPER.

We now arrive at the important group called the Carboniferous system, which comprises the Coal-measures and the Mountain limestone. The rocks of this group consist of limestone, shale, sandstone, and conglomerate; interstratified or intermingled with which, are large beds of coal.

Mountain limestone is a marine formation, and usually consists of a grey compact crystalline limestone, sometimes (as in the North of England) abounding in lead ore: it is most frequently found underlying the coal strata; but in some parts of Scotland it occurs in alternate layers with the coal-beds, and hence it has been included in the Carboniferous system.

All the fossils contained in the mountain limestone are marine, and include encrinites, echini, bellerophons, euomphili, lituites, orthoceratites, and other remains decidedly of marine origin. The most remarkable of these is the orthoceras, which, as well as some of the other genera, is not met with in rocks of more recent formation. The orthoceras is a chambered univalve shell, the form of which is conical, and it has been compared to a straight nautilus. Orthoceratites vary much in size, some exceeding a yard in length and six inches in diameter. The largest known are found in the mountain limestone of Closeburn, near Edinburgh. Part of the pavement in Hampton-Court Palace, and the hall of University College, Oxford, are paved with marble, (from the island of Oeland, off the coast of Sweden,) in which many of these shells may be observed. The *lituite* is another shell found in mountain limestone: it bears some resemblance to the orthoceras, but is partially coiled up.

The *Coal-measures*, or *Coal-fields*, are beds, or strata, in which that most valuable material is found. In the North of England, the coal-measures are three thousand feet in thickness; but by no means consist entirely of coal, being formed of abundance of sandstones and shales, as well as ironstone and limestones, amongst which seams or beds of coal are interspersed; the beds of coal in that part altogether amounting to about sixty feet in depth.

The fossils contained in the rocks which interstratify the coal beds, are partly fresh-water and partly marine. The fresh-water rocks, instead of containing corallines and other marine remains, like the mountain limestone, contain land plants and fresh-water shells and fish. Thus, in the Shropshire coal-field, a limestone occurs, in which a small species of *planorbis* is plentifully embedded; and in the shales of Northumberland, and the sandstones of Lanarkshire, various species of the fresh-water genus *unio* have been observed. The fish are also of fresh-water origin, and include the *megalichthys*, *gyracanthus*, *holoptychus*, and some other species. The shales also abound in fossil ferns, *stigmariæ*, *lepidodendra*, *sigillariæ*, and other coal plants. The ironstones of a coal district are sometimes found in beds, but mostly in layers of *nodules*, or round masses; and it frequently happens, that each nodule encloses some fossil, round which the ironstone appears to have accumulated.

SPHENOPTERIS AFFINIS.

This specimen of a wedge-shaped fossil fern is from the Derbyshire coal-field.

Bilfinny

Coal evidently owes its origin to accumulated masses of vegetables, altered and modified by being pressed beneath the weight of a thick deposit of mineral substances, and then exposed to a high temperature. If examined with a powerful microscope, coal presents a vegetable texture; and, as we have just remarked, numerous remains of plants occur in the rocks which accompany it. The quality of the coal appears to depend partly on the nature of the plants of which it was originally composed, and partly on subsequent changes produced by subterranean movements, and other causes. The principal difference, however, in its utility for fuel, arises from the variable quantity of gaseous matter. Thus, anthracite, or stone coal, contains little besides carbon and earthy mixtures; whilst the box or cannel coal of Lancashire and Gloucestershire, which blazes like a candle, contains nearly half its weight of gaseous matter; and the one species is applicable for purposes to which the other is unsuited*.

We have seen that coal is of vegetable origin; and the question has arisen, whether the plants of which it is composed grew in the localities where the deposits have been formed, or whether they were drifted thither by currents. Though it is by no means im-

* The use of anthracite has hitherto been chiefly confined to malsters; it has been more recently adopted for Dr. Arnott's and other stoves, and is now successfully applied to the reduction of iron ores in the vicinity of Swansea.

probable that some of these accumulations may have been formed, or perhaps increased, by drift wood, the balance of evidence appears in favour of the opinion, that the vegetable matter grew on the localities in which the coal is now found. And it is supposed, that the surface of the earth, at that period, presented a series of swampy islands; and that on these islands grew a luxuriant vegetation, consisting of ferns, *calamites*, coniferous trees, &c., which, decaying and regenerating, accumulated in the same manner as peat bogs. It is further supposed, that the islands, by the subsiding or sinking of the agitated crust of the earth, were depressed beneath the surface of the sea, and covered over with drifted sand, clay, and shells, until they were by this accumulation again converted into dry land, and clothed with another vegetation. An operation, it has been observed, which may have been repeated as many times in each coal district, as there are alternating layers of coal and of shale, or of other sedimentary strata.

It appears that the luxuriant forests to which coal owes its origin, belonged in great measure to plants included in the order cryptogamia, of which the ferns, mosses, &c., of the present day are the representatives. We may therefore suppose that the vegetation of this ancient period must have differed greatly from that which now adorns the earth with its beautiful and varied foliage; and, indeed, it appears that, with the exception of the tree-ferns, some species of which still occur in tropical countries, neither the stems nor the leaves of these ancient vegetables resembled any *trees* at present existing on the globe; and we must look for their modern representatives among our more humble plants*. The arborescent or tree ferns were very numerous during this period, and more than two hundred different species have been described. The *lepidodendrons*, which in some respects resembled ferns, but in others were allied to our lycopodiums, or club-mosses, were also numerous; thirty-four different species having been described. These trees sometimes attained the height of seventy or eighty feet. Another prevailing tree was the genus *calamites*, which bore a striking resemblance to the equisetum, or common horse-tail of our ditches and other marshy places; but which appeared in the form of a tree, fourteen or sixteen feet in height. At least four hundred species of plants belonging to the coal formation have been described, among which, besides those above enumerated, we may mention

* "The older naturalists," says M. Ad. Brongniart, "had referred them, (the plants of the primitive world,) to the bamboos, and palms, and the large species of cactus. But a more minute comparison between the trees of equinoctial regions, and these stems of the ancient world, very soon shows, that the vegetables which formed the primitive forests, cannot be compared with any of the trees which now exist on our globe."

the *sigillaria*, *sternbergia*, and *stigmaria*, as of frequent occurrence. Impressions of the stem of the *stigmaria ficoides* may be very commonly seen on the shales which occur among the coals used in our apartments. We have now before us a very fair specimen, which we have just rescued from the fire. The impressions may be traced, but less perfectly, after the shale has passed through the fire. Our readers are aware that shales are rocks which may be readily split into thin layers, and may be compared to a quire of paper, glued together. Each layer may be considered as a separate deposition. The stigmaria ficoides has been very frequently found in the shales, with the leaves attached to the stem, and spread out laterally, in a manner which never could have occurred, had the plant been drifted from a distance. The vegetable impressions most frequently met with consist, however, of the leaves of ferns. We have already given a representation of the *sphenopteris affinis*. With the exception of a few *coniferæ*, or plants of the pine kind, no large timber trees have been found.

In some of the sandstones and shales, broken fragments of coniferæ and other plants have been observed, having *serpulæ* attached to them. Worm casts have also been found on the rocks of this period; slabs of slaty sandstone having been met with, presenting the tortuous casts of vermiform bodies, either impressed in the stone, or in relief.

Not a single bone of any land animal has been discovered; but the scorpion, and some species of insects, have been met with.

Brief and imperfect as are the above remarks on the subject of the coal plants, they may perhaps suffice to convince us, that the beneficent Creator, who has provided for us the invaluable supply of fuel formed by the growth of these immense and remarkable forests, has not, even in those remote ages, been unmindful of man's interest. And, in truth, had not this useful material been thus abundantly prepared for us, it would have been impossible to have procured a sufficient supply for all the purposes of comfort and utility to which coal is at present applied. Our manufactories, our steam-engines, never could have been furnished with fuel by any other means; nor could they have been brought to the perfection which has raised Great Britain so high in the commercial world, and which, by extending her influence over the globe, has enabled her to spread to far distant lands, the benefits of civilization and religious truth.

The present consumption of coals in this country is enormous. In the year 1838, 2,581,085 tons were imported into London, of which above two million tons were drawn from the collieries of Newcastle and Sunderland. The annual consumption in the whole of Great Britain and Ireland, has been computed to exceed twenty-nine million tons. We cannot suppose that the supplies of this very valuable material are inexhaustible; and we might almost entertain some apprehension of its failure*. Recent investigations, however, have shown it to be highly probable, that extensive carboniferous or coal-bearing strata exist in Worcestershire and other central counties, hitherto little worked.

Coal is, indeed, remarkably abundant in our favoured isle, especially in the western and northern districts, to which the *true* coal formation is nearly confined. The most southerly of our coal fields is in Somersetshire; this is not, however, of very great extent, being about twelve miles in length and three in width. The South Gloucestershire coal field, which extends from the Avon northwards, and which is of nearly similar size, is the nearest place to London at which coal has been found. The coal field of the Forest of Dean, in the same county, is of smaller extent, but is important from the iron manufactory carried on there. Directly west of the last-

* The waste of the small coal at some of our collieries having been very considerable, Dr. Buckland called attention to the subject; and successful experiments have been made of manufacturing fuel from the waste coal dust. This fuel is formed of a mixture of coal dust, river mud, coal tar, lime, and water, which is pressed into the form of bricks: and it appears, that a greater degree of heat (with very little smoke and residue) is obtained from this compound, than from the coal from which the dust was taken. A saving also of one-third in bulk is effected, which circumstance especially adapts it for steam navigation.

mentioned deposit, and at a distance of less than twenty miles, lies the extensive coal district of South Wales and Monmouthshire, which is one of immense area, and of great importance, both from its present enormous produce, and from the large portion which, being yet unwrought, may be considered as a provision for future demands. This coal field is upwards of one hundred miles in length, extending from Pontypool to St. Bride's Bay, and includes the great iron-works of Merthyr Tydvil. This deposit is supposed to have been anciently continuous with the culm fields of Devonshire, but to have been separated from that formation by some mighty convulsion.

The Shropshire coal field, which includes Coalbrook Dale, and the Plain of Shrewsbury, extends for nearly eighty or ninety miles. The North Wales or Flintshire coal field, which may be considered as a continuation of the latter, extends from the estuary of the Dee to the Irish Sea, appearing also in the Isle of Anglesea. The Staffordshire coal field is one of vast importance, and also remarkable for the thickness of some of its seams or layers of coal. The manufacture of iron is there carried on to an immense extent; and in the more northern parts of the district, the occurrence of pottery clay has led to the establishment of extensive earthenware manufactories. The coal districts of Lancashire, Derbyshire, and Yorkshire, spread over a vast tract of country, and have given rise to the various manufactures so successfully carried on in those counties. The Whitehaven coal field borders on the shores of the Irish Sea, and is extensively worked.

We now arrive at the great northern coal field, extending into the counties of Durham and Northumberland, and containing those immense deposits of excellent coal, from which not only the metropolis, but a vast circuit of towns and villages, on and near the line of coast from Berwick to Plymouth, and also (by means of the railroads) numerous places in the most inland districts, are supplied with this species of fuel. The southern extremity of this coal field is near the Tees, and, with the exception of a small interruption near the river Coquet, it extends northwards to the neighbourhood of Berwick, a distance of about eighty miles. Between Berwick and the Tyne, the coal extends along the coast line, dipping, indeed, under the German Ocean. In a westward direction, it stretches to Brampton, near Carlisle. The figure of this immense coal field is very irregular, but the whole area is estimated at fifteen hundred square miles.

Thus extensive are the depositories of this valuable mineral in South Britain; and, as before remarked, it is more than probable that, besides the districts here enumerated, similar formations occur in various unexplored localities, which future research will place among our important and valuable coal fields.

Scotland contains some highly important coal fields, though occupying a comparatively insulated district, the true coal strata being chiefly confined to a tract included between Berwick and St. Andrew's on the eastern coast, and Girvan and Saltcoates on the western coast. In some districts the produce is very abundant, especially in the south side of the county of Fife. There are also productive collieries at Saltcoates, in Ayrshire, and in the vicinity of Paisley, in Renfrewshire. Lanarkshire also contains a vast coal field, resting upon the Old Red Sandstone formation, and interstratified with mountain limestone. A particularly valuable deposit extends from Glasgow to Carluke, a distance of twenty miles. The coal is in some parts associated with valuable black-band ironstones. The celebrated iron-works on the river Carron are supplied from this coal field; and, to the vicinity of this rich deposit, Glasgow owes much of its prosperity. The neighbourhood of Glasgow, indeed, abounds in mineral treasures; scarcely any district in Britain (not even excepting Cornwall itself) being more abundantly supplied with metallic ores. East Lothian also contains large deposits of excellent coal: at Culross, a detached portion of the county of Perth, bordering on the Frith of Forth, coal has been worked for ages; and the Culross chalder, or chaldron, was in 1663 made by act of parliament the standard measure of the kingdom, and thus continued until it was abolished in the year 1831.

The Scotch coals are mostly what are termed *open burning*, in contra-distinction from *caking* coal, such as that of Newcastle. The Scotch coals do not last so long as the Newcastle, nor do they yield so much heat, but they make a very pleasant cheerful fire; and, for most household purposes, the best fire is said to be made up of a mixture of these and of the Wallsend coals.

There are four principal coal districts in Ireland: the Leinster and Munster, both of which produce chiefly anthracite or stone coal; and the Ulster and Connaught, which produce bituminous coal. The Munster coal district is by far the most extensive in Ireland, and occupies a considerable portion of the counties of Limerick and Kerry, and a large part of the county of Cork. In some parts of this district, coals and culm have been wrought for about a century; and the advantages accruing to the inhabitants from this impetus to industry, have been shown by the improvement of that portion of Ireland.

It has been mentioned that beds and nodules of ironstone occasionally occur in the strata of shale which alternate with coal. As this ironstone affords most of the iron manufactured in this island, it is a circumstance which has proved of much importance in working that most useful of metals. And in some districts, not only are the iron ore and the coal met with in near conjunction, but they are also accompanied by limestone, necessary for the process of fusion, and even millstone-grit, adapted for the construction of furnaces. This arrangement, so remarkably calculated to assist human industry, has, as we have seen, rendered these districts the usual site of the principal iron foundries.

Iron is also met with in the coal beds, (as well as in many other formations,) in the form of *pyrites*. The mineral called *martial pyrites*, or *bisulphuret of iron*, which consists of a combination of sulphur and iron, is sometimes found mixed with the coal at Newcastle and other places in such abundance, as to render the latter unsaleable for fuel. These iron pyrites have a metallic lustre, and their colour is brass-yellow, from whence they are vulgarly called "brassy coals." Though the proportion of iron in these pyrites is not sufficient to render them valuable for the produce of that metal, these martial pyrites* are not wholly useless: and at Newcastle persons are employed to separate them from the coal, and convey them to places where the manufacture of the salt called *sulphate of iron* is carried on. This is obtained by exposing iron pyrites for several months to the action of the air and moisture of the atmosphere in great masses, called *copperas beds*. By this

* These pyrites probably acquired this name from having been used instead of flints for guns.

means, the iron pyrites become decomposed, and the substance called *copperas**, or green vitriol, which is a sulphate of iron, is obtained in the form of green crystals. This is used for various purposes, especially for dyeing black, and for giving its black hue to ink. The iron pyrites of Cornwall, where they occur in great abundance, and are known by the name of *mundic*, have recently been brought into use for the supply of sulphur they afford. This is obtained by means of nitric acid, which dissolves the iron, and deposits the sulphur.

We cannot but be sensible that the mineral treasures of our favoured country are very great: and from recent investigations, it appears that the average value of the annual produce of the mines of the British Islands, amounts to the enormous sum of twenty millions sterling; of which about eight millions arise from iron, and nine millions from coal.

Before concluding this account of the mining district of Great Britain, we must direct our attention to the remarkable arrangement of the strata, which renders them so readily accessible to man. Had the different rocks been all horizontally disposed, in regular order, one above the other, the upper, or more recent strata, would alone have been known to the

* It will be evident that the term copperas thus applied is equally erroneous with that of "brassy coals." The term would be more appropriate to *blue* vitriol, which is obtained from copper pyrites.

inhabitants of the earth's surface, and the valuable coal-formations never could have been disclosed; but, owing to the basin shape which so generally prevails, the different strata come to the surface, or *outcrop*, as it is termed, in particular localities. And, again, had these basins been excessively deep in proportion to their extent, the inclination or slope would have been such, that the strata would soon have become inaccessible to man; but the gradual slope which the usual form of these basins causes the strata to assume, is the most advantageous for working the valuable minerals, for, as has been well observed, they "are so placed as to render them accessible by the exertion of human skill and industry, and, at the same time, to secure them from wanton destruction and natural decay." And, to quote the words of an old divine, "we may as reasonably suppose that iron was designed for our use, though first we be put to dig for it, then must employ many arts and much pains before it become fit for our use, as that the stones were therefore made, which lie open to our view, and which, without any preparation, we easily apply to the pavement of our streets, and the raising of our fences."

After the deposition of the Carboniferous system, and apparently before the superjacent or overlying rocks were formed, very extensive dislocations or disturbances appear to have taken place. In the British Islands, every coal district has been disturbed and shaken, in every square mile of its breadth, by faults, (locally termed galls, slips, troubles, and dikes,) passing in many directions, and some of them much affecting the working of the mines. But these faults or dislocations appear almost insignificant in a geological point of view, when compared with the gigantic disruption of Tynedale, the Penine chain, the Craven fault, the Derbyshire elevation, and the disturbances in South Wales. North of the Tynedale fault, there is a "throw" or depression of from 1000 to 2000 feet; west of the Penine fault, 2000 or 3000, or perhaps 4000 feet, under Cross Fell; and south of the Craven fault, at least 3000 feet, under Ingleborough. In some instances the dislocation has been so violent, that the strata have been actually overthrown.

Igneous rocks have not unfrequently been observed in the coal-measures. At the colliery of Birch Hill, near Walsal, in Staffordshire, a dike or vein of greenstone passes through the coal-beds, and has deprived the coal of its bitumen. And in the North of Ireland, a dike of greenstone has indurated the slate clay belonging to the coal-measures, and converted it into flinty slate. In another place in the same locality, one of these dikes passes through a bed of coal, which it has reduced to cinder † for the space of nine feet on each side. It appears probable, however, that this intrusion of the igneous rocks took place long subsequently to the deposition of the coal.

† ausgeglüht [illegible]

CHAPTER VII.

MAGNESIAN LIMESTONE. NEW RED SANDSTONE, OR POIKILITIC SYSTEM.

Seek'st thou the plashy brink
Of weedy lake, or maze of river wide,
Or where the rocking billows rise and sink
On the chafed ocean tide?

Thou 'rt gone! the abyss of heaven
Hath swallowed up thy form; yet, on my heart
Deeply hath sunk the lesson thou hast given,
And shall not soon depart. BRYANT.

THE next group is the Magnesian Limestone. This and the New Red Sandstone are by some geo logists placed in one group, but we will follow Mr. Lyell's arrangement, and consider them separately.

The *Magnesian Limestone*, or *Alpine Limestone*, contains several varieties of limestone. The magnesian limestone of England is generally of a yellowish-white colour, but some varieties are of an ochre-yellow colour. It has received its name from the magnesia which enters into the composition of some of the rocks belonging to this formation. The *zechstein* of the Germans, and its accompanying marl slate, loaded with copper ore, belong to the Magnesian Limestone group; as do also the red and dolomitic conglomerates, which occur in the neighbourhood of Exeter and of Bristol.

This formation does not abound in fossil remains; but such as occur are peculiar, having been hitherto observed only in the strata included in this group. Among these we meet with *fuci*, and *zosteræ;* with some species of corals and crinoideans; and of the mollusca division, with different species of *productæ*, which are very numerous, of the *ammonite, spirifer, mytilus*, and *terebratula.* The remains of fishes are also found. This group, however, is more remarkable, on account of its containing the earliest indication of the existence of reptiles; some organic remains resembling the modern monitor, having been discovered in the zechstein of Germany. And, more recently, the bones of extinct animals, approaching in character to the modern iguana and monitor, have been found in the magnesian conglomerate of Durdham Down, near Bristol.

These reptiles are called *saurians;* the term saurian including all animals of the lizard and crocodile kind. These extinct saurians appear to have been gigantic animals, which in some respects resembled the modern crocodile, and in others, the lizard, the monitor, or the iguana. Many of these enormous reptiles were exclusively marine; others amphibious; others inhabitants of the land: some even appear to have been tenants of the air, bearing, in this respect, some resemblance to the vampires of the present day.

The magnesian conglomerate of Durdham Down appears to contain a very large assemblage of the bones of these animals, among which are two new species, which have been named the *Palæosaurus* and the *Thecodontosaurus*.

Basaltic dikes divide the magnesian limestone of the North of England; and similar dikes, as well as interposed beds of igneous rocks, are extremely abundant in the Island of Arran. Masses of porphyry also occur at Exeter, and the red conglomerate in that locality appears to be formed of fragments of porphyry, accumulated by the action of violent water-currents. Metallic veins are very rarely met with in these rocks, and nowhere worked in this country.

The next group is the *New Red Sandstone*, *Variegated Sandstone*, or *Poikilitic* group, which consists of red and white sandstones; variegated, red, white, and other clays, with gypsum; of marls, which are a mixture of clay and lime; besides conglomerate of older rocks, embedded in sandstone. Salt is associated with the Red Sandstone system in England, France, and Germany; though in England it appears to be confined to the localities of the variegated marls. The salt-mines of Cheshire are situated in this formation. The *muschel-kalk*, or shell limestone of Germany, which usually rests upon the new red sandstone, but which has not hitherto been found in Britain, may be included in this group.

The new red sandstone occurs largely in the central counties of England, and almost universally occupies a low, or level country. Some of the most considerable dislocations of the border of the coal fields of Dudley and Coalbrookdale, are supposed to have happened after the deposition of the new red sandstone.

Organic remains do not appear to be extensively diffused in this group; though, in certain localities, they are very numerous. The shells and other organic remains are generally marine; but terrestrial plants occur both in the *muschel-kalk* of Germany, and in the new red sandstone of this country. The lepidodendrons seem to have wholly disappeared at this period; and though arborescent ferns and calamites still occur, they appear to be gradually giving place to the *coniferæ*, of which the fir, the pine, the yew, and the cypress, furnish well-known examples; and to the *cycadeæ*, or Mantelliæ, of which the cycas and zamia are the only modern representatives. Some remains of gigantic ferns and palm-trees have been found in the muschel-kalk of Germany. And in the new red sandstone of Allesley, near Coventry, a discovery has been recently made of some *silicified*, or *mineralized* trunks of trees, which are considered to be coniferæ. The remains of other plants, among which is part of a flabelliform, or fan-shaped palm-leaf, have also been discovered in Worcestershire.

The singular and beautiful crinoidean, called the *lily encrinite*, is peculiar to the muschel-kalk. That formation also abounds in well-preserved fossil shells. Among the molluscous animals met with in the New Red Sandstone group, we may mention the *producta horrida, spirifera undulata, mytilus acuminatus, ammonites nodosus, posidonomya minuta*, &c.

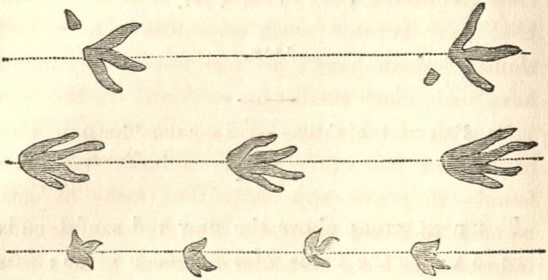
Among the vertebrated animals of this period, we find fishes and reptiles; the remains of various species having been discovered, both in the German formations included in this group, and in those of our own island. The New Red Sandstone, in the neighbourhood of Warwick, contains many of these remains, the teeth and bones of fishes and of saurians having been found at Guy's Cliff, near that place, and also at Shrewley Common, about five miles from Warwick. These remains are generally in a very mutilated condition; but the fish found in this neighbourhood have been referred by Mr. Owen to two species of *sauroid*, or lizard-like fishes; and among the reptiles, three species have been distinguished, one of which is the *phytosaurus*, and another has been named the *platygnatus*.

At Shrewley Common, the surface of some of the beds is impressed with the footmarks of an animal having four claws, and which is supposed by Mr. Strickland to have been a *batrachian* reptile, of which the salamander may perhaps form the best modern representative. It is supposed that at the period when the creature passed over the surface, the rock was still in a state sufficiently soft to receive impressions, but that it subsequently became hardened without disturbance, and thus retained the prints of the animal's footsteps.

That such evanescent traces of animal existence should be preserved, appears perhaps even more extraordinary than the discovery of all the fossils that have been brought to light. We may frequently observe, on the sands by the sea-shore, the print of a dog's foot or horse's hoof distinctly marked; but the next flow of the sea will unquestionably efface every vestige of such impressions; or the wind will cause them to crumble to dust. Such at least is the case on our shores, but there is a remarkable formation mentioned by Mr. Schomburghk, as occurring in the Island of Anegada, one of the group called the Virgin Islands, in the West Indies, which appears to present a phenomenon very analogous to that just noticed. The beach of Anegada is found in many places to be coated with a gray, siliceous, and calcareous substance, apparently deposited by the waves, which, as the tide retires, hardens, and slowly assists in increasing the size of the island. In some parts of the interior of the island, (but where, perhaps, at no very remote period, the waters deposited this peculiar substance,) the impression of birds' claws and of human feet are distinctly visible: the latter, from the outward turn of the toes, are supposed to be those of the Indians who inhabited the neighbouring coasts. These impressions are not of very recent formation, for they have existed beyond the memory of the oldest inhabitant of the island, and in some places grass has grown over them; but they are highly interesting, as proving to the student in geology, that such impressions, frail and perishable as they usually appear, may under some circumstances become permanent. And if these footsteps have been preserved for fifty or a hundred years, we may as well suppose those in the red sandstone to have remained unchanged for untold ages.

Many impressions of fossil footsteps, similar to those at Shrewley Common, have been found in other localities; but all that have been hitherto discovered, occur in the sandstone formations. Fossil footsteps of animals resembling the tortoise, have been observed near Dumfries. Some remarkable impressions have also been noticed in the old red sandstone in Forfarshire, to which the superstitious Scotch peasantry had given the name of Kelpies' feet. Fossil footsteps, remarkably distinctly marked, of animals known only by such traces, have also been observed at Storeton Hill, near Liverpool. These footsteps occur in a bed of white stone, belonging to the New Red Sandstone group. The most remarkable of these footsteps are those of the hind feet of an animal to which the name *cheirotherium* has been given; the impression of the animal's hind paw bearing much resemblance to a large clumsy human hand; the fore feet of this animal have made much smaller impressions. In the same slabs with the footsteps of the cheirotherium, those of four or five other smaller animals have been found; they are apparently the tracks of small aquatic and land tortoises. In the same locality, indentations have been also observed on the surface of the stone, which are supposed to be fossil impressions of a shower of rain and hail. Ripple marks and worm tracks likewise occur. Similar impressions have been observed in the sandstone of Grinshill Hill, in Shropshire, at which place the foot-prints of an animal have been found, which differed from the cheirotherium in having only four toes, three of which were directed forwards, and were armed with long nails, whilst the hind toe, which pointed backwards, had a very long claw.

Some fossil footmarks, occurring in the Valley of Connecticut, in the United States, are peculiarly interesting, on account of their presenting the earliest indication of the existence of *birds*. These footmarks are imprinted on the sandstone in regular succession, showing the track in which the bird proceeded. From the form of the footmarks, the birds are supposed to have belonged to the order of birds called *grallæ*, or "waders," which frequent marshy situations.



ORNITHICHNITES.

Among the footmarks which have been observed in Connecticut, we find those of a gigantic bird, which seems to have been twice as large as the African ostrich; its foot appearing to have measured seventeen inches in length, and its usual step to have been from four to six feet. The footmarks of seven different species of birds have been observed in this formation. These traces of birds have been named *ornithichnites*.

CHAPTER VIII.

LIAS.

Fragments of shells——sea monsters' bones.
J. MONTGOMERY.

THE next group above the new red sandstone is that to which the name *Lias* has been given: this is an English provincial term, but has been very generally adopted for rocks of this formation. The Lias, the Oolite, and the Wealden, are by some geologists arranged in one large group, termed the "Oolitic system," but as the fossils of these formations are numerous and interesting, it will perhaps be more advantageous to consider these groups separately.

Lias consists of clay and marlstone, with strata of blue, white, and yellow limestone, all more or less argillaceous or clayey; with occasional layers of slaty and bituminous clay; and also of sandy, irony rocks, and of septaria, which are flattened balls of stone, generally consisting of a kind of ironstone, and which, on being split, are found to be separated in their interior into irregular masses.

Lias occurs at Lyme Regis, Bath, Bristol, Stratford-upon-Avon, Barrow-on-Soar, Whitby, and in many other parts of England. It retains a *uniform mineralogical character* throughout a great part of France and Germany; that is, the earths and other materials of which it is composed are similar. This is by no means, as we have before seen, of constant occurrence with formations included in the same group; for as all stratified rocks are in great measure formed by the *disintegration*, or mouldering away of older rocks, both igneous and stratified; if the older rocks differ in different localities, the newer rocks must necessarily differ also; and this difference we may expect to increase as the number of formations is augmented. And accordingly rocks are frequently only known to belong to the same period, by the similarity of the organic remains they contain.

The fossils which have been observed in the Lias are chiefly marine; they are very abundant, particularly at Lyme Regis, where some very interesting specimens have been discovered.

Belonging to the vegetable kingdom, the principal remains that have been found are fuci; some fossil wood, and impressions of cycadeæ; and some cones, apparently belonging to a tree resembling the Norfolk Island pine.

Of the radiata division of animals, we meet with a remarkable and singularly beautiful Crinoidean, called, on account of its numerous arms, or branches, and feelers, the *Briarean*, or many-armed *pentacri-*

nite. The number of plates, or divisions, in the Briarean pentacrinite, has been computed to amount to a hundred and fifty thousand. Pentacrinites, as has been already observed, are so named on account of the pentagonal and star-like form of the plates which compose the frame of the animal. These plates are frequently found in a fossil state in detached portions, and have long been known as *asteriæ*, or star-stones. The Briarean pentacrinites are very abundant in the lias at Lyme Regis.

Among the articulated animals we find some species of crabs, and other crustacea.

Belonging to the mollusca division we meet with several highly interesting remains; the most remarkable of which are the *fossil ink-bags* of the *loligo,* called also the *sepia,* or *cuttle-fish.* The modern cuttle-fish is provided with no external shell, and the soft body of this molluscous animal might, therefore, appear to be exposed to the attacks of predaceous fish; it is not, however, left without protection, having a peculiar internal provision, which affords the means of defence. This consists of a bladder-shaped sac, or bag, containing a black, ink-like, and viscid substance (from which sepia is prepared), which the cuttle-fish has the power of ejecting, and thus of thickening the water, so as to conceal itself from its enemies. Ink-bags of this description have actually been found preserved in a fossil state in the lias at Lyme Regis; some even distended as when the animal' still existed. The sepia, or cuttle-fish, also possesses, enclosed within its soft body, a bony or horny substance, generally of an oval form, though varying in different species. Those of the sepia vulgaris, or common cuttle-fish, are very frequently found on our shores. These substances have been discovered accompanying the fossil ink-bags; and from their form, and also from their having been found in connexion with these ink-bags, they have been termed fossil pens. They are composed of a laminated semi-transparent substance resembling horn.

blättig

AMMONITES COMMUNIS.

Among other molluscous animals belonging to this group, the *nautilus*, the *gryphea*, or *gryphite*, the *belemnite*, the *scaphite*, and the *ammonite*, are the most remarkable. Ammonites are found in the whole series of fossil-bearing strata, from the earliest to the chalk inclusive. At least two hundred and seventy species have been observed; varying in size from a line, to four feet in diameter. They are very universally diffused. The same species of ammonites which occur in the lias, have been found in the Himalaya mountains, at the height of 16,000 feet above the level of the sea. The specimen here given is from the lias at Lyme Regis.

Among the vertebrated animals of the lias formation, we meet with the bones of an extinct genus of fishes, called *sauroid*, or *lizard-like* fishes, which appear to have been of enormous size. The bones of sharks are also found: indeed, there is no period in geological history during which the family of sharks did not prevail. Some fossil teeth of a fish called the *acrodus*, are also found, which, from their singular form (that of a contracted leech), have received the name of *fossil leeches*. The term *ichthyodorulite* has been applied to some peculiar spines which supported the dorsal, or back fin of the *hybodus*, an extinct species of shark, and which are of frequent occurrence in this formation.

The lias formation is remarkable for containing, in great abundance, the remains of *enaliosaurians*, or *sea lizards*, which include the *ichthyosaurus* and the *plesiosaurus*. These marine reptiles were not, however, confined to this group; for the ichthyosaurus has been met with in the various formations extending from the lias inclusively to the close of the secondary period. The plesiosaurs, though not confined to the lias, appear to have been more abundant at this earlier epoch than at subsequent eras. Sixteen different species of the latter genus have been found in Great Britain, and ten species of ichthyosaurs.

The ichthyosaurus in its structure exhibited a combination of the characteristic features of reptiles, fish, and cetaceous animals, and it is supposed by Mr. Owen to have presented the general external figure of a huge predatory fish, with a longer tail than usual. The general form of the skull resembled that of the dolphin; presenting, however, some affinity to the lizard tribe, and resembling the crocodile in its formidable jaw and teeth. It was provided with four paddles, not unlike the paddles of animals of the cetaceous or whale tribe, whilst it possessed a *caudal*, or tail fin, like that of the shark*. Some species exceeded thirty feet in length, and the eye of the ichthyosaurus grandis was of enormous magnitude, said to exceed the size of a man's head. It is also considered to have been an instrument of great and varied power.

The plesiosaurus, like the ichthyosaurus, ap-

* An impression of the soft part of the caudal, or tail fin of the ichthyosaurus, has been recently found in the lias at Barrow-on-Soar, in Leicestershire.

Hydrarchus Harlanii 116

proached the lizard and crocodile in the form of its head, and structure of its jaw, though it does not appear to have been so formidable an animal as the ichthyosaurus. The plesiosaurus was remarkable for the length and mobility of its neck, which bore much resemblance to the body of a serpent; and probably imparted to the animal, whilst skimming the surface of the waters, a graceful appearance, not unlike that of the swan. In some species, the neck was equal to three lengths of the head; the head and neck together being equal in length to the body and tail. The paddles of the plesiosaurus appear to have been of a more elegant and tapering form, and also to have possessed greater flexibility than those of modern cetacea; and from a peculiar modification in the structure of these organs in the plesiosaurus, a compound motion appears to have been given to the propelling stroke of the paddles, similar to that which in skilful rowing is called "feathering the oar."

The remains of crocodiles also occur in the lias formation; but these reptiles, which in the present day rank among the most terrific inhabitants of tropical regions, almost sink into insignificance when compared with those gigantic enaliosaurs, which at this era of geological history tenanted the waters; and which, from their remarkable forms, appear to us almost like creatures of the imagination.

Enalio-saurus, [illegible]

CHAPTER IX.

OOLITE. WEALDEN GROUP.

All teeming nature, when her plastic hand
Left framing of these monsters, did display,
Past doubt, her wisdom; ———
—————————And if she
Repent her not of th' elephant and whale,
Who ponders well, confesses her therein
Wiser and more discreet. DANTE.

THE *Oolite*, or *Jura limestone* formation, consists of oolitic, shelly, and coraline limestones, fuller's earth, sandstones, and blue clay. This group has received the name of *oolite*, or *oolitic*, because many of the formations present a peculiar structure resembling the roe of a fish. It is called the *Jura limestone* group, on account of the great resemblance existing between the formations of the Jura chain of mountains, and the oolitic group of England. This group is very extensively developed, as *Bath oolite*, in the neighbourhood of that city; as *coral rag**, in the valley of Oxford, in the extensive hills to the north of Berkshire, and in those of North Wiltshire; and as the *Portland stone*, in the Isle of Portland.

* So called because the blocks present a rough or ragged appearance when quarried.

Among the fossil plants which have been discovered in the oolite group, we find the araucaria, and the pine: the cycas family appears to have been very abundant at this period, these trees having been found in the oolitic formations between Whitby and Scarborough, on the coast of Yorkshire; and also in those at Stonesfield, in Oxfordshire; and in the Isle of Portland.

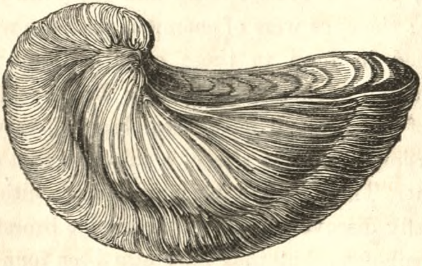
Among the radiated animals of this group, we meet with abundance of corals; but the most remarkable is a species of crinoidean, called the *pear-encrinite*. At Bradford, near Bath, these curious remains are so numerous, that the bed of the sea, in which they lived, appears to have been completely studded with them.

The *echinus*, or sea hedge-hog, also occurs very abundantly in this formation. Echini are found, though rarely, as early as the carboniferous group: they become more abundant in the muschel-kalk and lias; but are very numerous throughout the oolitic and cretaceous formations.

In the oolitic group, we also meet with various remains of articulated animals. Besides some crabs and the wing-covers of *coleoptera*, or beetles, which have been found in the oolitic slate at Stonesfield, and at Solenhofen, twenty-four different species of insects have been observed, among which are five species of *libellulæ*, or dragon-flies. Fossil spiders have also been discovered.

The molluscous animals found in the oolitic group, much resemble those before mentioned in the lias formation; the same species of nautili, ammonites, and belemnites frequently occurring. At the base of Golden Cup Hill, near Charmouth, in Dorsetshire, the shore presents two strata almost paved with belemnites.

Ammonites are very abundant in the formations of this period in the neighbourhood of Bath. We have seen some very splendid specimens in the walls of cottages near that city, and picked up gryphites among the stones placed to repair the roads. This gryphea, or gryphite, is from the Bath oolite.



GRYPHEA INCURVA.

The sauroid fishes are abundant throughout the oolitic formation. A species of fish, named the *microdon*, appears to have been very numerous at this period; this fish possessed a peculiar provision for masticating its food, which consisted of a kind of pavement of flat teeth in all parts of its mouth.

These palatal teeth are called *Bufonites*, and occur very abundantly throughout the oolitic formation.

The reptile tribe still continued greatly to prevail during this period; among these we find the *megalosaurus*, or *giant-lizard*, which is supposed to have been an enormous carnivorous animal, forty or fifty feet in length, formed for inhabiting the land. Mingled with the remains of this animal, are found those of a small fossil tortoise, and of the *pterodactyle*, which latter may be ranked among the most extraordinary discoveries of geology.

This remarkable animal appears to have been a flying lizard. The head and neck resembled those of birds, though some species had the jaws of a crocodile; the eyes were of enormous size; the wings approached in form to those of a bat, and the body and tail resembled those of a lizard. Eight species of pterodactyli have been observed, varying in dimensions from the size of a snipe, to that of a cormorant. These remarkable remains have hitherto been chiefly discovered in the lithographic limestone near Solenhofen; but they have also been found in the lias at Lyme Regis, and in the oolitic formations at Stonesfield.

The remains of cetaceæ, or animals of the whale tribe, have been met with in the oolitic formation.

A discovery of great interest has been made in the Stonesfield slate,—that of the remains of two small species of an extinct terrestrial quadruped, allied to the modern didelphys, an animal resembling the oppossum. To these the names of *Thylacotherium* and *Phascolotherium* have been given. This discovery is remarkable, as presenting the first and only remains of terrestrial mammalia, hitherto observed in any formation, antecedent to the tertiary period.

Some evidences of dislocations, or disturbances, during the oolitic period, are met with in the North of England; but the most remarkable is a disturbance which may be distinctly traced in the Isle of Portland. In that locality, it appears that a limited tract of oolitic formation, now constituting the Portland stone beds, had been raised into dry land, been covered with soil, and prolific in trees; that this oolitic formation was again quietly submerged; (the rise and fall probably exceeding one thousand feet;) that it was subsequently covered by a partially fresh-water deposit, which accumulated to a considerable depth above the bed in which these trees flourished, and now forms the *Purbeck beds.*

The soil in which that ancient forest grew, forms a separation between the Portland and Purbeck beds, and is termed by the quarrymen, *the dirt bed.* This remarkable deposit appears to be composed of black loam, mixed with decayed parts of vegetables resembling tropical plants; and contains, nearly at the same intervals at which trees are found growing in a modern forest, an assemblage of fossil stumps of

Lehm, terre glaise, terre grasse, (argile large trees, *with their roots attached to the earth in which they grew.* Among these, stems of the Mantellia, a plant resembling the modern cycas and zamia, frequently occur; but the coniferæ are the most numerous; and the trunks of very large trees, of the latter description, some exceeding thirty feet in length, are often found laid prostrate. The black earth which contains the roots of these trees seldom exceeds a foot in thickness; but the stumps are from one to three feet in length, and are found to project upwards into the substance of the superjacent stone, called *Burrstone*, which gives indication of their occurrence by rounded concretions, accumulated over the top of each stem. This cut will convey some idea of this remarkable formation.

The Purbeck-beds belong to the Wealden formation, to which we will now turn our attention.

The *Wealden* formation consists of sandstones and clays of various descriptions, with layers and nodules of limestone. The whole of this group is characterized by containing the remains of land and freshwater animals and plants. It is largely developed in the South of England, where it extends over a tract of land two hundred and twenty miles in length, and two hundred in width. It is subdivided into three formations,—the Purbeck-beds, the Hastings sand, and the Weald clay.

The *Purbeck-beds*, of which we have already spoken, consist of various kinds of limestones and marls: the *Hastings sand* consists of gray, yellow, and reddish-brown sand and sand-rock, with calciferous grit; variegated loam and clay; slaty clay, with shale, and with iron ore. This formation is so named from occurring near Hastings, in Sussex; it also extends to Tunbridge Wells, Horsham, and Tilgate Forest. The *Weald clay* consists generally of clays, occasionally including thin beds of sand and shelly limestone, called Sussex or Petworth marble. The Weald clay is so called, from occurring in the *wealds* or *woods* of Sussex and Kent, which formerly consisted of a forest tract, extending from Winchelsea to Riverhill.

Some of the vegetable remains of the Wealden formation, belong to plants which appear to have held an intermediate place between the equiseta and the palms; among these, is the *endogenites erosa*, portions of which are frequently found on the beach at Hastings. Some resemble the yucca, some the dracæna, or dragon's-blood tree; and others, again, approach to arborescent ferns, the species being very peculiar, and not known in any other deposit: though they may recall to our remembrance some

+ Grit; fine sand ‡ old Saxon

of the more ancient trees, which have contributed to form our supplies of coal. Examples of that material are, however, few and insignificant in any of the strata subsequent to the carboniferous group, our supplies of fossil fuel being almost exclusively derived from that formation.

Nevertheless, before geology had brought such important facts to light, there was no apparent reason for expecting the presence of coal in one series of strata rather than in another; and thus, experiments in search of coal, might frequently be made in spots, where the geologist would now at once pronounce the certainty of failure.

Not very many years ago, an attempt was made to establish a colliery at Bexhill, in Sussex, which is situated on the Hastings sand formation. The appearance of thin seams and sheets of fossil wood, and of lignite, or wood-coal, with some other indications similar to those usually occurring in the neighbourhood of the great coal fields in the North of England, led to the sinking of a shaft, and the erection of machinery, on a scale of vast expense; little less than eighty thousand pounds having been expended on this project. It will be foreseen that the whole scheme terminated quite unsuccessfully; for we have already remarked, that no useful coal deposit occurs in this formation; and the Hastings sand is separated from the carboniferous strata, by a series of beds of such enormous thickness, as to render all idea of penetrating through them, an unprofitable, if not altogether a hopeless, undertaking.

But although there might be no chance of discovering useful fuel in the Hastings sand formation, the occurrence of the seams and sheets of fossil wood, and of lignite, appears not without interest. The Wealden group is the first fresh-water formation we have observed since the carboniferous strata, and the trees bear a considerable resemblance to some of those found in that formation. We may therefore suppose, that these accumulations resembled, on a small scale, those in the coal measures; though probably heat and great pressure, or some other agents essential to the formation of useful coal, no longer extended their influence at this period.

Another point of resemblance between the Wealden and the carboniferous strata, consists in the occurrence of slaty clay and shale, with rich iron ore in very regular beds, in conjunction with the deposits of lignite and carbonized wood. Some years ago, when it was the practice to use charcoal for smelting, the iron ore in this district was of great value, owing to the proximity of this mineral deposit to the extensive forests of the Weald, and the consequent facility of obtaining charcoal, and of working the iron on the spot; and formerly, furnaces were numerous along the verge of the Weald. Among the localities from whence the rich iron ores of

Sussex were at that period obtained, was the immediate vicinity of Covehurst, or the Govers, near Hastings. This deposit of iron may be observed from the beach in the cliffs at that place: the lowest visible strata consist of dark-coloured shale, containing roundish masses of sandstone, whilst several layers of rich argillaceous or clayey iron ore occur, forming ledges in the cliffs. With this iron ore are found thin layers of lignite, and innumerable fragments of carbonized vegetables, among which traces of ferns have been discovered.

It thus appears, that the Wealden group is, in the general character of its mineral composition, very similar to the coal measures; the two groups being, however, distinguished by peculiar and characteristic fossils, though in some instances, as in the case of the trees before alluded to, to which may be added that of the *unio*, (a fresh-water mollusc,) the same genera are found in the two groups, though the species altogether differ.

This uniformity in the midst of change, which is so generally displayed in the operations of nature, and of which this forms an example, is further shown in the resemblance which some impressions found on the sandstones of this group, bear to those we have noticed in the red sandstone formations. We find that many of the flags of Hastings sandstone exhibit traces of worms, and other marine animals, and even the ripples of the waves, so distinctly marked, as to present the appearance of recent sands, left by the retiring tide. Formations of this description may be noticed in the pavement at Horsham, in Sussex, and frequently in the stones heaped on the road side to repair the ways, in the Wealden portion of the route from London to Worthing. Very fine specimens of these slabs may also be met with at St. Leonard's. In the summer of 1840, the hill or cliff almost immediately behind the Marina, at the latter place, was partially removed, and amongst the blocks and flags then brought to light, many such might be observed. The rock is naturally divisible into thin flags, the surface of which is waved in ridges resembling those upon the shore after the retreat of the tide. Among the specimens we there found, some are covered with worm tracks, others contain casts of shells, whilst one distinctly exhibits the sandy froth, and minute fragments of fuci, &c., as left by the retiring waves.

Among the organic remains of the Wealden group, we meet with equiseta, ferns, cycadeæ, or Mantelliæ, and plants allied to the palms, dracæna, thuja, and yucca.

The fossil shells of this group will not bear comparison with those preceding groups, either in number of species, or in beauty of appearance: they consist entirely of the inhabitants of lakes and rivers or of estuaries. But though there is little variety among the molluscous animals of this period, the individuals appear to have been very numerous, entire beds of limestone being sometimes formed of shells, some of which are so minute, that they can only be distinguished by the aid of a microscope. The paludina is very abundantly diffused among some of these rocks, and forms the common and characteristic feature of the Petworth marble. The cyclas, a bivalve shell, is another very abundant genus. The unio, mytilus, and ostrea also occur: the latter are in some parts very abundant; layers, composed almost entirely of the shells of extinct species of the ostrea, or oyster, occurring in various localities. The articulated animals are very abundant, especially the genus cypris, which may be considered as characteristic of the Weald clay. Of this there are several species, some of which are very minute, the remains of myriads of these tiny creatures being met with. Some species are, however, of larger size. Besides the cypris, the articulated division includes a new crustaceous animal, called the *isopod*, and various species of insects, some of which are microscopic, and among which are beetles, flies, dragon flies, &c. One beetle was found with the antennæ attached.

Among the vertebrated animals of this period, we meet with fishes, tortoises, crocodiles, saurians, and birds. The fish are fresh-water, and the most characteristic is the *lepidotus Mantellii.* Several other species have, however, been met with, among which are some of the genus *silurus*.

The Hastings sand formation at Tilgate Forest, has been very prolific in the remains of saurians. Bones of the megalosaurus have been discovered both in that locality, and at Langton, near Tunbridge Wells, by Dr. Mantell, who has also found, in Tilgate Forest, the *hylæosaurus*, or lizard of the Weald, which appears to have been an animal about twenty-four feet in length, and which is distinguished by a horny spine on its back, formed of long, flat, and pointed bones, resembling that of the modern iguana. Dr. Mantell has likewise discovered a new species in the same neighbourhood, named the *iguanodon*, which appears to have differed from the megalosaurus in having its teeth formed for feeding on vegetable substances: it was more gigantic than that animal, the iguanodon having apparently attained the enormous length of seventy feet or more. This gigantic creature resembled the modern iguana, in having a horn on its nose.

The bones of birds, supposed to have belonged to the tribe of waders, have been discovered by Dr. Mantell in the Wealden formation; + this being the most ancient occurrence of such remains.

+ secondary

crystalline

CHAPTER X.

CRETACEOUS GROUP.

Millions of millions here, from age to age,
With simplest skill, and toil unweariable,
No moment and no movement unimproved,
Laid line on line, on terrace, terrace spread,
To swell the heightening, brightening gradual mound,
By marvellous structure climbing towards the day.
Omnipotence wrought in them, with them, by them:
Hence, what Omnipotence alone could do,
Worms did. J. Montgomery.

The next group, which is the uppermost in the Secondary series, is the *Cretaceous*, so called from *creta*, "chalk," because the mineral called chalk forms a principal feature in this group. The cretaceous group is subdivided into *green-sand*, called also *Shanklin-sand*, which consists of green and irony sandstones and limestone; *gault*, or *Speeton clay*, which is a blue clay; *hard chalk;* and *chalk with flints*.

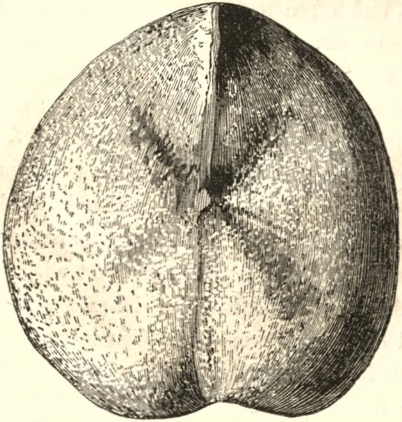
The cretaceous formations occur very extensively over Europe; and it has been supposed that, at the period when these strata were deposited, a considerable portion of Europe was covered by an immense ocean, extending from the Atlantic into Asia; and that these strata were formed whilst the sea occupied that position,—a conclusion drawn from the similarity of certain fossil remains occurring in the whole range.

The chalk, and its associated beds, are very extensively developed in England, particularly in the south-eastern parts, but are not met with in Scotland; and only in a small portion of the north-eastern districts of Ireland.

Chalk differs greatly in its composition and structure from most other calcareous formations; for, though it is evidently formed by a watery deposit, it presents no appearance of stratification, but consists generally of an earthy mass. Nodules of flint, variously shaped, are sometimes met with in beds of chalk, disposed in layers almost parallel to one another, and often at regular distances, from three to six feet apart. These nodules frequently contain organic remains, round which it appears that the silex, of which the flints are formed, must have accumulated, and thus become separated from the calcareous matter of which the chalk is composed.

The vegetable remains which have been observed in the cretaceous group, are mostly marine; though fossil wood has been occasionally met with, both in the chalk and in the flints which are embedded in it; and on some parts of the Continent, large beds of lignite have been found in the formations of this period; as also some very small deposits of useful coal: we may therefore conclude, that forests existed at this period; though the site of the land on which they grew is at present unknown.

The radiated animals are very abundant; and include a great number of corals, sponges, and other zoophytes, many of which are beautifully preserved in the flints of this formation. One species, the *choanite*, commonly called the petrified sea anemone, is very frequently found on the shores of Sussex, especially at St. Leonard's. The crinoideans are sparingly distributed in the cretaceous group; the most remarkable is the *marsupite*, which appears to have been an unattached crinoidean. Asteriæ, or star-fish, are also found; and the echini are exceedingly numerous, occurring both in the chalk and in the accompanying flints. Among those met with in



SPATANGUS COR.

the former, we may mention the *spatangus cor*, of which the accompanying specimen was procured from the chalk cliffs at St. Margaret's Bay, near Dover.

The cretaceous group contains the remains of several genera of crustacea, among which is a species of crab, which is supposed in its habits to have resembled our hermit crab.

Molluscous animals are very abundant in this group, about a thousand different species having been discovered. Among these, the *conchiferæ*, or bivalve shells, are the most numerous, and include many well-known genera, such as the oyster, scallop, tellen, arca, cardium, or cockle, &c. This *ostrea carinata*, or keel-shaped oyster is from the chalk cliffs in the vicinity of Dover.

OSTREA CARINATA.

The ammonite is also found in the cretaceous group, but this is its latest appearance. We here likewise meet with the nautilus, baculite, hamite, hippurite, scaphite, turrilite, belemnite, nummulite, &c. Our common white chalk is also full of excessively minute shells and corals. From a pound of the white chalk at Brighton, at least a thousand of these tiny fossil bodies have been obtained. They appear to the eye like particles of chalk, but when examined with a strong magnifying power, are found to be fossils in a beautiful state of preservation. Others, indeed, incalculably more minute, have been observed; for it appears that the white mealy-looking casing of black flints, is formed of the shells of infusoria.

Several species of fish are found in the cretaceous formations; some in an excellent state of preservation: and the palatal teeth of the shark family abound in the chalk at Steyning, and in other parts of Sussex. With the exception of the shark, which we have already met with in older groups, the fish of this period are the first which approximate to species now in existence: among these are some resembling the dog-fish, and the salmon, or the smelt. [illegible] pike, [illegible]

The gigantic saurian reptiles, which have formed so remarkable a feature in many of the strata we have been considering, are still met with in the cretaceous formations, but not so abundantly as in

seal, sea-dog

some of the preceding groups, and this period is the last of their occurrence. There is one species, however, which is peculiar to this group, which has been named the *mososaurus.* This animal was long known as "the great animal of Maestricht," in consequence of a nearly perfect skull having been found near that place. The mososaurus appears to have resembled the modern monitor, but to have possessed four large paddles, like those of the whale, in the place of feet; and to have been adapted for living in the water. It is supposed to have been twenty-four feet in length, and to have had a very long tail. Some bones of this animal have been found in the English chalk. Remains of the ichthyosaurus have been discovered by Dr. Buckland in the gault, near Benson, in Oxfordshire; and by Dr. Mantell, in the chalk marl near Dover. The latter geologist has also discovered a large portion of the skeleton of an iguanodon in the quarries of Kentish rag, near Maidstone, which are included in the cretaceous formations. The remains of crocodiles, and of large turtles, also occur; and a small fossil lizard has lately been found near Chatham.

The remains of two species of birds have very recently been discovered in the formations of this group. One species, which has been met with in the Kentish chalk, is considered to have resembled the albatross. The other, of which a nearly perfect skeleton has been found, in the lower cretaceous for-

+ = tortoise; turtle auf [illegible]

mations near Glaris, in Switzerland, is a small bird, not unlike a swallow.

No rock of igneous origin has been observed to be associated with the cretaceous formations in England; but in the north-east of Ireland a very remarkable instance occurs. In this part of the island, a mass of igneous rocks almost covers the chalk, which in some parts (when in contact with these trap rocks) is converted into crystallized limestone. The celebrated Giant's Causeway forms part of this remarkable range; it consists of a platform composed of basaltic pillars, which

> Stretch far to sea their giant colonnade.

The precipitous banks are ornamented with long ranges of basaltic pillars, sometimes placed above each other, and chequered by horizontal strata of red-ochre, which, when contrasted with the dark gray or black appearance of the columns, produces a very striking effect: in some places, the earth has wasted away, and left single columns standing insulated and erect, on the brink of the precipice, like the ruined colonnade of some ancient temple. The magnificent "pillared rocks" of Staffa, are of the same date as those of the Causeway.

There is no proof of any considerable disturbance having occurred in England, during the cretaceous period, but it is considered probable that the English chalk underwent a gradual elevation, by which the seas between this island and the continent of Europe were contracted, and sloping shores of chalk were formed, probably bearing some resemblance to those still existing on the coasts of England and France.

Having now traced the revolutions which have occurred in the earth's crust, from the earliest stratified rocks to the cretaceous group, inclusive, let us, ere we close this account of the Secondary Period, turn our attention to a few particulars relating to this portion of geological history.

One of the most remarkable, is the evidence afforded by the organic remains, of the high temperature which must have prevailed on the earth's surface. All the existing representatives of the fossils of this period, are inhabitants of tropical regions, but, from their small size, when compared with the gigantic remains of the ancient world, it is supposed, that the heat in those remote ages must greatly have exceeded that of the hottest regions of the earth in the present day; it being a well-known fact, that the size of most animals and plants is much influenced by increase of temperature.

The terrestrial surface in those far distant periods, appears to have been divided into an infinity of low islands, which were covered with immense vegetables. But these gigantic plants, instead of presenting the varied tints, and brilliantly coloured flowers and fruits, which array and adorn many of our trees, differed little from each other in their aspect, or the colour of their foliage,—a circumstance which must have imparted to vegetation a singularly monotonous character. And when we consider that, as far as we can discover, no feathered choristers*, no terrestrial quadrupeds, excepting, indeed, the saurians of the Weald, animated these mighty forests, "we may form a tolerably just idea of this primeval state of nature; sombre, melancholy, and silent, yet at the same time deeply imposing, both by its grandeur, and by the important part which it has acted in the history of the globe†." Nor must we forget, that though this vegetation was less calculated to delight the eye, and even, perhaps, for the support of animal life, such as it now exists, than the beautiful and prolific trees of the present day; there was no human eye then to be delighted, there were no animals to be supported, similar to those which now regale on the varied produce of our groves and orchards. Whilst, at the same time, these ancient forests were peculiarly adapted for forming the valuable supply of fuel, which, particularly in Great Britain, more than furnishes a substitute for the woods of the present era; and which flourished at a period, when land was not required for the growth of corn, and of other vegetables, of immediate and especial utility to man.

* We have noticed the occurrence of the remains of birds; but none of these appear to have been tenants of the grove. The vegetable world, we may also remark, seems to have consisted chiefly of flowerless plants.

† Ad. Brongniart.

CHAPTER XI.

TERTIARY PERIOD. ITS DIVISION. EOCENE PERIOD.

Thou takest away their breath; they die, and return to heir dust.

Thou sendeth forth Thy Spirit, they are created: and Thou renewest the face of the earth.—*Psalm* civ. 29, 30.

The *Tertiary Period* appears to be marked by the commencement of a new system of phenomena, very analogous to those now in progress on the surface of the globe. Thus, the rocks and other formations greatly resemble those which still continue to be formed by the deposits of our seas, rivers, and lakes; and the remains of animal and vegetable life approach gradually nearer and nearer to species at present in existence in the waters, and on the land.

Another distinguishing feature of the Tertiary Period, is the local distribution of animals and plants, which becomes strongly marked in some of the organic remains of this period, and which is still observed to prevail; for, in the present day, it is found, that certain animals and plants inhabit particular parts of the globe, and are confined to those regions. Thus the camel is peculiar to certain parts of Asia and Africa, the llama to South America, and the oppossum family to some portions of that con-

diurnal

tinent, and to Australia. And we shall perceive, as we proceed, that during the later eras of the Tertiary period, a distribution in many respects similar seems to have prevailed. The ancient types, however, appeared in a magnified form; and we find that when the genus was the same, the species differed from existing creatures.

It may not be out of place here to mention, that the term *genus* is used to express a particular kind of animal or plant. To take an instance from the animal world:—the *elephas,* or elephant, is a genus, or kind of animal, belonging to the order *pachydermata,* or "thick-skinned," and to the class *mammalia.* Of this genus there are only two known existing species, the Indian elephant, and the African elephant. Both species have many characteristic features, which mark them as belonging to the same *genus;* but certain peculiarities are observable, which distinguish them from each other, and constitute two distinct *species.* Thus, among other differences, the head of the Indian elephant is oblong, while that of the African species is round; and the other bones are found to correspond so remarkably with the form of the skull, &c., that skilful anatomists, by investigating a single bone, or even tooth, are enabled not only to decide to what *genus* an animal belongs, but to what particular *species.*

The science of comparative anatomy has been of inestimable value to the geologist: for not only has he thus been able to trace the progressive forms of animal life which have tenanted this earth, but even so far to restore them, as to give us probably a very correct idea of their actual appearance. The same remark is applicable to the vegetable world, for botany has also lent most valuable aid to geology. Indeed, there is scarcely any science, which does not tend to throw light on the hidden treasures of Providential wisdom and goodness, which it falls under the province of the geologist to investigate.

The Tertiary formations are divided into three groups, or as they are usually termed, periods.

1. The Eocene.
2. The Miocene.
3. The Pliocene.

The *Eocene* group has been so termed by Mr. Lyell, in reference to the fossils discovered in the formations of this period*: for this era appears to be the *dawn*, or *break of day* of the *recent*, or existing order of things; a small number of fossils being now first found, belonging not only to existing *genera*, but to existing *species*. These fossils consist of testacea, or shell-fish; and it thus appears, that these particular species were called into life at the commencement of the Tertiary period, and that they have continued to inhabit the ocean from that era to the present time. Great changes, however, seem

* From the word *eos*, aurora, or break of day, and *kainos*, recent.

to have taken place in the temperature of the earth's surface, since their first appearance on the globe: for the same testacea which then inhabited the shores of Britain, are now found only in the hottest regions; and it is supposed that the temperature of Middle Europe during the eocene period, was many degrees higher than the present climate at the equator.

Some remarkable formations of the eocene period occur in the South of England, which are known as the "London" and "Hampshire basins." These formations have been deposited in extensive basins, or hollows of chalk, which mineral, indeed, generally forms the base of all the tertiary strata; whence they are sometimes called *supra-cretaceous* formations.

It has been mentioned that the rocks of the same group frequently vary from each other in different localities: this is much more strikingly observable in the tertiary formations. Like the secondary, they are all composed of calcareous, sandy, and clayey matter, but the English series differ from the French, and these again from the Italian; a diversity evidently attributable to the difference of the secondary rocks, in whose vicinity they have accumulated. Thus, Mr. Lyell has supposed that the eocene deposits in the London and Hampshire basins have been formed by the wasting away (through the action of tides and waves) of the chalk beds which he supposes at one period to have covered the whole of the Wealden group; and that the sands and clays of the latter formation being thus denuded, or laid bare, have contributed largely to the sands and clays of the London basin. The manner in which our chalk cliffs are continually crumbling away by the action of the waves, combined with the water-worn appearance of many of the rocks of the Wealden formation, (of which the sandstone rocks at Tunbridge Wells form a striking illustration,) appears to countenance this opinion. In other localities, the Paris basin for instance, formations differing from the Wealden group being situated beneath the chalk, the *detritus* is different, and the tertiary formations also vary.

The English Eocene formations may be divided into four groups.

1. Plastic clay.
2. London clay.
3. Hampshire Fresh-water formation.
4. Bagshot sands.

The lowest group, called the *Plastic clay,* consists of clays and sands, and may be observed to great advantage at Alum Bay, in the Isle of Wight; where in some parts it alternates with the London clay, and where the several strata of pipe-clay and sands may be distinctly observed, displaying bright and varied tints of yellow, orange, red, green, gray, lilac, white, and black. The evidence of a considerable dislocation having occurred, increases the interest of this locality: for the strata of chalk, plastic clay, and sands, have been so thrown out of their original position, as to be nearly, if not absolutely, perpendicular: at a short distance from this spot, however, the beds recover their horizontal direction. This disturbance has produced a singular effect on the flints embedded in the chalk, which present the appearance of having been shivered by a blow of inconceivable force. These flints retain their complete form and position in the bed of chalk, which closely invests them on every side; and until removed, nothing different from other flints can be perceived, excepting fine lines indicating a fracture, as in broken glass; but when disturbed, they at once fall to pieces, being broken in every direction into pieces of all sizes, from three inches in diameter, to an impalpable powder.

The *Bognor beds* belong to the plastic clay group; they consist of grayish-green sands, with layers of pebbles, and sometimes pass into sandstone and limestone. Beds of this formation occur also at Pegwell Bay, Herne Bay, Hampstead, Watford, Reading, &c. The fossils in all these beds are similar to the well-known Bognor shells.

The *London clay*, so called because the city of London stands on this formation, is most fully developed in the vale of the Thames. This great argillaceous deposit, which in the vicinity of the metropolis is usually covered with a stratum of alluvial gravel, is in some places five or six hundred feet in thickness, and consists of a blueish or blackish clay, sometimes passing into marl, but rarely into solid rock. It is little varied, but abounds in marine fossils and drifted wood, and contains some remains of land animals: it also contains some layers of large partially-flattened stones, called *septaria.* These nodules are formed of limestone, and the interior is generally intersected by cracks, which are partly or wholly filled with calcareous spar. Shells and other organic remains frequently form the nucleus of these nodules. Layers of stratified limestone have been observed at Harwich; and shelly beds sometimes occur in the London clay.

The *Hampshire fresh-water formation* occurs in the northern part of the Isle of Wight, and also in part of the opposite coast of Hampshire, being found resting on the London clay. It consists chiefly of marls, which are often of a green colour, and the fossils include fresh-water shells, and some remarkable land animals, which will hereafter be described.

The *Bagshot sand* is a marine deposit, occurring in many of the heathy tracts in the neighbourhood of London. This formation had long been considered as devoid of fossils, but the casts of shells have lately been found near Chobham Park, in Surrey. And, in cutting through Goldworth Hill, on the line of the Southampton Railway, nearly in the same locality, the remains of marine fish have been discovered; some of new species, and others similar to those found in the London clay. The remains of a marine turtle have also been found.

A remarkable formation belonging to the Eocene period, and in many respects similar to the London and Hampshire basins, occurs in France, in the neighbourhood of Paris. This formation, which has received the name of the Paris basin, is, like the English, situated in a basin of chalk. Some of the strata differ from those of the London basin, but others agree specifically in the organic remains they contain.

The fossils of the eocene period are very numerous and very remarkable. Pursuing our usual course, and commencing with the vegetable world, we may notice the abundant occurrence in the London clay, of fossil wood, of jet, and also of fossil fruit. Some of these fruits resemble the cocoa-nut, others the date, others a species of pandanus, or screw-pine; and many different species bear a near resemblance to the aromatic fruits of the cardamom. They occur in great abundance in the Isle of Sheppey, at which locality an assemblage of from six to seven hundred different species have been found*. These all belong to plants, of which the existing genera grow in the hottest regions of the earth.

* A numerous collection of the fossil fruits from the Isle of Sheppey, may be seen in the British Museum.

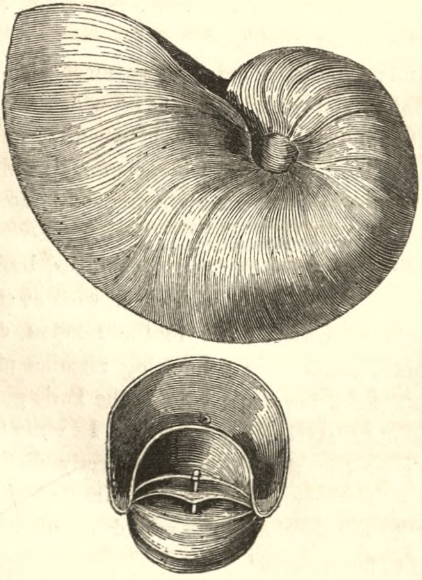
Fruits of a similar description have also been found in the Isle of Wight; likewise near Hampstead, and in various other parts where excavations have been recently made for the Birmingham and Southampton railroads. Beds of lignite also occur in some places, associated with fossil fruit. The beds of lignite, or imperfect coal, near Poole, in Dorsetshire, and those near Bovey, in Devonshire, are considered to belong to this period. The remains of palm-trees, and of plants allied to the cinnamon, have been found in the latter formation, but pines are the most abundant.

Among radiated animals, we meet with the pentacrinite; stems and portions of which are found in great abundance, in the cliffs between Herne Bay and Whitstable. The fragments, commonly called asteriæ*, or star stones, may be frequently seen on the beach at the Isle of Thanet.

The articulated division of animals, besides presenting us with several crustaceæ, such as crabs, lobsters, &c., which occur in the London clay, also includes some very interesting remains of insects, which have been met with in the Paris gypsum, in a beautiful state of preservation. In some instances, the nerves of the wings are perfectly distinct; the claws, and even the colouring, are also retained; and, in one specimen, the very down on the head is said to be preserved.

* These fragments must not be confused with the asteria, or star-fish.

The molluscous animals are very numerous; the Bognor beds present many varieties; some of these shells are filled with sulphuret of iron, others with calcareous spar, or with selenite. In other instances the shell itself appears converted into that material: but others, again, retain their mother-of-pearl in a perfect state, and even their colour. The upper beds of the London clay contain a very interesting assemblage of fossil shells, of which the nautilus is the most remarkable.



NAUTILUS COMMUNIS.

These molluscs, in the present day, are found only in the tropical seas, but during the eocene period, they were evidently inhabitants of this part of the globe, being of frequent occurrence in the London clay. The above two beautiful specimens are from the London clay formation, near Wandsworth Common, and were discovered when excavations were in progress for the Southampton railroad. The smaller specimen is peculiarly interesting, on account of its exhibiting the curious internal structure of the shell; the siphuncle or pipe being distinctly visible.

Besides the nautilus, we meet with the nummulite, conus, turritella, murex, buccinum, bulla, cerithium, cardium, &c.; and among these, with a great number of so minute a size, as to be only discerned by aid of the microscope. These little creatures appear, indeed, to have been very numerous during this period; for in the formations of the Paris basin, which correspond to the London clay, a kind of rock or stone occurs, called milliolite limestone, which is used in building, and which is almost entirely composed of millions of minute shells, no larger than a small grain of sand. Yet these are by no means the most minute creatures whose remains have been discovered; a peculiar kind of stone is found in Tuscany, in an ounce of which ten thousand four hundred microscopic chambered shells have been found. Of this species, a thousand would nearly weigh a grain. And even these are large compared with the fossil infusoria, which Professor Ehrenberg has lately discovered.

These infusoria, which, in the present day, are found in almost every infusion (whence their name), and with which stagnant water is replete, though they are even met with in fog, rain, and snow, are such excessively minute creatures, that they are indiscernible without a strong magnifying power: and yet Professor Ehrenberg has discovered, and succeeded in determining, the species of the fossil remains of similar animalculæ, some extinct, and others resembling recent species, and occurring in rocks of various formations. One of the most remarkable of these rocks is tripoli, which belongs to the Tertiary period, and is a substance peculiarly useful for polishing stones and metals. This rock is almost wholly formed of the siliceous coverings, or shells, of infusoria. These are extremely minute; it having been calculated that a hundred and eighty-seven millions weigh a grain; and that a cubic inch of this stone contains forty-one thousand million individuals.

With this remarkable mass of fossils, the soldier cleans his arms; the worker in metal and stones, and the engraver, polish their works. In Berlin alone, the annual consumption of tripoli, has been estimated at from fifty to sixty hundred weight. And when we consider, that at every stroke of the polishing stone, several thousands of perfect fossils are crushed to pieces, we cannot but feel how incalculably numerous these animalculæ must have been, and how greatly they have contributed, not only to our benefit, but even to our luxuries.

Professor Ehrenberg has also discovered that the white stripes in the semi-opal are composed of these minute creatures; and, as we have already mentioned, that the white mealy-looking casing of black flints, is also formed of the shells of infusoria. Nothing, perhaps, tends more to impress on our minds the length of time which must have elapsed, ere man was placed on the earth, than the consideration that entire rocks are formed of the *exuviæ*, or remains, of myriads of these minute creatures. Indeed, it would seem that the infusoria have exercised much greater influence on the present condition of the earth's crust, than all the gigantic saurians, which, during the secondary period, performed so conspicuous a part; or than the tribes of pachydermata, which we shall presently have occasion to notice.

The vertebrated animals become more numerous at this era, and we now find representatives of all the four classes,—fishes, reptiles, birds, and mammalia.

Sharks' teeth, and the bones and scales of fish, are met with in the London clay, and, with the other characteristic fossils of this formation, have been found in excavating the tunnel near Camden Town, for the Birmingham railroad. The most remarkable collection of fishes, however, belonging to this period, is that at Monte Bolca, near Verona, where the fish are found in a very perfect state of preservation, and so closely packed together, that several are contained in a single block. Some of the specimens even retain a trace of colour on the skin.

The remains of marine turtles have been found at Harwich, at Sheppey, in the tunnel near Camden Town, and in other parts of the London clay; as have also those of crocodiles.

Some remarkable and highly interesting fossils have recently been discovered in the London clay formation, including the remains of an extinct species of serpent, and also an extinct species of bird, from Sheppey, and those of some mammalia, from Studd Hill, near Herne Bay, and from Kyson, or Kingston, near Woodbridge, in Suffolk.

The serpent, which has been named the *palæophis toliapicus*, is considered by Mr. Owen to be allied to the modern python and boa. He concludes that it was not provided with poisonous fangs, and infers that the creature attained the length of eleven feet. The bird Mr. Owen supposes to have belonged to the vulture tribe; and it has been named the *lithornis vulturinus*.

The recently discovered remains of mammalia consist only of small fragments, or of teeth of the respective animals. From careful examination of these, however, Mr. Owen has been able to determine the generic, if not the specific character, of these extinct animals, and thus to give us some notion of the inhabitants of the dry land during this era. The remains found at Studd Hill, a locality which abounds in fossil cones, fruits, and other seed-vessels, are those of a new species of pachydermatous animal, which in some respects appears to have resembled the modern hyrax, and in others, the hog. This extinct animal has been named the *hyracotherium*. The remains discovered at Kyson consist of an animal apparently of the marsupial order, and allied to the opossum; of a small mammal, nearly resembling a bat; and of a species of *macacus*, or lemur. The latter is the first instance of the occurrence of quadrumanous animals, or animals of the monkey tribe, in deposits of the eocene period; and it is thus shown that this order of animals existed long anteriorly to the human race.

A fresh-water stratum which occurs in the Paris basin, and which is analogous to the Hampshire fresh-water formation, is remarkable for the assemblage of organic remains it contains. We have already mentioned the well-preserved remains of insects found in this formation; about ten different species of birds have been met with in the same locality, and also some fossil eggs.

The most remarkable among the animals of this formation are, however, the extinct land mammalia, the remains of which occur so abundantly in the

Paris basin, that scarcely a block is taken from the gypsum quarries in that locality, which does not contain some portion of a skeleton of one of these extinct animals. Similar remains, though in small numbers, occur in the fresh-water formations in the Isle of Wight. Some of these organic remains, like those we have just met with in the London clay, belong to extinct *species* of existing genera, and some to extinct *genera*. Among the former, we meet with extinct species of the bat, wolf, fox, coati, racoon, genette, opossum, dormouse, squirrel, hippopotamus, &c. Among the latter, we find the *palæotherium*, *anoplotherium*, *lophiodon*, *anthracotherium*, *cheropotamus*, *adapis*, &c. The celebrated French naturalist, M. Cuvier, devoted much time and attention to the consideration of these extinct genera, and, aided by his laborious researches, we are able to form a tolerably correct idea of these ancient animals. They all appear to have belonged to the order *pachydermata*, or "thick-skinned," of which the elephant and the horse are examples; and to which the hyracotherium of the London clay also belonged.

The *palæotherium* appears to have been an animal which in some respects resembled the modern rhinoceros and tapir, and in others the horse. Eleven or twelve species have been found; the largest being about the size of a horse, and the least no larger than a little pig. Four species have been found in the Isle of Wight.

The *anoplotherium*, in its form, much resembled the pig, though one species is supposed to have been of a slight make, and as light of foot as the most beautiful gazelle; another species was remarkable for the length of its tail, which resembled that of the otter; a third was no larger than a hare. Two species of anoplotherium, and another animal, nearly allied to this genus, called the *dichobune*, have been discovered in the Hampshire fresh-water formation.

The *lophiodon* nearly resembled the modern tapir, approaching also in some respects to the rhinoceros and to the hippopotamus. Fifteen species have been discovered.

The *anthracotherium* genus includes seven species, some of which resemble the hog, and others the hippopotamus.

The *cheropotamus* in some respects resembled the hog, and in others the babyroussa. The remains of this animal occur in the Isle of Wight.

The *adapis* greatly resembled the hedge-hog, but was three times the size of the modern species.

The nearest approach, among existing animals, to these extinct mammalia, is found in the tapir, which inhabits the warm regions of South America, Molucca, and Sumatra, and in the hyrax, which is a native of South Africa. It is therefore supposed that these animals must have been adapted for living in a very hot climate; such, as we have before mentioned, appears to have prevailed at this deriod.

There is no evidence of any igneous action having occurred in the British isles during the eocene period, unless to this era be referred the formations of the Giant's Causeway and the Isle of Staffa; for, as before observed, they appear to be subsequent to the deposition of the chalk, and therefore may have been formed during the eocene period. As, however, no organic remains have been found mingled with these trap rocks, their age cannot be positively determined. They appear to belong to the class of igneous formations which have cooled under the pressure of water.

But, though we have no authenticated instances of volcanic eruptions occurring during the eocene period in these islands, there are some interesting and decisive proofs of such outbursts having taken place at this time, in the mountains of Auvergne, in Central France; volcanic tufa having been found in that district, alternating with strata, containing fossils belonging to the eocene period. These volcanos are supposed to have continued in a state of activity during the next geological era, the miocene, but to have been extinct since that period. Mont D'Or is the most conspicuous of the volcanic rocks of Auvergne, rising suddenly to the height of about six thousand feet above the surrounding platform, and still retaining the conical shape so usually observed in volcanic formations.

The dislocation by which the chalk, plastic clay, and brilliantly-tinted sands, at Alum Bay, have been displaced from their original horizontal position, and thrown into one of nearly vertical direction, may be referred to this era. The same convulsions appear to have caused disturbances in other parts of the South of England.

CHAPTER XII.

MIOCENE PERIOD.

He who through Nature's various walk surveys
The good and fair her faultless line pourtrays,
Whose mind, profaned by no unhallowed guest,
Culls from the crowd the purest and the best;
May range at will bright fancy's golden clime,
Or, musing, mount where Science sits sublime,
Or wake the spirit of departed time.—ROGERS.

THE term *Miocene** has, like the word eocene, reference to the fossil testacea found in the formations of this period; at which time, though several recent species of testacea existed, the proportion was greater of species which have become extinct. The recent species were therefore still in the *minority*, though considerably exceeding in number those found in the eocene formations. The temperature of Middle Europe during the miocene period, is supposed to have been similar to that of Senegal and Guinea in the present day.

The formation called the *coralline crag*, which occurs in Norfolk and Suffolk, is by some geologists referred to this era, and by others placed in the pliocene period. Nor, when we take into consider-

* This term is derived from *meion*, minor, and *kainos*, recent, and may be literally rendered minor-recent.

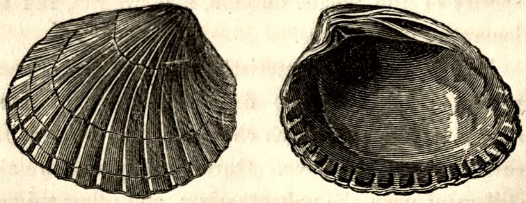
ation the number of patient investigations required before such points can be settled, shall we feel surprised that they sometimes remain long undecided. "Shells must be compared with shells, fish with fish, plants with plants, both extinct and existing;" and it is only by the united labours of numerous scientific observers, that we can ever hope to attain this knowledge.

We find the vegetable productions of this period, approaching very nearly in character to those at present existing in some parts of Europe. In the neighbourhood of Oeningen, there is a formation of lignite, or imperfect coal, which is of little importance for fuel, but is highly interesting to the geologist, from the very perfect vegetable remains found in the accompanying strata of marly slates and limestones. The greater part of these plants belong to *genera*, which still grow in that locality, though the *species* differ, and correspond more nearly with those now existing in North America. Some genera, however, occur, which are not at present indigenous to Europe. But poplars, willows, and maples, appear to have been the predominant trees; and there was a linden tree, bearing a close resemblance to our large-leaved linden tree, as also an elm, very similar to a small-leaved species of our elm. The buckthorn has been met with, and the cytisus: a leaf has also been found, apparently belonging to a species of wheat. Ferns and equiseta also occur; though no longer the gigantic ferns and equiseta of the secondary period, but small plants, resembling our modern species.

The radiated animals were represented by sponges, and by the indefatigable coral builders which continued their labours during this period. Among the articulated animals, we meet with various insects, formed for tenanting the varied vegetable productions which at this era covered the earth's surface.

The molluscous animals were abundant, including gigantic oysters, which have been found in South America; and the helix, or land snail, which occurs in European formations; besides many others, some of which are fresh-water, and others marine. One small shell, a species of paludina, compared in size to grains of rice, occurs so abundantly in some districts on the left bank of the Rhine, near Alzey, that beds from fifteen to thirty feet in thickness, are almost entirely composed of these shells.

Some of the fossil shells are peculiar to the miocene period, others occur both in that, and in the eocene; others, again, in the miocene and pliocene; but there is one species, the *cardita ajar*, which is remarkable on account of its occurring in the miocene formations, and also as a recent shell in tropical seas, but never having been met with in any pliocene formation. The inference drawn from this circumstance is, that the climate of France and England was, during the miocene period, similar to that of Senegal at the present day, but that, during the pliocene period, the temperature of these parts was not sufficiently high to suit the habits of the cardita ajar. And it is not impossible, if strata could be explored in the northern parts of Africa, about latitude 25°, that the pliocene formations of those regions, (should any exist,) might contain this species; which thus might be supposed to have gradually shifted its quarters, as the temperature of the earth's surface diminished. Annexed, is a representation of this remarkable species.



CARDITA AJAR.

A large deposit of fossil fishes belonging to this period, occurs at Aix, in Provence; and the collection of fossil fishes at Oeningen has long been celebrated. In the same neighbourhood, the remains of a very curious tortoise have been found, as well as those of a gigantic aquatic salamander.

A tertiary deposit in the Sewalik Hills, in the North of Hindostan, has recently been explored, and has been found to contain a most remarkable assemblage of fossil remains. Among these are crocodiles of enormous size, and others resembling the modern gavial, which now inhabits the Ganges; tortoises of the ordinary size, and some bones and part of the shell of a gigantic species, which has been named the *megalochelys,* and which must have equalled the Indian rhinoceros in dimensions.

In the same strata, birds of the grallæ order have been found, which greatly exceeded in size the modern gigantic crane of Bengal.

The European seas of this era, appear to have been peopled by marine mammalia, including extinct species of the whale, dolphin, seal, walrus, and the lamantin, or manatus.

But the most characteristic feature of the miocene period, is that of the first appearance of *ruminantia*, or animals which chew the cud; such as the cow kind, the deer, &c. During this period we also still meet with the palæotherium, and other animals of a similar description, belonging to extinct genera: but this is considered as the latest era of their occurrence. We might therefore suppose that any formations, which contain the remains of these two descriptions of animals mingled together, must belong to the miocene period. This, however, is a point which has not yet been ascertained; but for the convenience of arrangement, we will introduce under this period, all such assemblages of organic remains, as include both the extinct theria, and animals of the ruminantia order.

In the miocene strata of France and Germany, a numerous collection of mammalia occurs: among these we meet with the palæotherium, anoplotherium, anthracotherium, dinotherium, &c., and with extinct species of tapir, hippopotamus, rhinoceros, elephant, hog, bear, horse, hyæna, cat, (as large as a panther,) animal allied to the dog, (of equal size,) fox, genette, otter, glutton, beaver, hare, water-rat, &c. &c., associated with ruminant animals, including the ox and deer.

The *dinotherium*, which was the largest land mammifer that has been discovered, was a gigantic herbivorous animal, fifteen or eighteen feet long; this creature seems to have been formed for digging like a mole; it possessed two curious tusks, like those of the walrus, and is supposed to have inhabited fresh-water lakes and rivers. The remains of this animal have been found near Alzey, in Germany, and also near Orthes, at the foot of the Pyrenees.

Some very remarkable fossil remains, which we shall also refer to this period, have been recently discovered in South America. We before mentioned that the Tertiary strata differed from those of the Secondary, in containing some animal remains peculiar to particular divisions of the globe: we have a striking illustration of this in the fossil remains which very lately have been found, both in South America, and in Hindostan.

Among *recent* animals peculiar to the New World, we meet with the sloth, the ant-eater, the armadillo, the capybara, or water-hog, the llama, or guanaco, the didelphys, or American opossum, &c. Fossil remains, corresponding to these animals, but of much larger dimensions, have been met with in the Tertiary strata of that continent, to which they are also peculiar in a fossil state.

One of the most remarkable is the *megatherium;* which is considered to have been nearly allied to the sloth and ant-eater. The body of the megatherium was twelve feet in length, and eight in height; the feet were a yard long, and terminated by gigantic claws. These claws, however, appear rather to have been designed as instruments, to enable the animal to retain firm hold of the ground, than as weapons of offence, for it seems to have been formed for feeding on vegetable productions. It apparently possessed an enormous tail; and there can be little doubt that it was very slow in its motions. The remains of the megatherium are mostly found in the Pampas, or great sandy plains of South America, but they also occur in the United States.

Among the recent discoveries made by Mr. Darwin, in the sandy plains of South America, are some of extreme novelty, interest, and importance, including organic remains, which, from their magnitude, afford a striking illustration of the gigantic size of the ancient tenants of the globe, when compared with the present races occupying those regions, to which, however, they mostly bear a general resemblance. These interesting remains comprise the *glyptodon*, a gigantic species of armadillo, nearly the size of a horse; the *toxodon*, which nearly resembled the capybara, or water-hog, but which appears to have equalled the rhinoceros in size; a huge animal resembling the wombat, but greatly exceeding the size of the modern species; the *macrauchenia*, a gigantic species of llama, or guanaco, which is considered to have been fully as large as a camel, but with a longer neck. Associated with these, have also been found an immense *mastodon;* the megatherium; the horse, &c.

A nearly perfect skeleton and cuirass of the *glyptodon*, have been recently discovered at no great distance from Buenos Ayres. This singular animal, though belonging to the armadillo family, in some respects resembled the extinct megatherium. It possessed a tessellated bony coat of mail, similar to that of the modern armadillo: the tail, however, differed from that of the latter animal; for, instead of being encompassed with armour, it was only protected on the upper surface by a narrow covering of mail. The feet of the glyptodon, are described as being without parallel in the animal kingdom, being singularly broad, thick, short, and massive; and evidently expressly modified to form the base of a column, destined to support an enormous superincumbent weight.

Allusion has already been made to the bones of a gigantic tortoise, and some other remains, found in the Sewalik Hills; in the same formation, a peculiarly-interesting group of organic remains has also recently been brought to light. The Sewalik Hills are situated between the rivers Sutlege and Ganges, and form part of the sub-Himalayan range. In this locality, the remains of the anoplotherium and *sivatherium* have been found, associated with those of quadrumanous animals, and accompanied by bones of extinct species of the camel, antelope, elephant, mastodon, hippopotamus, rhinoceros, hog, horse, cat, dog, hyæna, together with a bear of very large size, a musk deer, no larger than a hare, &c.

The *sivatherium* was a gigantic ruminant animal, greatly exceeding in size any other hitherto discovered belonging to that order. This creature was armed with four enormous horns, two in front, and two large branching *tri-furcated* horns behind, resembling those of some animals of the deer tribe; but at the same time it possessed the lip, and probably the trunk of the elephant, which animal it must have approached in size.

Three different species of fossil quadrumanous animals have been found in the Sewalik Hills; two of which are considered to have resembled the modern semno-pithecus entellus, or solemn ape, and the third to have resembled the pithecus rhesus, or common Indian monkey. They all appear to have belonged to genera now inhabiting many parts of India, but to have been of larger size than the existing species.

The volcanic rocks of Hungary, Transylvania, and Styria, are referred to this period. The volcanic cones of Hungary, though no eruptions appear to have occurred later than this era, still retain their form, and rise abruptly from extensive plains covered with tertiary deposits; giving the impression that they may have constituted islands in an ancient ocean, which probably, during the miocene period, covered this portion of Europe.

There is no reason to suppose that Britain experienced any violent disturbance during this era; but great changes appear to have been in progress in some parts of Europe; for it is supposed that

> The Alps,
> The palaces of Nature, whose vast walls
> Have pinnacled in clouds their snowy scalps,

were, during the Miocene Period, upheaved, and raised to their present remarkable elevation.

CHAPTER XIII.

PLIOCENE PERIOD.

Yet all these were when no man did them know,
Yet have from wisest ages hidden been ;
And later times things more unknown shall show.
Why then should witlesse man so much misweene,
That nothing is but that which he hath seene ?

SPENCER.

WE will now consider the *Pliocene Period*, which is the uppermost of the Tertiary formations, and is so named, because the proportion of recent species of shells found in the formations of this era, is *greater* than that of extinct species*. This group is again subdivided into the *Older* and the *Newer* Pliocene periods; the latter being sometimes termed the Pleistocene period†: a subdivision also having reference to the relative proportion of recent testacea in the formations of the different periods; these being found in much greater abundance in the Newer Pliocene strata, than in those of the Older Pliocene. During this period, the temperature of Central Europe is supposed to have been similar to that of the Mediterranean Sea at the present time.

* The term Pliocene, literally rendered greater-recent, is derived from *pleion*, greater, and *kainos*, recent.

† From *pleistos*, greatest.

The Older Pliocene formations are perhaps most extensively developed in Italy, (particularly in the sub-Apennine hills,) and in other countries bordering on the Mediterranean Sea; but there is a group in this island called the *English crag*, which has been referred to the Older Pliocene period. This crag is divided into three strata, the *coralline crag*, the *red crag*, and the *mammiferous crag*. The coralline crag is, as before stated, sometimes referred to the Miocene period, and sometimes to this era*; it is almost entirely composed of coral, and is supposed to have been formed in a tranquil ocean, by the gradual growth of coral reefs, similar to those at present in progress in tropical climates. Shells, corals, and sponges, occur in this formation in a good state of preservation. This stratum generally rests on the chalk, or on the London clay. Above the coralline crag, a stratum is found, called the *red crag*, on account of its red, or *ferruginous* colour, which it acquires from the large proportion of iron diffused through the whole formation. This stratum is composed of siliceous, or flinty sand, and contains marine shells, which are usually broken and worn, as if by the action of the waves. Above this, the *mammiferous crag* occurs, which has been so named from

* From some recent investigations made by Mr. Lyell, there appears reason to conclude, that both this formation, and the red crag, will ultimately be referred to the Miocene Period.

the numerous remains of terrestrial mammalia found in this formation, in which the bones of fishes, as well as an intermixture of land, fresh-water and marine shells, also occur.

The whole race of *theria* appear at this time to have been totally extinct, and we no longer meet with extinct *genera* of animals, though extinct *species* of existing genera still abound. The fossil mammalia of the latter stratum, include remains of the elephant, mastodon, hippopotamus, &c.; besides those of six or eight species of *rodentia*, (such as the squirrel,) and some ruminantia, among which we meet with the ox and deer.

Having taken some notice of the English crag in Norfolk and Suffolk, which presents the appearance of having been formed in a tranquil sea, we will now proceed to relate some particulars of a very remarkable deposit, which occurs in these counties, and which appears to have been the result of some violent convulsion.

This extraordinary formation, in great measure consists of a confused heap of mud and rubbish, containing fragments of various secondary, and even transition rocks. Thus, not only do pebbles and blocks from the London clay, the chalk, the oolitic series, with their characteristic fossils, occur, but even fragments of coal, and of mica-slate, containing garnets and tourmalines; and in making a drain at Ickworth, in Suffolk, a beautiful specimen of a trilobite was discovered. Masses of granite, porphyry, and of various trap rocks, have also been observed at Cromer, and though chalk flints are the most numerous, pebbles belonging to the primary and transition rocks are in great abundance, and are frequently found intermingled with boulders of various dimensions. boulder wall; [illegible]

These *boulders,* or *erratic blocks,* as they are also termed when of great size, are large rounded blocks of stone, either embedded in loose soil, or lying on the surface of the ground, usually differing from the rocks in the locality where they are discovered, and therefore appearing to have been transported from a distance; whence they have received the name of erratic, or wandering blocks. These granite boulders occur in many localities; and frequently, (as in the present instance,) where no granite rocks are found in their vicinity; we must, therefore, conclude that they have travelled from a distance.

The occurrence of these erratic blocks, as well as the fragments of ancient rocks, above the more recent formations of Norfolk and Suffolk, and other places, cannot but strike us as extraordinary. Various hypotheses have been suggested to account for this phenomenon; and there can be little doubt that it has been caused by some violent convulsion of nature.

It is supposed that, after the deposition of the crag, the whole district was alternately depressed and upheaved, until the crag formation attained the height of one hundred feet above the level of the sea. Possibly the convulsions attendant on these movements, may have shattered the more ancient rocks of Scotland, and of the north and west of England; and by the action of some mighty accompanying rush of waters, or, perhaps, the not less effective transporting power of ice-bergs, and drift ice, these boulders, and the fragments of coal, trap rock, &c., may have been spread in a confused mass over the surface, and by this means, the rocks and fossils of the whole series become mingled together. Similar formations occur at Holderness, and in other localities, in the north-eastern portion of England.

The dispersion of boulders from the Cumbrian mountains is very remarkable. The granite of Ravenglass, on the western border of this region, has been carried to the south, across the sea, along the flat country of Lancashire, and over the plains of Cheshire and Shropshire, towards the vale of the Severn. And on the eastern side of the Cumberland range, the blocks have been transported to the sea-side at Scarborough and Flamborough Head, a distance of a hundred and ten miles; and, in all probability, to Norfolk and Suffolk.

The remarkable accumulations of recent shells which are frequently found at considerable elevations above the sea, may probably be referred to the Newer Pliocene period. Thus, marine shells have been found on Moel Tryfane, near the Menai Straits, at the height of one thousand three hundred and ninety-two feet above the level of the sea. We may therefore suppose that, during the Pliocene period, this mountain was covered by the sea, but that at the termination of the Tertiary era, and immediately antecedent to the commencement of the recent period, it was upheaved, and raised to its present elevation, possibly during the system of convulsions which transported the Cumbrian erratic blocks to their present situation. It is not improbable that some such disturbances may have given origin to *caves* or *caverns;* and also to *fissures*, which are large cracks, or chasms, frequently met with, both in modern volcanic districts, and in more ancient formations, where disturbances appear to have occurred. Caverns are of most frequent occurrence in limestone formations. These caverns and fissures have become the depositories of the bones of various terrestrial animals, which, during the Pliocene period, inhabited the surface of the globe.

The description of organic remains of most frequent occurrence in these *ossiferous* (or bone-bearing) caves and fissures, are the bones and teeth of extinct species of mammalia. Those found in the celebrated cave of San Ciro, near Palermo, in Sicily, consist principally of bones of the *mammoth*, (an extinct species of elephant,) of the hippopotamus, and of animals of the deer kind. The bones in this cave were so exceedingly numerous, that, in 1829 and 1830, many ship loads were exported, with the design of their being applied to some manufacturing purpose, but they were too much changed from their original condition to be of any use. These remains were found embedded in *breccia*, which is a rock resembling conglomerate in its formation, but differing from it, in being composed of fragments which have not been rounded by the action of water, and which, consequently, retain an angular form; it is sometimes composed of shells, or of bones, cemented together by some mineral substance; and when this substance is formed of fragments of bone, it is termed *osseous breccia.*

These ossiferous caves have been found in various parts of England, and are particularly numerous in Devonshire, and also in the Mendip Hills, in Somersetshire. The cave of Kirkdale, in Yorkshire, which was visited by Dr. Buckland, in 1821, may serve as an example of this species of cavern. The rock in which this cave occurs is formed of that species of limestone called oolitic. The greatest length of the cavern is from two hundred and fifty to three hundred feet, and its breadth and height vary from two to seven feet; there being few spots in which it is possible to stand upright. The animal remains in this cave consisted of the bones and teeth of the hyæna, of an animal of the tiger kind, of the fox, bear, elephant, rhinoceros, hippopotamus, horse, ox, of some species of deer, of the rabbit, and water-rat. These bones had been strewed all over the cave, most of them being broken, and apparently gnawed, even showing marks of the hyæna's teeth; from whence it has been inferred that this cave must have been a den inhabited by hyænas. The roof and sides of this cavern were incrusted by stalactites, and the hardened mud in which these remains were deposited was covered with stalagmite.

The formations called *stalactites* and *stalagmites* are of frequent occurrence in such caverns, and are formed by the agency of water, which slowly *permeates*, or forces its passage through limestone, and in so doing holds in solution, or dissolves and bears away a certain portion of the carbonate of lime.

When the water reaches the roof of the cavern, it hangs on the ceiling, like dew-drops on a bell glass, and ere it falls, deposits on the surface a minute portion of its mineral contents: one drop succeeds another, until at length rods of this substance, resembling marble icicles, are formed, together with other incrustations assuming every imaginable shape, some of which are suspended from the roof, while others adorn the sides with natural frostwork, or fluted columns and pilasters. These incrustations are called stalactites.

Stalagmites are of similar origin to stalactites; but instead of being suspended from the roof, they are formed on the floor of the cavern, by the drops which fall to the ground, and have accordingly been called stalagmites. By degrees, the floors of caverns become incrusted with stalagmite, and sometimes, if the ground be gently sloping, appear as smooth as a sheet of ice; at other times, it accumulates in the most fantastic forms.

Sir Walter Scott, speaking of a cave of this class, on the western shores of Scotland, called Macallister's Cave, describes it as presenting the appearance of being "sheeted with white marble, partly smooth, partly rough, with rustic ornaments and beautiful chasing, and partly wrought into statuary:" adding, "there is scarcely a group that an active fancy may not trace among the grotesque ornaments which have been gradually moulded in this cavern by the dropping of the calcareous water, and its hardening into petrifactions."

The vegetation of this period appears to have borne great resemblance to that of the present era. The olive and the bay flourished in Southern Europe, the water-lily in the vicinity of Paris, the willow on the margins of the lakes and ponds of England.

A remarkable fossil, which it will not be out of place here to mention, though it may not belong exclusively to the Pliocene period, but rather to the whole of the Tertiary formations, is the beautiful substance called amber, which is supposed to be fossil resin, derived from beds of lignite. This remarkable substance, to the transparent varieties of which the term *succin* is sometimes applied, is not unfrequently met with on our eastern shores; and is very abundant on the Prussian coast. It is also found in quarries or pits, in the interior of Prussia. In digging for it, the first stratum is sand; to this succeeds a layer of clay, beneath which a bed containing trunks and branches of trees is found, then a quantity of pyrites, and lastly, a bed of sand, throughout which the amber is dispersed in small pieces, or collected together in heaps. The amber, when first dug, is flexible, but becomes hardened on exposure to the air. Leaves, pieces of wood and straw, insects, frogs, small fish, and even water, are sometimes found enclosed in amber. This substance was regarded as a precious stone by the ancients, and the Phœnicians navigated the North Seas in quest of it. The value of amber is now much lessened, but it is employed in some manufactories, a fine oil being obtained from this substance.

During the Pliocene period, we find the inferior animals much less abundant than in the preceding groups, and the more perfect greatly increased in number. Of the radiata division, we still meet with some corals, but they are comparatively rare. The articulated animals were abundant in the form of crustacea, including cray-fish and lobsters, and also in that of insects; specimens of the latter may be seen among those met with enclosed in amber, which

or craw fish – [illegible]

are considered to belong to existing genera, but to extinct species: among these, ants are the most numerous.

Molluscous animals were very abundant at this period. They are found in great numbers in the crag of Norfolk and Suffolk: among these, we find the *reversed whelk*, of which we give a specimen below, and which appears left-sided when compared with the common whelks of our shores. This is, however, by no means a universal character among the shells of this period, and we have placed another

+ Slatter?

FUSUS CONTRARIUS.

PECTEN IPSWICHIENSIS.

FUSUS STRIATUS.

whelk from the same formation by its side, to render this peculiarity more striking. These shells, as well as the accompanying *pecten*, are from the crag formation at Ipswich.

The remains of fish are very abundantly dispersed throughout the red and mammiferous crags; but no bones that can be satisfactorily referred to the class of reptiles, have hitherto been observed in these formations. From the specimens embedded in amber, we may, however, infer that frogs existed at this period. The remains of birds occur in the crag; but the particular species have not yet been determined.

Of the terrestrial mammalia belonging to this period, we have already taken some slight notice, in our description of Kirkdale Cave; much that is interesting, however, yet remains to be related. This era has been termed the *age of elephants;* for though numerous carnivorous animals, such as the lion, tiger, and hyæna, are met with;—though horses, oxen, and deer, including the gigantic horned elk, occur;—and though vast numbers of rhinoceroses and hippopotami are found;—their number is small, when compared with that of the extinct elephants of this period, to which the names of *mammoth* and *mastodon* have been applied, and which appear not only to have been exceedingly abundant, but also very universally diffused.

The remains of the *mammoth* have been found in many parts of England: they occur in the crag of Norfolk, and have been met with in some places in the London Basin, embedded in the alluvial gravel resting on the London clay. Thus, near Brentford, they have been observed in a fresh-water formation containing land and river shells, and accompanied by bones of the hippopotamus, deer, ox, &c. The tusks of one of these mammoths is said to have measured nine feet three inches. The horn of an ox, found in the same place, measured four feet six inches, whilst that of another measured only six inches. Some of the oxen of this period appear to have nearly resembled our modern species; others approached to the buffalo, and others to the bison. There is reason to suppose that these remains of the mammoth, hippopotamus, &c., had accumulated in the spot where they were found, (about a mile from the Thames, and forty feet above its level; probably an ancient creek, when that river may have been a broad stream, greatly exceeding its present contracted limits:) for they very evidently had not been exposed to the long-continued action of the waves, and cannot, therefore, have been borne from any distance. It accordingly appears that these animals must have been inhabitants of some neighbouring land.

Another remarkable formation in which the bones of the mammoth occur, skirts the shore between Brighton and Rottingdean, in Sussex. This formation, to which Dr. Mantell has given the name of the Elephant-bed, is about fifty feet in thickness, and consists of layers of chalk detritus, and broken flints, containing the bones of these animals, associated with those of the ox, horse, and deer. It appears to have been formed since the chalk cliffs assumed their present outline.

Similar remains also occur in various other parts of England: in some instances, associated with marine shells, which appear to have been subjected to the action of water. Thus, at Bromwich Hill, near Worcester, bones of the elephant and rhinoceros have been found in a bed of gravel about fifty feet above the Severn, and accompanied by rolled or worn marine shells. In other instances, these remains are met with in fresh-water formations. Of this we find an example at Leamington, which town is situated on the site of an ancient lake, and under the foundations of some of the houses, the remains of elephants, hippopotami, hyænas, buffalos, and numerous other animals of extinct species have been found.

The remains of the mammoth have also been found in Ramsgate. But perhaps one of the most remarkable accumulations of these fossil bones, is that which occurs on the coast of Norfolk, especially near Mundesley and Hasborough, or Happisburgh. In the latter locality, a vast submarine forest occupies a considerable space, probably also extending inland, beneath the upper deposits, or strata. This frequently forms a bed of peat; and near this are found numerous remains of mammalia, among which are bones of the mastodon, mammoth, rhinoceros, hippopotamus, horse, ox, three or four species of deer, &c. These remains are frequently found on the beach at Cromer and at Hasborough, whilst at Mundesley, they are mostly met with in the cliff. The great deposit of these fossils in this neighbourhood, however, appears to be in the bed of the sea, some miles from land, in the vicinity of an oyster-bed, where the remains of upwards of five hundred of these animals have been found. Indeed, the whole area of the German Ocean, as well as the English channel, appears to be more or less strewed over with the remains of these extinct mammalia; for bones, tusks, and teeth, of the mammoth and mastodon, have been found in various parts of the deep sea; and the Ramsgate fishermen employed in trawling in the North Sea and English Channel, frequently bring up in their fishing gear, fragments of these fossil bones. These remains, on account of their being generally charged with worms, and covered with decaying marine substances, are seldom capable of being preserved; but specimens in a good condition are sometimes procured. Among these, we may mention a very large bone, and a tusk, eleven feet long, but so soft as to be cut through with a knife, which were found between Dungeness and Boulogne; a tusk trawled up at the back of the Goodwin Sands; and some bones obtained about midway between Yarmouth and the coast of Holland. These remains are found in the deep hollows or marine valleys, and never on the summits of recently accumulated banks or shoals. Boulders, or rounded masses of rocks, belonging to various geological eras, similar to those spread over part of Norfolk, also occur in the same parts; and it is supposed that the bed of the ocean in that locality is covered with a deposit, much resembling the boulder formation of Eastern Norfolk.

The remains of the gigantic horned elk are said to have been met with at Mundesley. This animal appears to have been no larger than the modern elk, but to have been distinguished by enormous antlers. In some specimens which have been found in a fossil state, each branch of these antlers measured five feet: the whole expanse from the extreme points of the horns being no less than ten feet six inches. The remains of this extinct animal are, however, mostly found in the peat-bogs of Ireland, and in the Isle of Man*.

* The gigantic horned elk is by some geologists referred to the recent era; but the circumstance of its remains occurring associated with those of extinct species, has induced others to place it in this period. It has also been considered probable, that at the period these animals existed in such abundance in the Isle of Man, that island may have formed part of the main land of Ireland.

The remains of the rhinoceros occur very abundantly in some caverns in Devonshire. The hippopotamus, which occurs in the mammiferous crag of Norfolk, has also been met with in many other localities.

A traditionary belief prevails in the neighbourhood of all the lakes in Scotland, both Highland and Lowland, that they are tenanted by a very large amphibious animal, called by the natives the water-bull, and which several of them assert that they have seen. "The description popularly given," says Sir Walter Scott, "uniformly corresponds with that of the hippopotamus." We cannot imagine that hippopotami resembling existing species, can, in recent times, have tenanted a region so little congenial to their habits. Perhaps, therefore, it will be most in accordance with probability, to suppose that the remains of an animal of this kind, had by some means been so well preserved as to give rise to this tradition.

The remains of the *mastodon* have been recently found in the mammiferous crag of Norfolk and Suffolk. This animal appears to have greatly resembled the elephant in its size and general form, though the body was rather longer, and the limbs thicker. The principal difference between the two animals consisted in the form of the teeth, which in the mastodon are considered to have been adapted for feeding on roots.

Two or three species of mastodon have been discovered; the remains of one species have been found in great abundance near Santa Fé de Bagota, in South America. The locality where these remains occur, has received the name of the *Field of Giants*, most probably because these bones have been mistaken, by the inhabitants of the district, for gigantic human remains.

Another species, the great mastodon, is found very abundantly in the United States. These remains are mostly met with in salt marshes, which are called *salines*, or *licks*. One of the localities where they are most numerous, is Big-bone Lick, in Kentucky, which has received its name from this circumstance.

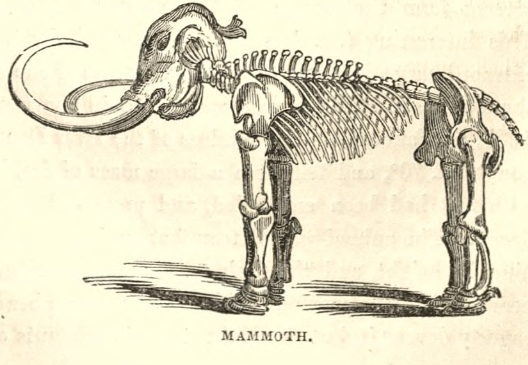
The American Indians possess a traditionary story relative to these bones, which, though more highly coloured, reminds us of the Scottish tradition regarding the hippopotamus. They relate that the mastodon was a terrible carnivorous animal, (quite contrary to its evident nature;) and that in ancient times a herd of these tremendous animals rushed down to Big-bone Lick, where they commenced a voracious attack on the deer, buffaloes, and other animals; but that they were arrested in their unsparing carnage, by the thunderbolts of Heaven, and that the destroyers were themselves overwhelmed in sudden destruction. The largest of the herd, however, though wounded, escaped to the Great Lakes, where the Indians conceive that he is living at the present day.

Mastodons are sometimes found at the very surface of the ground. In 1824, as the proprietor of a farm in New Jersey was walking over a newly drained marsh, he struck his foot against some hard substance projecting through the turf, which he soon found to be the tooth of a mastodon. On further examination, the remainder of the skeleton was discovered in its natural position, with one foot a little in advance of the other, in the attitude of walking. It seems extraordinary that this skeleton should have been thus preserved; but perhaps we may accouut for it, by supposing that the marsh in which it was found (which was composed of soft peat) had not been sufficiently firm to bear the weight of the animal, which consequently suddenly sank into the marsh, until it reached the floor of sand that arrested its further progress, and on which it was found standing. This bog having remained undisturbed, the skeleton had retained its original position.

The remains of mammoths are met with in North America, but not so abundantly as in some parts of Europe, over which continent they are very widely spread; though they are nowhere in such profusion as in Northern Asia; particularly in the Lowlands of Siberia, included in the space extending from the borders of Europe, to the extreme point nearest America, and from the mountains of Central Asia, to the shores of the Arctic Sea. In the New World, these remains even extend further to the north, for Sir Edward Parry discovered an enormous assemblage of the bones of the mammoth, in Melville Island, which is situated in N. lat. 75°. In the northern parts of Asia, the tusks of the mammoth have been found in such extreme abundance, and the ivory in such excellent preservation, that these stores of the ancient world have proved a valuable article of traffic to the inhabitants of that region. And though the search for these tusks has been carried on for more than a century, and thousands have been used in turning, the number still remaining is supposed to be enormous.

The mammoth, or Siberian elephant, appears to have resembled the recent species in many respects, but differed from it in being provided with a hairy coat, which may have fitted it to endure a far colder climate than that of those regions which at present form the abode of the elephant family. This interesting fact has been ascertained, by the extraordinary discovery of an entire carcase of one of these animals. This carcase was found in the year 1803, at Yakoust, on the borders of the river Lena, about lat. 70°, and fell from a large mass of ice, in which it had been embedded, and preserved from decay. The animal was sixteen feet in length, and nine in height, and the flesh was in such excellent preservation, that not only did the wolves and bears eagerly devour it, but the Yakouts, or inhabitants of the district, actually cut up the flesh to feed their dogs. The animal was very warmly clad, the skin being covered with a close wool of reddish-brown colour, over which was a coat of hair, or fur, of similar colour; whilst above this hung an outer covering of black bristles thicker than horse hair, which increased in length on the neck and spine, so as to form a kind of mane. Its tusks, which were of very fine ivory, were rather longer than those of the recent elephant, and bent spirally, as also turned gently outwards. The accompanying cut presents a representation of the skeleton of this mammoth. The remains of a hairy rhinoceros have also been found in Siberia.

The Greenlanders have a tradition regarding the mammoth, resembling the Scottish account before alluded to: for they declare that in the interior of their country, there exists a black and shaggy animal,



MAMMOTH.

having the form of the bear, and thirty-six feet in height. Such a tradition may very probably have arisen from the discovery of the carcase, either of the mammoth or the rhinoceros.

The name mammoth was originally given in Siberia, where the natives, to account for the appearance of these monstrous remains beneath the surface of the earth, assert that an animal exists in that country of the size of the elephant, but which burrows under ground like the mole. To this imaginary creature, they have given this name; and they regard the tusks as the horns of the animal. A similar fiction is said to prevail in China; and it appears that these animals are known to exist in some parts of that country in a preserved state, similar to the mammoth found on the borders of the Lena; and it is even asserted, that the omnivorous Chinese consider their flesh very wholesome. However this may be, we may infer from hence, that they are not unfrequently discovered in that country.

In some caverns of Australia, the remains of a gigantic species of kangaroo have been found, accompanied by the bones of some other animals peculiar to that region. Caves of a similar description have been observed in North and South America. In the latter portion of the globe, they contain bones of the megatherium, mastodon, *megalonyx*, (a gigantic species of sloth,) elk, ox, horse, &c. It is not a little remarkable, that the latter animal should have been found in a fossil state in America; for in the recent era, the horse appeared to be wholly unknown in those regions, until introduced by the Europeans.

There is evidence that some volcanos were in activity during the Pliocene period, in a district situated on the banks of the Rhine between Bonn and Coblentz. In this region of extinct volcanos, which extends on both sides of the river, there appears to have been a long series of eruptions, some of which apparently took place during the Older Pliocene period, and others during the Newer Pliocene period. Some of these volcanos appear to have burst out in valleys, or at low elevations; and the extinct craters of such are now converted into lakes: others again have poured forth their streams of lava from conical-shaped hills; these are now covered with fields of corn and vineyards.

But there is another volcano, which is considered to have been in active operation during the Newer Pliocene period, and which to the present day, perhaps, continues as energetic as when it first burst forth: this interesting, though tremendous link between the ancient and modern world is Mount Etna, in Sicily, which, by some geologists, is supposed to have been an active volcano for ten thousand years.

This supposition may at first startle us; but a little reflection will convince us that there is nothing in the assertion beyond the range of probability. We have read that some of the more ancient volcanos, those in Auvergne, appear to have been in activity during both the Eocene and Miocene periods; and if we find two of the older geological eras thus connected, we may as well suppose Mount Etna to have continued its eruptions from the Pliocene to the present period. The epoch of its first outbreaking, would, according to this, doubtless be antecedent to the creation of man; but the geological changes we have been considering, will have taught us that there is nothing in this supposition contrary to reason, or to Scripture. We may imagine that *some* convulsion occurred at the conclusion of the Tertiary period, but we shall have learnt enough to be aware, that all the mountains and strata of the earth were not shattered by this revolution, since, to take one instance, we find the Eocene formations retaining their original position above the chalk basins in which they were deposited.

At the period we have now been considering, animal life appears to have been brought to the highest degree of perfection, but man was not included in it: "the sound of man's voice was not yet formed." The changes, however, by which the earth's surface had been prepared and fitted for his abode, were now accomplished. By the successive geological depositions, by the decay of vegetable matter, and by the instrumentality of some species of animals, soil was formed, suited for the growth of vegetables adapted to man's sustenance, and for that of the animals which were placed on the earth at the epoch of his creation. That some change or revolution, analogous to those which form the separation between the different geological eras, took place at this period, appears evident, from the change which is observable in the animal world: for though we still meet with the genera of all the animals we have enumerated in the Pliocene period, the species which then existed are altogether extinct, with the exception of some of the testacea, or shell-fish. Folly

It seems remarkable that this exception should exist, but is, perhaps, by no means unaccountable; for though the *earth* appears to have undergone a series of changes, there is no reason to suppose that this had been the case with the waters of the ocean: these apparently had changed their place, but not their condition, and may have continued the same as when they were first called into existence by the great Creator of all things: for "the sea is His, and He *made* it; and his hands *prepared* the dry land." If we turn to the description of the Creation, in the first chapter of Genesis, we may observe that no mention is made of the creation of the waters, but that that account commences by inferring their actual existence;—"And the Spirit of God moved on the face of the waters." Subsequently we read, that "God divided the waters from the waters, and commanded the dry land to appear:" from whence we may assuredly conclude that the waters already existed. We may also suppose that some of the inhabitants of the ocean, such as the testacea before alluded to, may have continued from the Eocene, Miocene, and Pliocene periods to the present era.

Changes may have occurred to cause the *destruction* or the *removal* of certain species, whilst others may have continued to occupy their ancient haunts. It has been mentioned that some species of testacea, which inhabited these latitudes during the Tertiary period, are at the present day found only in the hottest regions; these may have shifted their abode. Other species are not greatly affected by difference of temperature; and such may still be met with in the same zones in which their fossil ancestors are found. But others again are suddenly destroyed by diminution of temperature; such may have disappeared. The cold produced by the waters of the river Glatt, which falls into the lake of Gryffensee, in the canton of Zurich, has been observed to cause the immediate death of thousands of barbels. There appears good reason therefore to believe, that a considerable diminution of temperature took place at this epoch; and those species of fish and testacea which then became extinct, may have been annihilated by such means.

Whether inundations and marine irruptions may have destroyed the then existing races of terrestrial animals, can only be matter of conjecture; but the circumstance of the discovery of the mammoth preserved in ice, gives countenance to the opinion, that such events may have occurred, possibly accompanied by a sudden decrease of temperature.

The recent researches of M. Agassiz and others, tend so greatly to confirm the latter supposition, that we cannot but anticipate that it will ultimately be borne out by facts. From these investigations it appears, that at the latest epoch antecedent to the Recent era, a long period of intense cold occurred, during which a large portion of Europe, Asia, and America, was covered with ice. It would further seem, from the observations of M. Agassiz, Dr. Buckland, and Mr. Lyell, that at the same epoch, glaciers also existed in the British Isles; traces of their occurrence having been noticed in the north of England, in Scotland, and in Ireland. Extraordinary as this may appear, it is seconded in a remarkable manner by the researches of Mr. James Smith, who has discovered that in the latest beds of the Newer Pliocene formation, occurring in the west of Scotland, the most common fossil shells are those of species at present inhabiting the Arctic Seas: from whence he concludes that the climate of Scotland, during the accumulation of these beds, must have been colder than at present. Similar indications of a cold period, are presented by the Newer Pliocene formations of Sicily, where several species of fossil testacea are met with, now found living only in more northern seas; from which circumstance it has been inferred, that the climate of Sicily was at that time colder than at the present day.

And, not only would the occurrence of such a cold period account for the destruction of the then-existing terrestrial animals, but it would afford an explanation of various other geological phenomena; particularly some of those attending the boulder formation in Norfolk, which we have seen is referrible to this epoch; and in the accumulation of which, ice is supposed by Mr. Lyell to have acted a prominent part. And, if glaciers existed in the northern parts of Britain, icebergs and drift ice may well be supposed to have floated southwards, bearing with them boulders and detritus of all kinds, both from the rocks of various ages in the more northern parts of our island, and also, perhaps, from those of Scandinavia. detrition, abrading

And now, the earth being most bountifully prepared for man, and "the mountains being brought forth," or, as it is elsewhere expressed, being "settled,"—whether effected by slow movements, or by violent convulsions, matters little with Him in whose sight a thousand years are but as yesterday,—the sea and the land, as they at present exist, had their appointed bounds determined by the Almighty Creator: or, (as we read in the Book of Job,) "The

Lord brake up for the sea his decreed place, and set bars and doors, and said, hitherto shalt thou come, but no further: and here shall thy proud waves be stayed."

It has been a favourite notion, that the earth, previous to man's creation, was in a state of chaos; but, in fact, "the loud misrule of chaos,"

> Outrageous as a sea, dark, wasteful, wild,

has had its origin solely in the poet's imagination. Neither the word, nor the idea of chaos, are met with in the Bible*: and cannot, therefore, have been drawn from that source. Geology, also, in lieu of confirming us in the notion of this fancied unorganized confusion, which has been the offspring of ignorance, clearly unfolds to us that "order is heaven's first law." And, whilst pursuing this study, we cannot but be forcibly impressed with "the manifold and manifest footsteps of admirable wisdom, skill, and design, apparent in the general order, and

* Possibly the expression occurring in the first chapter of Genesis, "the earth was without form and void," accompanied by the intimation of the absence of light, may have been misconstrued to indicate a state of chaos; but these words, as a scriptural phrase, have not so forcible a signification: the identical terms being used in another part of Scripture to denote desolation, and being thus applied by the prophet Jeremiah, when prophetically lamenting over the miseries to which the land of Judah should be subjected by the Chaldean army:—"I beheld *the earth*, and, lo, it *was without form and void;* and the heavens, and they had *no light*," &c.—Jer. iv. 23.

in the particular frame of all creatures; the beautiful harmony of the whole, and the artificial contrivance of each part of the world. But with this wisdom are always combined no less evident marks of goodness*."

* Dr. Isaac Barrow.

CHAPTER XIV.

RECENT PERIOD. EMBEDDING OF ORGANIC REMAINS.

Whales stranded on the shallows; sea grown weeds
Hurled out of darkness by th' uprooting surges;
These, with unutterable relics more,
Heaped the rough surface, till the various mass,
By Nature's chemistry combined and purged,
Had buried the bare rock in crumbling mould.

J. MONTGOMERY.

AT the commencement of the RECENT PERIOD, the land, which had anciently been covered by the waters of the deep, and had not received its present form, and was void of life, having emerged from darkness into light, "earth in her rich attire consummate, lovely smiled." A new race of creatures was placed in this delightful abode, and man was created "in God's similitude," whilst

God was everywhere; the God who framed
Mankind to be one mighty family,
Himself their Father, and the world their home.

The period which has elapsed since this epoch, does not present any of the striking features of the ancient geological world; for, as far as human knowledge extends, no mighty convulsions appear to have taken place within this era; and if, with an eminent geologist, we consider all geological changes to have been brought about by slow and gradual operations, similar to those now in progress on the earth's surface, the lapse of years since man's creation is too inconsiderable, (according to such calculations,) for any great alteration to be discernible. Some changes, however, have occurred, and such changes still are taking place, even on our own shores; and it will be interesting to consider a few of these instances of increase and of destruction, particularly as we shall find them illustrative of some of the phenomena of geology.

Nor shall we any longer, in the era at which we have arrived, meet with the remains of unknown animals; for, though organic remains are met with in Recent formations, they all, with one exception, belong to species still in existence on the earth. This single exception is the *dodo*, which is supposed to have become extinct within the last two hundred years. This bird is described by many voyagers from the end of the fifteenth to the beginning of the seventeenth century, as having been met with in the Mauritius, the Isle of Rodriguez, &c.; but it appears to have become extinct towards the close of the seventeenth, or beginning of the eighteenth century. An entire stuffed specimen is recorded to have been in the possession of the celebrated naturalist, John Tradescant, and to have been subsequently removed, with the rest of his collection, to the Ashmolean Museum, Oxford: but, being in a state of decay, it was destroyed about the year 1755; and thus this very interesting specimen was lost: though the head still remains in that museum; and the foot is preserved in the British Museum. Bones of this extinct bird have been found under lava in the Mauritius; and also in a cave in the Isle of Rodriguez.

The organic remains met with in the Recent formations, though they belong to species familiar to us, and may not therefore be so striking as some of the remarkable fossils occurring in more ancient rocks, are, nevertheless, not without interest in a geological point of view; for they afford both a clear illustration of the manner in which such remains may be preserved, and also evidence of the existence of these animals at a remote era of the history of the world. Whilst at the same time, the very fact of their preservation in an unfossilized state, proves that the extinct organic remains, which have been converted into mineral substances, must have been subjected to conditions, either altogether differing from those at present prevailing on the earth; or carried on through countless ages, long antecedent to the recorded creation of man.

The principal situations in which the remains of recent species have been found, are in *caves* and *fissures;* in *lacustrine formations*, or deposits formed in lakes; in peat *bogs* or *marshes;* in *volcanic formations;* by means of *landslips;* in accumulations of *mud* or *sand;* and enclosed in *coral rocks.*

The bones of recent species of animals, as well as those of the human race, and even coarse pottery, have been discovered in *caves*, similar to that at Kirkdale; and in some instances, these remains have been found mingled with those of extinct species of animals. The latter circumstance may, in some cases, be accounted for, by supposing the bones to have been washed in by a river or flood; either at successive periods, or simultaneously, owing to the disintegration, or crumbling away of older rocks containing the bones of more ancient animals; which, by such means, might become mingled with the recent. In other instances, however, as in the cave of Paviland, in Glamorganshire, the remains appear to have become mingled by means of ancient diggings.

These "mountain cells" often afforded a place of retreat for the native inhabitants in times of invasion, even at a comparatively modern period. As late as in the reign of Edward VI., we learn that, during the Protector Somerset's expedition into Scotland, some of the Scotch peasantry took shelter in caves near Long Niddry, when these unfortunate fugitives were smothered in their place of concealment by some of Somerset's followers. Such occurrences may frequently have taken place in more barbarous ages, and bones and rude manufactured articles have thus been deposited in these caves; and when succeeding generations occupied these hiding-places, the new tenants may have dug the floor, either to conceal their treasures, or to render them more commodious habitations. The floor of the cave, in all these instances, may have become subsequently encrusted with stalagmite; in which state the mingled remains were discovered.

Shells of existing fresh-water molluscs are found in *old lakes* which have been filled up, together with peat, and remains of hazels, yews, oaks, pines, alders, &c. The bones of the stag, or red-deer, of the fallow-deer, the beaver, and other existing quadrupeds, as well as those of birds and insects, are also of frequent occurrence in *lacustrine deposits*, as these formations in lakes are termed.

Skeletons of animals, and of the human species, have not unfrequently been discovered in *peat-bogs*, or *peat-mosses*, into which they appear to have sunk in a manner similar to that in which the mastodon became entombed in the salt-lick of North America. The most remarkable instance on record, is that of an embedded moss-trooper. In the year 1542, the battle of Solway took place between Henry VIII. and James V. of Scotland, when the Scotch army was routed, and an unfortunate troop of horse, in making a hasty retreat, plunged into a morass, which instantly closed upon them. The account of this transaction was merely traditional; but, after the lapse of nearly two centuries, the truth of the narration was confirmed by the discovery (made by

frailed fallow, bay; fold; fallow-buck Dam [illegible] some peat-diggers) of a man and horse in complete armour, on the very spot where this event was recorded to have happened. The skeletons both of the man and horse were well preserved, and the different parts of the armour might be distinguished with facility.

Peat, the substance in which these remains were so remarkably preserved, bears so close an analogy to some of the most interesting formations which it falls under the province of geology to describe, that we cannot pass it unnoticed.

Peat, according to Dr. MacCulloch, is intermediate between vegetable matter and lignite; the conversion of peat into lignite being gradual, and brought about by the prolonged action of water, which, as we have before seen, appears to have been instrumental in forming all stratified deposits. Peat is formed in moist situations, and generally where the temperature is low, because in hot regions the decomposition or decay is too rapid to admit of its formation; it therefore is seldom, if ever, found within the tropics; but abounds more and more as we advance further from the equator. Peat-mosses occur in many parts of Great Britain, and are said to spread over one-tenth part of Ireland; they also cover a considerable extent of surface in the north of Europe.

This substance may be composed of any plants capable of growing in moist situations, but the peat in these islands, and in the north of Europe, is chiefly formed of a species of moss called the *spagnum palustre*. This plant possesses the peculiar property of throwing up new shoots in its upper part, whilst the lower extremities are decaying. Reeds, rushes, and other aquatic plants may usually be traced in peat, often so well preserved, that there is no difficulty in distinguishing the particular species. A certain quantity of earthy matter is generally interspersed through the peat, or disposed in layers, like the strata of shale in the coal-fields. Buried trees, or *subterranean forests*, as they are sometimes called, are frequently found in peat-mosses, occasionally with their trunks erect, in the attitude of growth, and with their roots still fixed in the sub-soil. The trees found in these spots consist principally of the oak, the birch, and the fir; the oaks being most abundant where the substratum is clay, and fir trees in sandy formations. Acorns, cones, leaves of the oak and fir, and hazel nuts, are frequently met with in peat.

It is a curious fact, that many peat-mosses cover the sites formerly occupied by forests, which have been known to be destroyed within the historical era; and it is supposed that the greater number in this island are not so ancient as the time of Julius Cæsar. At that period, extensive woods appear to have flourished on the spots now occupied by many of the peat-mosses: and the only remaining vestiges of the forests described by that general, as situated

Sphagnum

along the line of the great Roman way in Britain, are these accumulations of peat. This change has been attributed to the policy of Severus, and other Roman emperors, who caused the woods to be destroyed in the conquered provinces. Some of the British peat-mosses are, however, of more recent origin; the localities they now occupy having been covered with forests at a much later period; though many of these also were transformed by the agency of man,—the trees having been cut down and burnt to the ground on account of their affording shelter to rebels and outlaws, or to the still unsubdued natives. The Welsh woods were in this manner destroyed in the time of Edward I., and many of those in Ireland during the reign of Henry II. Some peat-mosses, however, have been formed by natural means; thus, the overthrow of a forest by a violent storm, about the middle of the seventeeth century, gave rise to a peat-moss near Lochbroom, in Ross-shire. The prostrate trunks prevent the free circulation of air, and water lodges and soon becomes stagnant in such situations; which, being favourable to the growth of aquatic plants and of mosses, peat-bogs rapidly accumulate, and "desolation reigns where stately forests of pine and oak once flourished."

But whilst the rulers of the earth, in the prosecution of their schemes of ambition, were thus laying waste lands capable of profitable cultivation, the mighty Ruler of nature employed His agents in rendering these desolated spots in another way conducive to man's benefit. Peat, though inferior to coal as an article of fuel, is a most useful substitute for that valuable material, especially in countries where

> . . . . Coals are dear,
> For they come far by wind and tide.

And in many districts in the British Islands, peat forms the entire supply of fuel for the peasantry.

In our progress through the various geological periods, we have noticed three distinct species of coal:—anthracite, or culm; bituminous coal; and lignite. Anthracite appears to owe its difference from coal to the peculiar conditions under which it has been formed, and both may be described as belonging to the more ancient part of the Secondary period; whilst lignite belongs to the later formations of that period, and to those of the Tertiary period. Peat may be considered as the species peculiar to the Recent period; for it evidently bears a great resemblance to the coal of the Carboniferous era, as well in the manner of its formation, as in its structure: both owe their origin to accumulated masses of vegetables, and, we may also add, both appear to have been chiefly formed by cryptogamic plants. One cause of the difference between peat and coal, appears to be the extreme pressure to which coal has been subjected; for it is a curious fact, that peat, when placed under artificial pressure, becomes more valuable as fuel, and taken weight for weight, affords light and heat equal to some kinds of coal. Perhaps the inference which may be drawn from this, is, that culm, or anthracite, has been formed (in a manner analogous to that employed in preparing charcoal, which, as before mentioned, it resembles in its composition,) by exposure to *heat* whilst under pressure; coal, under pressure of *super-incumbent rocks*, without a sufficient degree of heat to destroy the vegetable structure; lignite, under pressure of *deep water;* and peat, under that of the *atmosphere*. A supposition which will remind us of the circumstances under which the three descriptions of igneous formations, granite, trap rocks, and lava, are supposed to have cooled.

The most remarkable remains which have been found in *volcanic formations*, are those in the buried towns of Herculaneum and Pompeii. In the barracks at the latter place, the skeletons of two soldiers chained to the stocks have been discovered; and in the vaults of a country-house in the suburbs, those of seventeen persons were found, who had apparently retreated thither with the hope of escaping. In the same villa, was found the skeleton of a woman, (thought to have been the mistress of the house,) with an infant in her arms. Round the neck of this skeleton, a chain of gold was found suspended, and rings set with jewels still remained on the fingers.

Organic remains are liable to become embedded by means of *landslips*, which are portions of land which separate and slide down, either in consequence of being undermined by water washing away the lower beds which support them, or from the disturbance of an earthquake. By suddenly precipitating large masses of rock and soil into valleys, landslips sometimes overwhelm great numbers of animals, and even whole villages, with their inhabitants. The number of lives lost by the slide of the Rossberg, in Switzerland, in 1806, was supposed to exceed eight hundred. Landslips occasionally transport trees without injury, from the hills on which they grow, into the valleys beneath, where they continue to flourish; and during the earthquake in Calabria, in 1783, a small inhabited house, standing on the transported mass of earth, was carried down entire, and without injury to the inhabitants. A remarkable and interesting instance of a landslip occurred near Axmouth, in Devonshire, on Christmas-eve, 1839. By this extraordinary convulsion of nature, a vast mass was disrupted from the cliff, and thrown down from its former position, being separated from the main land by a deep chasm. This mass, though in some parts much shattered and rent, has not experienced much disturbance towards the centre; and a large area, consisting of four fields of young wheat and turnips, as well as an orchard and a large wood, subsided without suffering materially: two cottages were also borne down with the sinking mass; and though they were thrown out of the perpendicular, they remained entire, and their inmates escaped. This landslip extended along the coast for above a mile; and the chasm, which was between two and three hundred feet deep, and of about equal width, was nearly a mile in length. By the immense pressure of the sinking mass upon the shore on which it descended, a vast heap of less solid materials was forced upwards in the bed of the sea, at a short distance from the beach; and a reef or ridge formed, forty feet in height, on a spot where there had previously been thirty feet of water. This landslip was evidently caused by the action of water undermining the lower beds of this portion of the coast. The higher part of the cliff consists of a stratum of chalk, beneath which occurs a layer of sandstone and chert, with a substratum of loose green-sand; all these strata being *pervious* to water, but resting on a bed of lias clay, *impervious* to that fluid. The season of 1839 had been unusually rainy, and the water percolating through the chalk and sandstone, but being arrested by the clay, so entirely saturated and softened the loose green-sand, that it gave way, and the upper strata losing their support, suddenly subsided, sliding forwards towards the sea, apparently in the direction of the dip of the strata.

On a smaller scale, landslips often give rise to narrow ravines, or *chines;* at the head of these chines there is always a spring, the waters of which are instrumental in producing these slides, which frequently take place after severe frosts. Shanklin chine, in the Isle of Wight, appears to have been thus formed.

The drifting *sands* of Asia and Africa have entombed many of the relics of antiquity, and in some places the only traces of cities are the minarets which are seen penetrating through the sand. A subterranean city was discovered in India, in the year 1833, situated near Behut, to the north of Saharunpore, and about one hundred miles from Delhi. This town appears to have been buried in *mud* and *silt*, washed down from the neighbouring hills. The remains hitherto discovered, have led to the supposition that this city must have been buried at a period not long subsequent to the Christian era. The bones are not fossilized, and many of the implements found in this place, much resemble some still in use in Hindostan. This city was buried seventeen feet below the present surface of the country.

Organic remains are also not unfrequently found, embedded in accumulations of sand and mud, at the mouths of rivers, or in *deltas*, as such formations are termed. Many large rivers, before they empty themselves into a lake, or into the sea, divide into separate streams, forming two sides of a triangle, of which the sea makes the base, within which an island, or formation of land, is included. The name delta was originally given to an accumulation of this description, at the mouth of the river Nile, on account of the resemblance of its form to that of the Greek letter Δ (delta). The term is, however, applied by geologists to all such accumulations, even though they may not assume that particular form. The length of time a delta takes to accumulate, depends greatly on the nature of the soil through which a river flows; for if hard granite rocks form the channel, the *detritus*, or particles *abraded*, or worn from the rocks, by the action of the water, will be small; but if the stream should pass through soft formations, or through sandy soil, this will be very considerable. In hot climates, deltas, on account of their being surrounded by water, and the consequent moisture of their atmosphere, are peculiarly adapted for the growth of some species of plants; and usually become the abode of numerous animals, particularly of crocodiles, the modern representatives of the saurian tribe; and, when succeeding accumulations are formed, their remains are frequently found embedded in such formations.

The most remarkable remains that have been discovered in *coral rocks*, are some fossil skeletons of the human species, which have been found in the West Indies, on the north-western side of the Island of Guadaloupe. The rock in which these skeletons are embedded, is the work of small coral polypes, very similar to those which have so largely contributed to the formation of the limestone rocks, from the earliest stratified rocks, to the present day. These formations are not very compact at first, but sand and minute shells usually drift into the interstices, and thus a solid rock is formed. That at Guadaloupe is said to be as hard as statuary marble. The polypes, which form the coral, do not exist at any great depth under the water, nor do they carry on their operations above its surface; we must therefore suppose that at the period these human remains were deposited in this spot, the coral formation existed at a certain depth below the surface of the ocean, and in a situation where a vessel or canoe might probably be wrecked: the bodies of the navigators might thus be lodged in the coral formation, and subsequently encased, by the polypes continuing their labours. A skeleton from the Island of Guadaloupe may be seen in the British Museum. The skull, however, in this specimen is wanting: though a skull discovered in the same formation, and which is in the collection of the Literary and Philosophical Society of South Carolina, is said to have belonged to this identical skeleton. These remains are considered to differ from the Carib, and to present all the characteristics of the American or Peruvian race.

We have already alluded to the fossil infusoria discovered by Professor Ehrenberg, in the more ancient formations; the remains of existing species of these minute creatures have been found in the recent formations, and the greater number have been identified with species still inhabiting the localities where they have been found in a fossilized state. One remarkable mineral substance, called *berg-mehl*, or *mountain meal*, has been found to contain no less than nineteen different species of infusoria, the mineral being wholly composed of their siliceous shields. This substance has been met with in Tuscany, in Lapland, and in other places. In Lapland, it is sometimes eaten in times of scarcity, when the Laplanders mix it with ground corn, and the bark of trees, to make their bread. It was thus used in the district of Degerfors, in 1833, and is superstitiously considered as a gift of the great spirit of forests. There can be little doubt that the animal matter contained in the berg-mehl, may render this in some degree nutritious. Probably it was a formation similar to this, that, many years since, was used to make bread by the inhabitants of Lusatia, when, in a season of distress, some persons are said to have been almost entirely supported by a kind of earth.

Before geological investigations had thrown light on the subject, all accumulations of shells found in elevated situations, were supposed to have been deposited in such localities by the waters of the Deluge. Careful observations have, however, shown that in many instances the animals must have lived and died on the spot, and in some cases must have existed there for very many years: whereas, according to the Mosaic account, the waters of the Deluge only prevailed on the upper parts of the earth for a few months. These waters also appear to have risen gradually, and gradually to have abated. Nor have we reason to suppose that any terrible convulsion of nature accompanied this destruction of the guilty race of man: nay, on the contrary, we may imagine these waters to have been instrumental in increasing the fertility of the earth, in diffusing the soil over certain portions of the globe, and in spreading seeds of plants. For, the ground, which at the fall of our first parents had been cursed for man's sake, and doomed to bring forth thorns and thistles, had, if we may so express ourselves, by this immersion beneath the waters, this baptism, become regenerate, and the announcement was at this epoch graciously made, that the ground should no longer be cursed for man's sake*. And as, when the dove was sent forth out of the ark, we find that the olive-tree was growing, we have ample reason to conclude that all vegetation had not been destroyed.

It is curious to observe the attempts that were made, before geology, and the sciences which lend their valuable aid in its illustration, had been brought to the perfection they have now attained, to account for the extraordinary remains that were occasionally met with. Shells found on the summits of mountains, were conjectured to have been deposited there

* See Gen. iii. 17, 18; and viii. 21.

by pilgrims in their progress to various shrines: the bones of elephants to be those of animals of that kind brought into the north, either by the Carthaginians or by the Romans, and which had perished on the spots where they were found. The immense numbers that were discovered, however, soon rendered these, utterly unsatisfactory explanations; and it was surmised that these shells and bones, as well as other kinds of fossils, were mere accidental forms assumed by stones; or, as they were termed, "sports of nature." Happily all these absurd notions are exploded; but one or two instances of mistake and deception arising from want of better information, which occurred in those days of ignorance on such subjects, may not be wholly without interest or advantage.

A professor of the name of Scheuzner, who lived in the beginning of the eighteenth century, and who in his day ranked high as a man of science, having discovered some fossil bones, mistook them for those of a man, and published a particular account of these curious remains, as affording evidence of the universal deluge. These bones have been ascertained to be none other than those of the gigantic salamander, already mentioned as having been found at Oeningen*.

Some bones were discovered in the year 1577, near Lucerne, and a famous anatomist having ex-

* See page 195.

amined them, pronounced that they must have belonged to a giant, nineteen feet in height: an imaginary portrait of this supposed giant of the human race was painted and deposited in the Hôtel de Ville in that city, where it remained for many years. There can be little doubt that had these bones fallen into the hands of Dr. Buckland, or of Dr. Mantell, they would at once have pronounced them to be those of the megalosaurus, or of some other animal of the saurian tribe.

But perhaps the most absurd story of this description, though at the same time not quite so blameless as the preceding accounts, is the imposition which was practised in France, at the commencement of the seventeenth century. In the year 1613, some bones were discovered in a sand pit not far from Serres; (in the department of the Hautes Alpes.) Many of these bones were broken by the workmen, but a surgeon in the neighbourhood having obtained possession of them, succeeded in imposing on the credulous public. These bones were exhibited in Paris and other cities of France, as those of a man of gigantic stature; and in order to give an interest to these remains, the possessor gave out that he had discovered them in a sepulchre, thirty feet in length, bearing the inscription of *Teutobochus Rex*. He further asserted, that he had found fifty medals bearing the head of the Roman consul Marius, and that there could be no doubt that these remains must be those of Teutobochus, who was king of the Cimbri, at the period of the contest between that nation, and the Roman forces commanded by Marius. This fiction gained universal credit in France; but it was subsequently discovered that the medals were fabricated, and that the pretended giant's bones were those of an elephant.

Any person possessing some knowledge of anatomy, might readily have perceived the difference between these bones and those of a man; but in all probability, those to whom these remains were exhibited, were totally ignorant of that science; and geology had not then brought to light the various "long-buried bones" which have been disclosed in this age of research.

Error is the offspring of ignorance; and were there no higher end in view attached to the pursuit of science, the mere circumstance of avoiding the risk of being thus imposed on, might be sufficient to induce us to give it a share of our attention. But there *is* a more exalted end in view: for we are aware that it is the object of all science to attain to a knowledge of truth; and the attentive consideration of the facts it discloses, tends "to confirm us in the conviction of that truth, which is the foundation of all religion and piety—the Being of one God, incomparably excellent, the Maker and Upholder of all things."

CHAPTER XV.

RECENT PERIOD. CHANGES IN PROGRESS. CONCLUSION.

Cliffs which have been rent asunder,
A dreary sea now flows between:
But neither heat, nor frost, nor thunder,
Shall wholly do away, I ween,
The marks of that which once hath been.

COLERIDGE.

It has been before observed, that changes have taken place within the Recent period, even on our own shores. Thus, in some parts, flourishing cities, which existed at no distant period, have been swept away, and their site is now occupied by a sand-bank, or a shoal, beneath the waters of the sea; whilst, in other localities, land has been gained, and large and populous towns have been erected on tracts formerly occupied by the waves. Hence, though in this country we may not witness any of the striking effects which in some other regions are brought about by earthquakes and volcanos, we may have frequent opportunities, by means of historical records handed down to us, of tracing *aqueous changes*, or those which time and the action of the waves have produced. We may see

——— The hungry ocean gain
Advantage of the kingdom of the shore;
And the firm soil win of the watery main,
Increasing store with loss, and loss with store.

An account of some of these *changes* may not be uninteresting. Commencing with the Shetland, or Zetland Isles, we find that the wild winds and waves are making great devastations on the shores. The Zetland Isles are formed of the hardest description of rocks, including granite, gneiss, mica-slate, serpentine, and porphyry; but, being exposed to the unbroken violence of the Atlantic Ocean, and to the strong westerly gales which sweep across that vast expanse of water, these solid rocks are undermined and shattered; and thus large masses of granite are frequently detached, and sometimes carried by the force of the waves, a hundred and twenty, or a hundred and fifty feet, up the steep shores. And, (to use the words of a distinguished writer, who visited these islands,) "the foam of the sea plays at long bowls with a huge collection of stones, some of them a ton in weight, but which these fearful billows chuck up and down, as a child tosses a ball."

Such devastations, in the course of time, reduce the size of islands, and it not unfrequently happens that clusters of bare granite rocks remain, which there is every reason to suppose were at one time united to the land. This arises from the different composition of the masses which form the shores, in consequence of which some parts are sooner acted on by the waters than others. Thus, in these islands, we find that the gneiss and slate formations yield to the mighty force of the waves, whilst the granite longer withstands their fury, and accordingly often presents these detached clusters of rocks, which sometimes assume the most fantastic forms.

The action of the sea, when the coast is low and sandy, leads to very different results. The waves, in that case, impel the sand forward upon the shore, where, at every ebb of the tide, it becomes partially dried, and is drifted along the beach by the wind. By degrees, *dunes*, *downs*, or *hills of sand*, are formed, the higher parts of which are continually carried slowly forward inland; and not unfrequently by this means fertile lands are overwhelmed, and buried in sand. In some instances, however, certain plants, capable of thriving in such soils, take root in these sand-hills, and the creeping roots binding the mass together, their further progress is thus prevented.

The coast of Elgin affords a striking example of the *sand-flood*, as it is termed. In this county, to the west of the river Findhorn, there existed, previous to the year 1677, a remarkably fertile district, between which and the sea, hillocks of sand, covered with vegetation, had stood from time immemorial. The inhabitants of the district, however, inconsiderately pulled up the bent-grass and juniper which had bound these hills together; this natural guard being thus removed, the sand was set at liberty, and drifted inland, overwhelming the habitations, and desolating the whole of the fertile district before mentioned. The mouth of the river Findhorn was also choked up by the sand, but the waters of that river cut out for themselves their present channel; and the old town of Findhorn, which had originally stood on the eastern side of the river, was left on its western bank. This, however, was deserted, and a new town erected on the eastern side of the newly formed channel. The site of the old town is now quite covered by the sea.

We cannot pause to consider all the changes which have taken place on the shores of Great Britain, but must content ourselves with a slight notice of the most remarkable. In Yorkshire, the rate of waste of land is said in some parts to be little less than twelve feet annually; and the ancient sites of many towns and villages in that county, are now occupied by sand-banks in the sea. Among these is Ravenspur, from whence, in the year 1332, Edward Baliol and the confederated English barons sailed to invade Scotland: where also, in 1399, landed Henry of Lancaster, afterwards King Henry IV., or, to use the words of Shakespeare,

> The banished Bolingbroke repeals himself,
> And with uplifted arms is safe arrived
> At Ravenspurg.

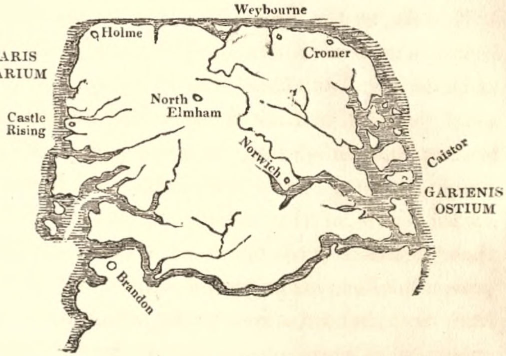
This ancient seaport town, once of such importance that it was a rival to Hull, has been altogether swept away, and nothing is now to be seen of the site it occupied, save extensive sand-banks, which are daily covered by the waves, though still visible when the tide retires.

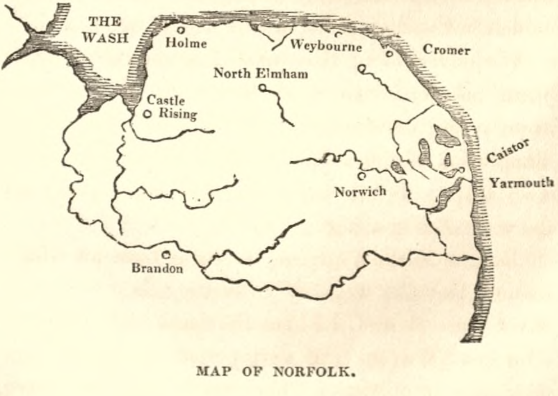
But whilst cliffs, and strata of sand, or clay, are thus falling to decay, we find in other parts, estuaries*, or arms of the sea, are not unfrequently filled up, and in some instances firm and habitable land is gained.

Rivers, in their course to the sea, usually carry down with them a considerable portion of *silt*, which consists of fine particles of sand, clay, or other earths. So long as the river finds a clear passage into the ocean, this silt is transported into the bed of the sea, and, in some instances, causes the water to be discoloured to a considerable distance from the shore; but should a shoal, or sand-bank, be formed at the mouth of an estuary, the silt will be impeded in its progress; and, in process of time, the mouth of the river will be choked, or, as it is termed, *silted up*. The river sometimes, in such cases, takes a new course, and not unfrequently lakes are formed. The soil thus accumulated, is termed *alluvium*, or *alluvial soil*, and usually affords excellent pasture-lands. We meet with some instances of estuaries thus filled

* *Estuaries* are inlets, or arms of the sea, which are entered both by a river and by the tides of the ocean. The mouth of the river Thames is an example of an estuary.

ROMAN NORFOLK*.





MAP OF NORFOLK.

* From the Archæologia.

up in Norfolk, in which county the historical records we possess, enable us to trace some remarkable changes.

Norfolk, at the period the Romans occupied this island, was, on account of its proximity to Denmark, at that time the abode of the Vikingr, or Sea-kings, much exposed to their attacks, and formed an important frontier station, in consequence of which numerous forts were erected by the Romans in various parts of this county. The greater part of these fortresses have crumbled to dust: the Roman power has long since passed away: but memorials have been handed down to us, which are of great geological interest, on account of their giving us an opportunity of distinctly tracing the various changes which have taken place in this part of our island.

We have placed this map of Roman Norfolk in juxta-position with a modern map of the same county, as the most efficient mode of affording an illustration of this subject. By a comparison of the two maps, the alteration that has taken place will be very readily observed.

Roman Norfolk appears to have been an island, bounded on the west by an estuary, into which the river Ouse flowed, and on the south, by the rivers Ouse and Waveney, at that period streams of considerable importance. The north and east were, as at present, bounded by the ocean. The ancient estuary, called the Metaris Æstuarium, has been silted up, and covered with alluvial soil; and though some parts still consist of swamps, or marshes, the greater portion of the space it occupied, is now converted into productive arable and pasture land. But whilst land has been formed in this spot, the cliffs near Holme, on the northern coast, owing principally to the undermining of the arenaceous, or sandy beds, below the chalk, by the waters of the ocean, have been rapidly crumbling to decay.

On the flat shores near Weybourne, again, dunes, or hills of blown sand, are fast accumulating; and as these are bound into a compact mass by the long creeping roots of a plant called marram, (the arundo arenaria,) they are not driven forwards by the wind, but retain their situation; forming a secure barrier, which protects the harbours of Wells, Cley, and some other places. Weybourne was a Roman station; and is also supposed to have been the usual landing-place of the Danes in their invasion of England: though probably the ancient site has been buried in sand.

Passing from Weybourne, we again meet with cliffs, which we find to be rapidly disintegrating; the whole site of ancient Cromer being in the German Ocean. Proceeding a little southwards, the progress of decay becomes very strongly marked, even on a map of this small scale; and it will be observed that in the modern map, the coast has entirely lost the rounded form represented in Roman

Norfolk. In this part of the county the waves are still continuing their work of destruction, for the cliffs appear to be decreasing at the rate of three feet annually; and many villages have disappeared, and much valuable land been lost by the power of the waves.

No sooner, however, do we arrive at the termination of the cliffs, than we find hills of blown sand fast accumulating. Referring to the map of Ancient Norfolk, we perceive that the eastern portion was at that period occupied by a bay, thickly studded with islands. The whole of this has been filled up with alluvial soil; and thousands of acres have thus been gained, and converted into cultivatable land. The numerous lakes which exist in this part of the county, are the only remaining evidences of this ancient bay. Caistor, (or Castle,) was one of the Roman stations, and in the time of the Romans, was situated on an island, at some distance from the mainland, while the portion of land on which Yarmouth now stands, formed part of the bed of the ocean. Accumulations of silt, borne down by the Yare, and other rivers, added to the hills of blown sand, have gradually filled up this estuary; and the sands on which Yarmouth is built, became firm and habitable land about the year 1008. The sea continued to make occasional inroads until the reign of Elizabeth, but since that period, the waves have made no considerable advances on this coast.

Great changes are also known to have occurred, both in Suffolk and Essex, within the historical era; but as we must confine ourselves to a few particulars, we will only mention the formation of Lowestoff Ness, and the loss of land at Dunwich, both in Suffolk.

At Lowestoff, there is an inland cliff, about sixty feet in height; and between this cliff and the sea there is a low flat tract of sand, called the Ness, about three miles long, the point of which projects nearly two thousand feet into the sea from the base of the cliff. This accession of land appears to have been formed at distant intervals, by the influence of currents running between the shore, and a shoal about a mile off Lowestoff, called the Holme Sand. The lines of growth are indicated by ridges, or embankments, several of which have been formed within the observation of persons now living, usually during some extraordinary high tide, attended with a violent gale. A bank of shingles has been first thrown up, and deposited at the foot of the cliff. The interstices between the shingles soon become filled with sand, in which the arundo, and other marine plants, by degrees introduce themselves, and by their creeping roots, bind the mass firmly together. In the mean time, another ridge is formed, which, in its turn, becomes consolidated like the preceding bank. Subsequently, the marine plants decaying, a vegetable mould is formed, in which grass and vetches thrive; and at length, the whole becomes covered with good pasturage, and the ridges sufficiently firm to support the habitations of man.

Dunwich, on the other hand, has been almost entirely demolished by the sea. This town was, in olden times, a place of much importance, and is said to have been an episcopal see in the year 630, in which case it must have been one of the earliest established in this island. The see was subsequently removed by William the Conqueror to the city of Norwich, probably on account of the ravages committed on Dunwich, even previous to that period; for it is on record in *Doomsday Book*, that considerable tracts of land had been devoured by the sea in that neighbourhood. It was once so considerable a place that, according to Spelman, it contained fifty-two churches and monasteries; and even as late as the fifteenth century, it was a populous town; but nothing of this once flourishing place now remains, except a small village with about twenty tenements, and scarcely more than a hundred inhabitants.

In the county of Kent some changes of great interest are on record. First, taking our course up the estuary of the Thames, we arrive at Herne Bay, to which, at one period, the name of "Bay" was not misapplied; but the waves and currents have entirely swept away the ancient headlands. Then retracing our steps, and proceeding towards the North Foreland, we pass Reculver, whose remarkable church, with its two lofty spires, has, for thirty-seven years, only formed a landmark to the mariner; the church-yard, and many adjoining houses, having been swept away in the year 1804: but in the reign of Henry VIII., this church was a mile distant from the edge of the cliff; and in the time of the Romans, it was an important military station, under the name of Regulbium.

At that period the Isle of Thanet was, in fact, an island, separated from the mainland of Kent by an estuary, which formed a navigable channel, and through which the Roman fleets sailed in their course to the Thames, instead of sweeping round the North Foreland. The entrance to this strait was at Rutupia, now Richborough Castle, near Sandwich; and this fort, with that of Regulbium at the other extremity, defended the entrances into this estuary. This arm of the sea, even as late as the eighth century, was three furlongs in breadth, and the village of Stourmouth marks the spot where the river Stour once emptied itself into the estuary, which is still called the Wantsum; though no indication of this ancient navigable channel now remains, save a line of marshy ground, girding the Isle of Thanet, and through which a small streamlet winds its way. + [illegible]

> There now no river's course is to be seen,
> But moorish fens, and marshes ever green.

A large tract of land appears also to have been added to the coast between Sandwich and Walmer. The latter place is supposed to have been the landing place of Julius Cæsar, in the year B.C. 55: not, however, the present beach, for owing to the accumulations of shingle on that shore, the actual beach on which Cæsar landed must now be very far inland.

This *shingle beach* does not appear to have been formed, like Lowestoff Ness, at distant intervals, by the action of currents during extraordinary tides, but by the ordinary and daily, though long continued, operation of the waves. Every breaker drives before it the loose materials it meets in its progress; but as, (unless it encounter opposition from a hard rock or cliff,) it returns with less impetus than it advanced, it has not sufficient force to sweep back the larger pebbles, which accordingly are deposited on the shore, though the finer particles usually descend the whole distance. If, however, the breaker should dash against a rock, it returns with force equal to that with which it advanced, and no such accumulation takes place; it is therefore principally on flat or shelving shores that shingle beaches are formed. These accumulations are much influenced by the prevailing winds, which on this coast are mostly from the westward, and drive the waves in one particular direction; and did the wind set perpetually from any one quarter, shingle beaches would increase rapidly; but, with a change of wind, the breakers take a different direction, and not unfrequently destroy the work of preceding waves: thus causing the endless variation we may observe in the arrangement of the sand and shingles on the sea-shore. And here, among numerous other beneficial effects resulting from the almost incessant changes in the wind, we cannot but notice that of preventing our harbours from being speedily choked up, and also our cliffs from rapid destruction.

In shingle beaches, or accumulations of shingles, we frequently meet with shells common to the sea-shore, in a more or less perfect state; with the bones of fish and of land animals, with twigs or branches of trees, which may have been brought from neighbouring land. Should such a mass become consolidated, these remains will be permanently embedded in it, and all the organic remains, (unless some fossils from the neighbouring cliffs should become mingled with the pebbles,) will belong to existing species. If, therefore, a geologist were to examine it, he would at once pronounce it to be a formation of the Recent period.

Such an accumulation, however, may convey to us some idea of the formations of earlier periods, and illustrate the manner in which fossils have been collected in some of the strata; though, in other cases, there is no appearance of their having been broken or washed by the action of the waves, but the animals seem to have perished on the spot they inhabited, and still to remain in the same locality. Instances of *raised beaches*, in which remains of this description are found, also occur in this country, but these belong to phenomena of another class; being supposed to have attained their present position by elevatory movements, occurring during the Recent period. An account of a raised beach in Barnstaple Bay, on the north-west coast of Devonshire, as described by Professor Sedgwick and Mr. Murchison, will form the best explanation of this phenomenon.

This raised beach forms regular sea-cliffs, several parts of which consist of stratified masses of calcareous grit and sandstone, so perfectly indurated, or hardened, that they appear like secondary formations; for which they might be mistaken, were it not for the organic remains they contain. These are all identical with the living shells on the coast, and are often well preserved, sometimes appearing in beds, and in their condition and arrangement exactly resembling the shells of a modern beach; though found in some parts, at the height of sixty or seventy feet above high water level. There is every reason, therefore, to suppose that this raised beach at one period during the Recent era, formed the actual beach, on which these molluscs had fixed their habitation, when it was daily washed by the tide; but that this coast was subsequently elevated to the situation it now occupies. Nor is this by any means a solitary instance of such a disturbance; for indications of similar elevatory movements occur in other parts of Devonshire and Cornwall, as well as in Lancashire, Cheshire, on the banks of the Severn in Shropshire, and in several other localities; recent shells having been found in many places, at elevations, varying from three to five hundred feet above the level of the sea.

As there is no reason to conclude that any earthquakes, to which such disturbances can be attributed, have occurred in England within the historical era, (unless we suppose this to have been effected by a long series of small and scarcely perceptible elevatory movements,) the probability appears, that these beaches were raised at some period antecedent to any accounts we possess. For, though numerous earthquakes are on record as having happened in England during the eleventh, twelfth, thirteenth, fourteenth, sixteenth, seventeenth, and eighteenth centuries, it has not been ascertained that they have produced any permanent changes of level, though in some instances they may have caused a temporary rise of land; for we are told that in the year 1110, the bed of the river Trent at Nottingham was dry for a whole day; and that the same phenomenon happened to the Thames at London, in the year 1158. The latter earthquake appears also to have been felt in many other parts of England*.

* No less than thirteen considerable earthquakes are recorded as having occurred in England during the twelfth century; some of sufficient violence to throw down several houses.

The most recent earthquakes of any importance on record in this country, are the repeated concussions, which in the years 1833, 1834, and 1835, were experienced at Chichester and the surrounding country; and these were rather remarkable from their frequent repetition, than from their violence. The severest shock was felt on the 23rd of January, 1834, but that was not sufficiently violent to occasion any serious damage, though the pictures and furniture in the houses were agitated, and the ornaments on the mantel-pieces visibly tottered: the sensation was that of a rumbling sound directly overhead.

The extensive underground communication which evidently exists between earthquakes in distant regions is very remarkable, and was singularly exemplified by the memorable earthquake of the 1st of November, 1755, by which the greater part of the city of Lisbon was destroyed, and above sixty thousand persons perished.

The movement on this occasion was most violent in Spain, Portugal, and the north of Africa; but nearly the whole of Europe, and even some parts of North America, and the West Indies, felt the shock on the same day. The agitation of the ocean in distant parts, as well as that of rivers, lakes, and springs, was remarkable. The sea ebbed and flowed in an unusual manner both at Antigua and Barbados. At Lyons, the river Saone suddenly overflowed its banks with extreme rapidity; and at

Avignon, the Rhone rose twelve feet above its ordinary extreme limits, and laid the surrounding country under water. The same phenomenon was observed in the rivers of Germany. The ships off Portsmouth were violently agitated; and the sea was observed to ebb and flow in a remarkable manner in many parts of the coast of Great Britain and Ireland. The rivers and springs were also affected, and even the ponds of Surrey and Kent. Wynander Mere rose in an instant seven feet, and as suddenly subsided. Loch Lomond also rose suddenly without any apparent cause, and overflowed its banks, depositing boats on dry ground above a hundred feet from its usual margin. No agitation of the ground however appears to have been felt, except at Irton, in Cumberland, and at Cork; a considerable shock having been experienced at the latter place.

The agitation was felt at sea, where the mariners in many instances supposed they had struck against sunken rocks; and one ship, forty leagues distant from Cape St. Vincent, experienced so violent a concussion, that the men were thrown up above a foot from the deck. In Portugal, where this convulsion of nature was most severely felt, chasms or fissures were formed in the earth, most of the mountains were rent, and large masses thrown into the valleys; and scarcely a town escaped without some marks of devastation. Successive shocks continued to agitate the earth at intervals for forty days.

The number of active volcanos on the surface of the globe is very considerable; and it is supposed that on an average, about twenty volcanic eruptions take place every year. In Europe there are five volcanic districts,—Vesuvius, Etna, Vulcano, Santorin, and Iceland; in these, about fifty eruptions are recorded to have occurred during the last century. There can, however, be little doubt that many eruptions may have taken place beneath the waters of the ocean, and have passed unnoticed. On some few occasions the gradual formation of an island by a submarine eruption has been observed; but these islands are rarely of long duration. A volcanic island made its appearance in 1831, in the Mediterranean Sea, between Sciacca, in Sicily, and the island of Pantellaria, to which the names of Sciacca, Graham's Island, and various others were given, but before the end of 1833, this island had disappeared, and nothing remained but a dangerous shoal.

In our consideration of the Recent period, we have perceived that changes are very evidently still in progress on the surface of the earth; and it is a highly interesting fact, that a close observation of some of these changes, tends to confirm the Mosaic account of the duration of the earth in its present condition.

"There can be no doubt," says Mr. Lyell, "that periods of disturbance and of repose have succeeded each other in every region of the globe." The commencement of the Recent period may be regarded as the epoch of the last disturbance, or revolution, that has occurred, at least in this part of the globe. The earthquake at Lisbon is, perhaps, the most violent convulsion of nature that has taken place in Western Europe within the historical era; yet even this catastrophe, with the exception of the formidable number of human victims, does not appear to have produced any remarkable effects, or to have given rise to any violent and permanent disturbance*.

* Some accounts recently published, also lead to the conclusion that the changes on the eastern coast of North America, within the last eight hundred and fifty years, scarcely equal those in this part of Europe. It appears to be established, that Nova Scotia and Newfoundland were discovered towards the close of the tenth century, by the Northmen, or Scandinavians, who subsequently appear to have visited several parts of the North American coast. The descriptions of these shores given by those adventurous voyagers have been preserved, and agree almost verbally with those of modern travellers. The instances of this accordance are numerous, but the account given of the remarkable promontory on which Cape Cod is situated, may suffice us for an example. To this, from the resemblance of its form to the keel of one of their ancient ships, the Northmen gave the name of Kialarnes, (from *kiölr*, keel, and *nes*, cape;) at the same time describing the coast as presenting a *desert* aspect, with *sandhills* of a very *peculiar appearance*. This promontory may be observed on modern maps, as still retaining the same remarkable form, jutting forth into the broad waters of the Atlantic Ocean, whose power it seems to have withstood: and its coast is thus described by a modern writer:—"the *dunes* or *sandhills* are often nearly *barren of vegetation*, and forcibly attract attention on account of their *peculiarity*." For further particulars, see *Journal of the Geographical Society*, vol. viii., part 1.

And, (if we adopt the views and almost the words of one of the most distinguished naturalists this, or any age has produced,) we shall find that a careful examination of the changes which have taken place on the surface of the globe, since the present dry land has appeared, and the continents have received their actual general configuration, clearly proves that the last revolution, and therefore man's existence on the earth, cannot be referred to an era more ancient than that assigned in the Sacred Volume to the creation of the human species, but, as nearly as can be expected in such investigations, accords remarkably with that date. This is a conclusion at the same time the most clearly proved, though perhaps the least expected from geology; a conclusion, however, peculiarly valuable, as it forms a link between history and the Bible*.

It can only be from calculating the effects produced in a given time by certain changes at present in progress, and from comparing these with former accumulations, that a tolerably correct estimate may be obtained of the length of time required for any formation to have attained its present dimensions; and thus of the lapse of years since the accumulation first commenced, and the period at which our continents received the form they still retain. For,

* CUVIER, *Discours sur les Revolutions de la Surface du Globe.*

from this era, our present mountains have commenced to crumble away, and the *talus*, or sloping heap at their base, to be formed; our present rivers have commenced to flow into our present lakes and seas, and to deposit alluvial matter; our cliffs to be undermined by the waves, and our dunes, or hills of blown sand, to be formed by the wind. And it is a very striking fact, that all these natural phenomena unite in giving testimony, that the present order of things cannot have existed above five or six thousand years; for it has been proved that it must have required nearly that number of years, and no more, for existing deltas to have been formed, and for lakes to have become partially filled up as they are at present; for dunes, and for sloping heaps at the foot of mountains, to have attained their actual elevation and extent.

Five or six thousand years would carry us back to the era assigned for the creation of man; and to a period above sixteen hundred years antecedent to that of the deluge. But, as has been before observed, the waters of the deluge appear to have risen gradually, and abated gradually. And, as we frequently find in ordinary inundations, that land will remain for months under water, without any marked alteration taking place in its general form, so may it have been with the waters of the deluge: they perhaps may have destroyed a certain number of the external or uppermost layers of sand, or of detritus, but we have no reason to conclude that the accumulations then formed, were in all cases swept away from the whole surface of the earth.

We have now taken a slight sketch of the leading features of Geology; but much, very much, yet remains to be told. These few particulars may, however, have been sufficiently interesting, to induce us to pursue this study, both in the works of the numerous and able authors to whose labours we are indebted for our knowledge of this science, and also in the sublime and inexhaustible volume of nature, the work of an "unseen guiding hand;" with which it is our duty, as well as our privilege, to make ourselves acquainted. We shall find this employment not only delightful, but conducive to the highest ends, for it has a tendency to improve and strengthen our minds, and at the same time to impart "a reverent adoration of God's unsearchable wisdom; an awful dread of His powerful majesty; and a grateful love of His gracious benignity and goodness."

But we must not consider that it is only in these past "ages and worlds," which we have been contemplating, and which we have seen "begin, grow old, and end," that these "chief and peculiar" attributes of the Most High are evidently displayed; for, would we but give our attention to the glorious theme, we should find that they are equally manifest in the ordinary operations of nature, daily presented to our view. And having now formed a slight acquaintance with Geology, or the earth in its past condition, we may find it interesting to extend our knowledge of the globe we inhabit, by considering some particulars of Physical Geography, or the Earth as it is: a subject to which we hope at some future period to introduce our readers, and which will include the present distribution of animals, plants, and minerals, and various other topics relative to the actual condition of the earth's surface.

And most assuredly, whilst pursuing this investigation, or any other which leads us to contemplate the works of the Creator, we shall unhesitatingly acknowledge, that in the present hour, as much as in "Creation's prime,"

> Time, space, height, depth, O God, are full of thee!

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GLOSSARY.

ABRADED. (Latin, *abrado,* to scrape or wear away.) In Geology, the term is applied to the wearing away of rocks by water or other means.

ACTINOLITE, (Greek, *actin**, a ray of light; and *lithos,* a stone,) a crystallized mineral of a green colour; so named because the crystals are arranged in the form of rays.

AGGREGATE, (Latin, *aggrego,* to collect together,) a mass of matter, formed of similar, or of different substances, heaped or joined together.

ALBITE, a species of felspar.

ALGÆ, (Latin, *alga,* sea-weed,) a division of the cryptogamic order of plants, including all marine vegetation.

ALLUVIAL, the adjective of alluvium, which see.

ALLUVIUM, (Latin, *alluvio,* to wash over,) earth, clay, sand, gravel, and other matter, transported by rivers, floods, or other temporary inundations, and deposited on land, not permanently covered by the waters of a lake or sea.

ALUMINA, (Latin, *alumen,* alum,) the earth called clay, of which aluminum forms the base. Common alum is *sulphate of aluminum.*

ALUMINUM, a metal, the base of clay.

* It has been deemed advisable to give the Greek words, as well as all the other roots, in italics.

AMMONITE, an extinct molluscous animal, allied to the nautilus, and inhabiting a chambered shell; so called from its resemblance to the horns on the statues of Jupiter Ammon. These fossils, before their real nature was understood, were familiarly called *snake-stones.*

AMYGDALOID, (Greek, *amugdalea,* an almond,) a species of trap-rock, in which agates and other simple minerals are scattered; presenting the appearance of almonds in a cake.

ANOPLO-THERIUM, (Greek, *anaplos,* unarmed; and *therion,* wild beast,) an extinct mammifer; so named because the animal appears to have been singularly destitute of the means of defence. See p. 189.

ANTHRACITE. (Greek, *anthrax,* coal.) This mineral, called also *culm, blind coal, glance coal,* and *stone coal,* is a black substance, consisting almost entirely of carbon, in the black state in which it exists in charcoal.

ANTHRACO-THERIUM, (Greek, *anthrax,* coal; and *therion,* wild beast,) an extinct mammifer; so named because the remains of this genus were first discovered in lignite, or wood-coal, of the Tertiary Period.

AQUEOUS, (Latin, *aqua,* water,) watery; formed by water.

ARENACEOUS, (Latin, *arena,* sand,) sandy; formed of sand.

ARGIL, (Latin, *argilla,* clay,) clay.

ARGILLACEOUS, clayey; composed of clay.

ARTICULATA, (Latin, *articulus,* a little joint,) a division of the animal kingdom. See p. 107.

ASTERIÆ. (Greek, *aster,* a star.) Portions of stems of the pentacrinite have long been commonly called asteriæ, or star-stones.

AUGITE, (Greek, *auge*, lustre,) a simple mineral of a dark green or black colour, and of shining appearance.

BASALT, one of the most common varieties of the trap-rocks, of a dark green or black colour, very compact in texture, and of considerable hardness. It is often found in regular columns, of three or more sides, called basaltic columns. Basalt is composed of augite and felspar, and frequently contains much iron. The name is supposed to be derived from *basal*, an Ethiopian word, signifying iron.

BASIN, a term applied to the sloping or trough-shaped cavity, occurring in older rocks, in which newer strata have been deposited.

BELEMNITE, (Greek, *belemnon*, a dart,) an extinct genus of molluscous animals, having a long, straight, and chambered conical shell.

BITUMEN, (Latin, *bitumen*, pitch,) mineral pitch, of which the tarlike substance which often may be seen oozing out of the Newcastle coal when on the fire, forms an example.

BITUMINOUS, impregnated with bitumen.

BLACK-LEAD. See Graphite.

BOULDERS, large rounded blocks of stone, found in some parts lying on the surface of the ground, and occasionally embedded in loose soil; which, on account of the difference of their composition from that of any rocks in their vicinity, bear every appearance of having been transported from a distance.

BRECCIA, (Italian, *breccia*, a breach made in a wall,) a rock composed of angular fragments, connected together by lime, or some other mineral substance; so named from having been first observed in fissures, or chasms.

CALCAREOUS ROCK, (Latin, *calx*, lime,) limestone.

CALCAREOUS SPAR, crystallized carbonate of lime.

CALCEDONY, a simple uncrystallized mineral, composed of silex. Agates are partly formed of calcedony.

CALCIUM, (Latin, *calx*, lime,) a metal, which forms the base of lime.

CALC-SINTER, (German, *kalk*, lime; and *sintern*, to drop, to trickle,) a deposit from springs holding carbonate of lime in solution; which are commonly called petrifying springs.

CALC-TUFA. See Tufa.

CAMBRIAN, an extensive series of rocks, belonging to the Secondary Period, of which it is the most ancient group. It is classed among the transition rocks. See p. 103.

CARBON, (Latin, *carbo*, coal,) a non-metallic elementary substance, which enters largely into the composition of coal.

CARBONATE OF LIME, limestone. See p. 81.

CARBONIFEROUS, (Latin, *carbo*, coal; and *fero*, to bear,) a term especially applied to one of the great systems belonging to the Secondary Period, which comprehends all the principal coal-bearing strata. Any stratum, however, containing coal, may be called carboniferous.

CETACEA, (Latin, *cete*, whale,) an order of vertebrated mammiferous animals inhabiting the sea. The whale, dolphin, and dugong, are examples.

CHAMBERED, divided into chambers, or partitions.

CHALCEDONY. See Calcedony.

CHALK, (Latin, *calx*, lime; German, *kalk*, chalk,) a white earthy limestone.

CHARCOAL, (Provincial, *char*, to burn to a cinder,) a sort of coal, made by burning wood under turf, or by some other means excluded from the air.

CHERT, (German, *quartz*, flint,) a mineral, composed of silex, and nearly allied to calcedony and flint, but less simple in texture.

CHIRO-THERIUM, (Greek, *cheir*, a hand; and *therion*, wild beast,) an extinct animal, known only by some traces left on the new red sandstone; so named from a certain resemblance to a hand in the print of the animal's paw.

CLINKSTONE, a rock of the trap formation; so called because it is sonorous when struck with a hammer. It is composed of felspar, and usually *fissile*, or capable of being split into layers.

CLAY. Pure clay is alumina: this earth, however, rarely occurs without some admixture of silica.

COAL FORMATION, or COAL MEASURES, terms applied to the group or system in which the most valuable coal is found.

COLEOPTERA, (Greek, *koleos*, a sheath; *pteron*, a wing,) an order of insects, including beetles; so named on account of the sheath afforded by their horny upper wings.

COMMINUTED, (Latin, *comminuo*, to break in pieces,) worn down into minute particles.

CONCHIFERA, (Latin, *concha*, a shell; and *fero*, to bear,) an order of molluscous animals bearing bivalve shells.

CONCRETION, (Latin, *concresco*, to coalesce into one mass,) a mass formed by the coalition or union of separate particles.

CONGLOMERATE, (Latin, *conglomero*, to heap together,) a mass composed of rounded water-worn pebbles, or fragments of rocks, cemented together by some mineral substance.

CONIFERÆ, (Latin, *conus*, a cone; and *fero*, to bear,) an order of plants which bear cones, in which the seeds are contained. The fir and pine are instances of coniferous trees.

CONSOLIDATED, (Latin, the particle *con*, together; and *solido*, to cement,) a term used when the particles of which rocks are composed become so closely cemented, as to form a hard and solid mass.

CRAG, a provincial term in Norfolk and Suffolk, for a deposit belonging to the Tertiary Period. It is so called on account of the rough appearance it presents.

CRATER, (Latin, *crater*, a great cup or bowl,) the circular cavity at the summit of a volcano.

CRETACEOUS, (Latin, *creta*, chalk,) formed of, or belonging to chalk. The name given to an extensive series of strata, the latest of the Secondary Period, in which chalk forms the predominant rock.

CRINOIDEANS, (Greek, *krinon*, a lily,) an order of animals belonging to the radiata division; so named on account of their resemblance to the form of a lily.

CROP-OUT, (Saxon, *croppa*, the upper end of anything,) a miner's term, used to express the rising to the surface of a stratum, or number of strata.

CRUSTACEA, (Latin, *crusta*, any shell, or external coat, by which a body is enveloped,) animals having a shelly coating or crust, which they cast at certain stages of their growth. Lobsters, crabs, and shrimps are *crustacea*, or *crustaceous* animals.

CRYPTOGAMIC, a name applied to a class of plants, such as ferns, mosses, seaweeds, and fungi, in which there are no conspicuous flowers.

CRYSTAL. (Greek, *krustallos*, ice.) Simple minerals are frequently found in regular forms, these being fixed, or determinate, for each peculiar species.

Thus, rock crystal, or pure quartz, to which the term was originally applied, always assumes a rhomboidal form; and from its resemblance to beautifully transparent ice, was called rock crystal, or literally, *rock ice.* The term crystal is, however, applied to all minerals that assume regular forms, whether they be clear or opaque.

Crystallized. A mineral which is found in regular forms is said to be crystallized. Rock crystal and sugar candy are crystallized.

Crystalline, consisting or formed of crystals. Regular crystals when broken exhibit a crystalline structure. A confused assemblage of ill-defined crystals is also called crystalline. Statuary marble and loaf-sugar are crystalline.

Culm. See Anthracite.

Cycadeæ, (Greek, *kukas*, a palm,) an order of plants, of which the modern species have mostly short stems, surmounted by a peculiar foliage, called *pinnated fronds.* These pinnated fronds, or "feathered leaves," proceed from the stem in all directions, spreading in a circle, and giving the plant a singular and striking appearance.

Delta, (the Greek letter, Δ delta,) a term applied by geologists to alluvial land, formed at the mouth of a river. See p. 244.

Density, a term of comparison, used to express the variation in weight of bodies of similar dimensions; the standard being water, at the temperature of 60° Fahrenheit.

Denuded. (Latin, *denudo*, to lay bare.) When some of the solid materials of the land are carried away by the action of water, and the *inferior*, or lower rocks, are thus laid bare, the latter are said to be denuded.

DETRITUS, (Latin, *detero*, to wear away,) particles worn off from rocks by currents of water, or other means.

DEVELOPED. (French, *developper*, to clear from a covering.) A general correspondence is observed to prevail in the construction of organic beings; clearly evincing that they are the work of one Mighty Hand, and that one general plan pervades the whole. In the inferior animals, however, it frequently happens that only the rudiments, or first indication, of some parts are met with; whilst, in superior animals, they are brought to perfection. Such parts, in the latter case, are said to be developed.

DEVONIAN SYSTEM, or OLD RED SANDSTONE, one of the more ancient systems included in the Secondary Period. See p. 114.

DIKE, DYKE, (Saxon, *dic;* Erse, *dyk*, a wall, or embankment,) a mass of igneous rock, which has been ejected into a crack or fissure in another rock; and which often not only fills the fissure, but extends beyond it, spreading like a wall, on the surface of the ground.

DIP. When a bed or stratum does not lie horizontally, but is inclined, it is said to *dip* towards some point of the compass.

DISINTEGRATION, (Latin, the negative particle *dis*, from; and *integro*, to make whole,) the act of crumbling to pieces.

DINO-THERIUM, (Greek, *deinos*, formidable; and *therium*, wild beast,) an extinct mammifer. See p. 197.

DISLOCATION, (Latin, the negative particle *dis*, from; and *locus*, place,) a term used in geology to express the displacement of a stratum, or series of strata, when disturbed, or thrown out of the original position after being consolidated; apparently by some earthquake or violent convulsion.

DOLERITE, one of the varieties of the trap-rocks, composed of augite and felspar.

DOLOMITE, (named from the French geologist, Dolomieu,) a crystalline limestone, containing magnesia.

DOLOMITIC. From the above.

DUNES, (Erse, *dune*, a hill,) low hills of blown sand, which have accumulated on the flat shores of Great Britain, France, &c.

DYKE. See Dike.

EARTH. The bodies called earths are composed of oxygen and a metallic base. The principal earths are silica or flint, lime, alumina or clay, magnesia, barytes, glucina, strontia, yttria, and zirconia.

EARTH'S CRUST, such parts of the earth as are accessible to man's observation.

EARTHY, composed of minute parts, resembling dried earth.

ELECTRO-MAGNETISM, the circulation of electrical currents.

ELEMENTARY SUBSTANCES, substances which are supposed to be perfectly unmixed; no chemical analysis having yet been able to detect that they possess a compound nature.

ENALIO-SAURUS, (Greek, *enalios*, marine, and *saurus*, a lizard,) a name applied to extinct fossil reptiles, which were inhabitants of the ocean; such as the ichthyosaurus and plesiosaurus.

ENTROCHI, (Greek, *trochos*, a wheel,) divisions of the stems, or columns of encrinites; commonly called wheel-stones.

EOCENE, (Greek, *eos*, dawn; and *kainos*, recent,) a group or period, belonging to the Tertiary strata.

ESTUARY, (Latin, *æstuo*, to rise and fall reciprocally,) an inlet, forming the mouth of a river, in which the tide rises and falls reciprocally.

EXTINCT. Organic beings, which no longer exist as species on the earth, are called *extinct.*

EXUVIÆ. (Latin, *exuviæ*, cast skins: cast shells; whatever is cast or shed by animals.) This term is applied generally to all animal remains left in the strata of the earth.

FAULT. This term is applied in geology to the sudden interruption of a stratum, or series of strata, by the sinking of one portion, or the upheaving of the other. Faults are usually accompanied by a crack, or fissure, varying in width from a mere line to several feet, which is generally filled with clay, fragments of rock, &c.

FELSPAR, a simple mineral, which, next to quartz, constitutes the principal mineral of rocks. Felspar always contains some alkali in its composition, and is, therefore, liable to be acted on by moisture.

FERRUGINOUS. (Latin, *ferrugineus*, rusty.) Of the colour of rusty iron, or impregnated with iron.

FISSILE. (Latin, *fissilis*, that may be cleft, or split.) A rock is called fissile, when the grain is so arranged that it may be cleft, or split into thin layers.

FISSURE, (Latin, *fissura*, a cleft, a narrow chasm,) cracks or chasms occasionally found in rocks, frequently caused by earthquakes.

FLAGSTONE, the name given to rocks which occur in smooth flags, or thin plates; and which are often used for flag pavements.

FLINT, the earth of which silicium forms the base. Silica.

FLUATE OF LIME, or FLUOR SPA, the mineral commonly known as Derbyshire spa. It is composed of calcium, oxygen, and fluorine.

Foliate, (Latin, *folium*, a leaf,) composed of thin smooth laminæ or leaves, laid over each other.

Formation. This term is applied in geology to groups of rocks formed or accumulated at the same period.

Fossils, (Latin, *fossilis*, that which is dug out of the earth,) the remains of animals and plants dug out of the earth. The term was formerly applied to all minerals, but is now confined to organic remains.

Fossiliferous, containing organic remains.

Freestone, a kind of rock, so constituted that it may be wrought or hewn *freely* in any direction. It is consequently very applicable for building purposes.

Fresh-water Formation. Any bed or stratum, containing organic remains, the productions or inhabitants of land, of rivers, or of lakes, and not of the ocean, is called a fresh-water formation.

Fucus, (pl. *fuci*,) a kind of sea-weed. The bladder-wort, so common on our shores, forms a well-known example of a modern fucus.

Gault, or Gorlt, a provincial name for a series of beds of clay and marl, included in the cretaceous group.

Genus, (Latin, *genus*—pl. *genera*—a kind, or family,) a term used for a subdivision in natural history; often comprehending various species.

Geology, (Greek, *gea*, the earth; and *logos*, a discourse,) a description of the structure of the earth.

Glance Coal, (German, *glanz*, lustre,) anthracite: so called from the shining appearance it presents.

Gneiss, a primary stratified rock, composed of nearly the same materials as granite, but having a laminated structure.

Grallæ, (Latin, *grallæ*, stilts,) an order of birds, having long legs, and adapted by their construction for inhabiting swamps and marshy places.

GRANITE, (Latin, *granum*, a grain,) an igneous or unstratified rock. The name is derived from its coarse granular structure. For a description of this rock, see p. 84.

GRAPHITE, (Greek, *grapho*, to write,) black-lead, or plumbago; so named from its useful application for writing or drawing.

GRAUWACKE, or GREYWACKE, a species of rock, occurring in the older stratified formations.

GREENSAND. Beds of sand, sandstone, and limestone, included in the cretaceous group; and so named because they frequently, though by no means invariably, contain an abundance of green earth.

GREENSTONE, a variety of trap-rock, composed of felspar and hornblende.

GREYWACKE. See Grauwacke.

GRIT, coarse-grained sandstone.

GYPSUM, a mineral composed of lime and sulphuric acid, and hence called sulphate of lime. Alabaster is a variety of gypsum. Plaster of Paris and stucco are obtained by exposing gypsum to a strong heat.

HERBIVOROUS, (Latin, *herba*, a herb; and *voro*, to feed on, to devour,) feeding on herbaceous plants.

HORNBLENDE, a simple mineral, of a dark-green or black colour, which enters largely into the composition of several varieties of the trap-rocks.

HUMUS. (Latin, *humus*, ground, earth.) Humus is the result of the slow decomposition, or decay, of organic matter in the earth, and varies in its qualities and composition according to the substances from which it has been formed, and the circumstances attending their decay. Humus is the product of organic matter, and also the source from whence it derives its supplies of nourishment; for without humus nothing organic can exist. This substance increases in proportion as men, animals, and plants increase on the earth. We may, therefore, conclude that the earth in the early geological eras, was comparatively deficient in this important material, which gradually accumulated through the untold ages which elapsed antecedent to the Recent period: thus preparing the earth for man's reception, and rendering it more and more adapted to nourish organic beings, until at length, by the abundance of humus, it became fitted for the sustenance of the present inhabitants of its surface. Humus is found in the greatest abundance in rich garden mould.

HYLÆO-SAURUS, (Greek, *ule*, a wood; and *saurus*, a lizard,) a gigantic extinct saurian. See p. 163.

ICHTHYO-DORU-LITE, (Greek, *ichthus*, a fish; *doros*, a hollow bag; and *lithos*, a stone,) teeth of an extinct fish; so named from their peculiar form.

ICHTHYO-LITE, (Greek, *ichthus*, a fish; and *lithos*, a stone,) the fossil remains of a fish.

ICHTHYO-SAURUS, (Greek, *ichthus*, a fish; and *saurus*, a lizard,) a gigantic fossil reptile. See p. 149.

IGNEOUS ROCKS. (Latin, *ignis*, fire.) All rocks known or considered to have been fused, or melted, by volcanic or other intense heat, in the interior of the earth. Such are granite, trap-rocks, and lava.

IGUAN-ODON, (*iguana*, the name of a modern animal of the lizard tribe; and Greek, *odous*—accusative *odonta*—a tooth,) an extinct reptile of gigantic size. See p. 163.

INDUCTION, (Latin, *in*, to; and *duco*, to lead,) the process of leading to, or collecting general truths, from the examination of particular facts.

Infusoria, (Latin, *infusio*, an infusion,) minute animals found in most infusions, whence the name; though the term is applied to all similar animalculæ, whether found in infusions, in stagnant water, &c., or in a fossil state in the ancient strata of the earth.

Kaolin, the Chinese name for porcelain earth.

Lacustrine. (Latin, *lacus*, a lake.) Formations which have accumulated in ancient lakes are called lacustrine.

Laminæ, (Latin, *lamina*, a plate,) a term used to express the thin layers, or plates, into which some species of rocks are capable of being divided: they are then said to have a laminated structure.

Laminated. See Laminæ.

Landslip, a portion of land that has slid down in consequence of an earthquake, or from being undermined by water.

Lapilli, (Latin, *lapillus*, a little stone,) small volcanic cinders.

Lava, the stone ejected in a melted state from a volcano.

Leucite, (Greek, *leucus*, white,) a simple mineral, found in volcanic rocks, crystallized, and of a white colour.

Lias, a provincial name which has been generally adopted for a bluish clayey limestone.

Libellulæ, dragon-flies.

Lignite, (Latin, *lignum*, wood,) wood converted into an imperfect kind of coal.

Lithographic Slate, (Greek, *lithos*, a stone; and *grapho*, to write,) a slaty compact limestone, used in lithography.

Lithological, (Greek, *lithos*, a stone; and *logos*, a discourse,) a term used to express the stony, or mineral structure of a mass or stratum.

LITH-ORNIS. (Greek, *lithos*, a stone; and *ornis*, a bird,) an extinct species of bird. See p. 186.

LOAM, a mixture of sand and clay.

LODE, (Saxon, *lædan*, to lead,) the leading vein in a mine.

LOPHI-ODON, (Greek, *lophis*, crest; and *odous*—accusative *odonta*—tooth,) an extinct quadruped; so named from eminences on the tooth.

LINE, one-tenth of an inch.

MACRAUCHENIA, (Greek, *makros*, long; and *auchen*, neck,) an extinct animal, resembling the llama.

MADREPORE, a genus of corals. The term is, however, generally applied to all corals with star-shaped cavities.

MAGNESIA, one of the earths.

MAGNESIAN LIMESTONE, an extensive group belonging to the Secondary Period. = Dolomite [illegible]

MAMMALIA, animals which give suck to their young. To this class belong all the warm-blooded quadrupeds, and the cetacea.

MAMMIFERS, MAMMIFEROUS ANIMALS, animals belonging to the class mammalia.

MAMMOTH, an extinct species of elephant. See p. 221.

MARINE PRODUCTIONS, animals and plants inhabiting the ocean. Marine deposits are such as are deposited by the sea.

MARL. (Welsh, *marl;* Latin, *marga*, marl. In Saxon, *merg* is marrow, which is supposed to be an allusive signification; marl being considered the fatness of the earth.) Marl is a fat mixture of clay and lime: it is usually soft; but when found hardened into a rock, it is called *indurated marl*.

MARSUPIAL ANIMALS, (Latin, *marsupium*, a purse or bag,) a tribe of quadrupeds, having a sack or pouch, in which they carry their young. The kangaroo is a well-known example.

MASTODON, a genus of extinct quadrupeds allied to the elephant. See p. 218.

MEGALO-CHELYS, (Greek, *megas—megalé*, great; and *chelus*, a tortoise,) the name given to a large fossil tortoise.

MEGAL-ONYX, (Greek, *megas—megalé*, great; and *onux*, a claw,) a fossil gigantic sloth.

MEGALO-SAURUS, (Greek, *megas—megalé*, great; and *saurus*, a lizard,) a fossil gigantic amphibious reptile. See p. 154.

MEGA-THERIUM, (Greek, *megas*, great; and *therion*, wild beast,) a fossil mammiferous quadruped, resembling a sloth. See p. 198.

METAMORPHIC. (Greek, *metamorpho-o*, to transform.) Rocks originally formed by deposits in water, and subsequently altered, or metamorphosed by volcanic or other igneous action, are called metamorphic rocks.

MICA, (Latin, *mico*, to shine,) a simple mineral, having a shining silvery appearance, and capable of being split into very thin laminæ. The brilliant particles in granite are mica.

MICA SLATE, slate containing much mica, mixed with quartz.

MINERALIZED, converted into a mineral substance.

MIOCENE, (Greek, *meion*, minor; and *kainos*, recent,) the second division of the Tertiary period.

MOLLUSCA, MOLLUSCOUS ANIMALS, (Latin, *mollis*, soft,) animals devoid of a bony skeleton, and with soft bodies. See p. 107.

MOSO-SAURUS, (Latin, *Mosa*, the river Meuse; and Greek, *saurus*, a lizard,) an extinct reptile; so named because the remains were first found near Mæstricht, on the river Meuse.

Mountain Limestone, a series of strata which in some parts alternate with the coal measures.

Muriate of Soda, common salt; so called because it is composed of muriatic acid and soda.

Muschel-kalk, (German, *muschel*, shell; and *kalk*, lime,) a limestone belonging to the new red sandstone group.

New Red Sandstone, Variegated Sandstone, or Poikilitic, an extensive series of rocks belonging to the Secondary period. The predominant colour of the strata is brick *red*, but some portions are met with of a greenish or gray tint. These usually occur in spots and stripes, giving a *variegated* appearance to the rocks.

Nodule, (Latin, *nodus*, a knot,) a rounded little mass or lump of rock, more or less regular in its form.

Nucleus, (Latin, *nucleus*, a kernel,) any solid substance, round which other matter accumulates on every side.

Nummulite, (Latin, *nummus*, a piece of money; and Greek, *lithos*, a stone,) an extinct genus of molluscous animals, of remarkably flat shape, resembling a coin. The shell is internally divided into chambers or compartments.

Obsidian, a volcanic product.

Old Red Sandstone. See Devonian.

Olivine, an olive-coloured simple mineral, found in basalt and lava.

Omnivorous, (Latin, *omnis*, all; and *voro*, to devour,) eating all things, animal or vegetable: not particular in the choice of food.

Oolite, (Greek, *o-on*, an egg; and *lithos*, a stone,) a peculiar sort of limestone; so named because it is composed of rounded particles, like the roe of a fish. The name oolite or oolitic, has been adopted for a large group of strata belonging to the Secondary period.

OPAL, a simple mineral, presenting a changeable appearance not unlike mother-of-pearl.

ORGANIC REMAINS, (Greek, *organon*, an instrument,) the remains of animals and plants; they are so called because they are of *organic structure;* that is, consist of various parts or instruments, co-operating with each other, admirably adapted for the offices they are destined to fulfil; and evidently the work of a most wise, powerful, and beneficent Being.

ORNITH-ICHNITES, (Greek, *ornis*, a bird—*ornithos*, of a bird; and *ichnos*, a track,) a name applied to the fossil impressions of birds' feet.

ORNITHOLITE, (Greek, *ornis*, a bird; and *lithos*, a stone,) the fossil remains of a bird.

ORTHO-CERATITES, (Greek, *orthos*, straight; and *keras*, a horn,) an extinct genus of molluscous animals, which inhabited a long chambered conical shell, resembling a straight horn.

OSSEOUS, (Latin, *osseus*, bony,) formed of bones.

OSSEOUS BRECCIA, a cemented mass of fragments of bones.

OUT CROP. See Crop Out.

OXIDE, the combination of a metal with oxygen. Rust is oxide of iron.

OXYGEN, a constituent part of atmospheric or common air, essential to animal existence. It enters readily into combination with a great variety of substances. See p. 70.

PACHY-DERMATA, (Greek, *pachus*, thick; and *derma*, skin,) an order of quadrupeds, including the elephant, horse, &c.; distinguished by having thick skins.

PALÆ-ONTO-LOGY, (Greek, *palaios*, ancient; *onta*, beings; and *logos*, discourse,) the science which treats of fossil remains, both animal and vegetable.

PALÆ-OPHIS, (Greek, *palaios*, ancient; and *ophis*, serpent,) an extinct serpent: the most ancient hitherto discovered. See p. 186.

PALÆO-SAURUS, (Greek, *palaios*, ancient; and *saurus*, a lizard,) an extinct reptile; one of the most ancient of the saurian tribe.

PALÆO-THERIUM, or PALÆO-THERE, (Greek, *palaios*, ancient; and *therium*, wild beast,) an extinct mammiferous quadruped. See p. 188.

PEAT, consolidated vegetable matter. See p. 237.

PENTA-CRINITE, (Greek, *penta*, five; and *krinon*, a lily,) a crinoidean, so named from the pentagonal, or star-shaped form of the plates, (commonly called bones,) of the stem or column.

PERMEATE, (Latin, *permeo*, to pass through.) Water is said to permeate a rock when it passes through the minute interstices occurring between the particles of which it is composed. Sandstone and limestone rocks are *permeable;* clay is *impermeable;* as are also igneous and metamorphic rocks generally.

PETRIFACTIONS, PETRIFY, (Latin, *petra*, a stone; *fio*, to make,) substances converted into stone; to convert into stone. These terms are nearly exploded, having given place to those of *fossil*, and *fossilize*, or *mineralize*.

PHONOLITE, (Greek, *phonos*, sound; and *lithos*, a stone;) another name for clinkstone, and so called because it is sonorous when struck with a hammer.

PHYSICAL GEOGRAPHY, (Greek, *phusis*, nature; *gea*, the earth; and *grapho*, to write,) a description of the natural productions of the earth.

PITCHSTONE, one of the trap rocks; so called from its resemblance to indurated pitch.

PLASTIC CLAY, (Greek, *plasso*, to form or mould,) the lowest bed of the Eocene period, so called because it is used in making pottery.

PLESIO-SAURUS, (Greek, *plesios*, near to; and *saurus*, a lizard,) an extinct reptile. See p. 149.

PLIOCENE, (Greek, *pleion*, greater; and *kainos*, recent;) the latest division of the Tertiary period.

PLUMBAGO, (Latin, *plumbum*, lead,) black-lead, or graphite.

PLUTONIC-ROCKS, granite, porphyry, and other rocks, supposed to have been consolidated from a fused or melted state, at a great depth below the surface.

POIKILITIC, (Greek, *poikilos*, variegated,) a name given to the new red sandstone group, which see.

PORPHYRY, (Greek, *porphura*, purple, red,) an igneous rock. The term was first given to a red rock, with small white angular pieces of crystallized felspar scattered through it.

POTASSIUM, a metal which forms the base of potassa or potash.

PRIMARY PERIOD, an extensive series of beds, comprehending the most ancient stratified rocks, and distinguished by the absence of fossils, and a highly indurated texture.

PRODUCTA, an extinct genus of bivalve shells, found only in the older secondary rocks.

PTERO-DACTYLE, (Greek, *pteron*, a wing; and *daktulos*, a finger,) an extinct animal of the saurian tribe, but furnished with *wings*, resembling those of bats, attached to the *fingers* of the fore-leg, or arm.

PUDDING-STONE. See Conglomerate.

PUMICE, a light lava, with a texture resembling sponge.

It may be considered as obsidian in a frothy state, and appears to be produced by the violent ebullition, or boiling up, caused by water confined in or having access to obsidian whilst in a state of fusion.

PYRITES, (Greek, *pur*, fire,) *iron* pyrites (which mineral is usually intended when we meet with the term pyrites) consists of a compound of sulphur and iron. Iron pyrites frequently occurs in nodules, or masses of various sizes and forms, presenting externally a dull, ferruginous colour, but when split, exhibiting internally a shining appearance and crystallized structure. These nodules are commonly called thunder-stones. The name pyrites is said to have been given, because, under particular circumstances, this mineral produces spontaneous heat, and even ignition, or fire.

QUADRUMANA, (Latin, *quadrus*, four-square; and *manus*, a hand;) the order of mammiferous animals, to which the monkey tribe belong. This name has been given because, in the animals which compose this order, the extremities both of the hind and fore leg have the character of *hands*.

QUARTZ, a German provincial term, universally adopted in scientific language for a simple mineral, composed of pure silex.

RADIATA, (Latin, *radius*, a ray,) one of the principal divisions of the animal kingdom. See p. 108.

REPRESENTATIVE, a modern representative of an extinct species is one that stands in its place in the organic world. Thus, crocodiles, monitors, iguanas, and lizards, are the modern representatives of the gigantic saurians, which, during a considerable portion of the Secondary Period, were in such great abundance. The modern species are small, compared with those of the ancient world, but they possess many characteristics in common with them.

ROCK-SALT, common culinary salt, or muriate of soda; it is found in vast masses, or beds, especially in the new red sandstone formation. It used formerly to be called fossil salt.

RODENTIA, (Latin, *rodo*, to gnaw,) animals, such as the rabbit, dormouse, &c., which subsist by gnawing roots and other substances.

RUMINANTIA, (Latin, *rumino*, to chew the cud,) animals, such as the ox, deer, &c., which ruminate, or chew the cud.

SANDSTONE, any stone that is composed of an agglutination of grains of sand.

SAURIAN, (Greek, *saurus*, a lizard,) any animal belonging to the lizard or crocodile tribes.

SCHIST, (Greek, *schistos*, capable of being split,) a kind of rock much resembling slate in appearance, but differing from it in structure, for slate may be split into an indefinite number of *parallel* laminæ, or plates, but in schist these laminæ, or layers, are *uneven*. Mica schist and gneiss have a *schistose* structure.

SCORIÆ, (Latin, *scoria*, refuse, cinders,) volcanic cinders.

SEAMS, thin layers of any mineral substance separating two strata of greater magnitude. The term is apparently borrowed from sea-faring language, the junctures of the planks of a ship being called seams, which, when filled with pitch, bear considerable resemblance to seams of coal, to which the term is more especially applied.

SECONDARY PERIOD, a vast series of the stratified rocks, which compose the crust of the earth, distinguished from the Primary Period by containing organic remains, and from the Tertiary Period by containing none that belong to recent species.

SELENITE, a simple mineral; crystallized gypsum.

SEPTARIA, (Latin, *septum*, an enclosure,) flattened balls, or nodules of stone, generally a kind of ironstone, which, on being split, are found to be partially hollow, and separated in their interior into irregular masses. Fossils are sometimes found enclosed in the interior.

SERPENTINE, a rock of a green colour, and containing much magnesian earth. It is usually classed among igneous rocks, though it is said sometimes to present the appearance of being a metamorphic or altered stratified rock. It frequently displays changing colours like the skin of a serpent, whence its name.

SHALE, (German, *schalen*, to peel, to split,) an indurated slaty clay or sandstone, so named from its capability of being split into excessively thin layers.

SILEX, (Latin, *silex*, flint,) one of the pure earths.

SILICA, the same as silex.

SILICEOUS, (Latin, *silex*, flint,) of or belonging to silex or flint. A siliceous rock is one chiefly composed of silex.

SILT, sand, clay, and other matter, transported by running water. It is often accumulated in banks or heaps by the action of currents, and thus the mouths of rivers sometimes become *silted up*, and the entrance into the sea impeded, so that the river's course is changed.

SILURIAN, (Latin, *Silures*, a people formerly inhabiting South Wales,) the name of an extensive series of strata, included in the transition or older Secondary Period.

SIMPLE MINERALS, unmingled mineral substances. They are called simple to distinguish them from compound minerals, which consist of two or more simple minerals more or less closely united together: thus, felspar, quartz, and mica, are simple minerals; but the granite which is composed of these three minerals is compound.

SLATE, (from *slit*, to cut lengthways,) a rock capable of being cleaved or split lengthways into an indefinite number of thin laminæ, or plates, parallel to each other.

SODIUM, a metal, the base of soda.

SPECIES, (Latin, *species*, sort, kind,) a term used to express a kind or sort of animal, vegetable, or mineral, distinguished from all others by certain peculiarities.

SPHEROID. (Latin, *sphæra*, a globe.) Those bodies are termed spheroids whose form approaches that of a sphere.

STALACTITES, (Greek, *stalazo*, to drop,) deposits formed by water holding lime in solution, and suspended from the roof of a cavern. See p. 209.

STALAGMITE. (Greek, *stalagmos*, a drop.) When water holding lime in solution hangs from the roof of a cavern, drops of this water fall to the ground, and the water evaporating leaves a deposit or crust; this is called stalagmite, on account of its having been formed by the *drops* which have fallen. See p. 209.

STRATIFIED. (Latin, *struo*, to strew.) Rocks formed by successive deposits, which have apparently been strewed in layers, usually by the agency of water, are said to be stratified.

TRATUM, plural STRATA, (Latin, *struo*, to strew,) a bed or mass of matter strewed or deposited over a certain extent of surface, usually by the action of water, and often consolidated into rock of greater or less hardness. Lowestoff Ness may afford an example of the formation of a stratum. See p. 262.

STONE COAL. See Anthracite.

SUB-APPENNINES, low hills which skirt the foot of the great chain of the Appennines, in Italy.

SUBLIMATION, a chemical operation, which raises bodies by the action of heat.

SUCCIN, (Latin, *succinum*, amber,) a term sometimes applied to the transparent varieties of amber.

SUPER-INCUMBENT, (Latin, *super*, upon; and *incumbo*, to rest;) super-incumbent rocks are such as are situated above, or *rest upon*, lower strata.

TALUS, (a term borrowed from the language of fortification; some walls are built flat within, but with a gradual slope outwards, to give them greater strength, this sloping masonry is called *a talus*.) In geology this term is applied to the sloping heap which often accumulates at the foot of a steep cliff, or rock, and which is formed by the slow but continual crumbling away of small particles from the face of the rock, by the action of the weather.

TERTIARY PERIOD, an extensive series of rocks, distinguished from the more ancient periods by containing some *species* of recent or existing animals.

TESTACEA, (Latin, *testa*, a shell-fish,) molluscous animals, having a shelly covering.

THYLACO-THERIUM, (Greek, *thulakos*, a pouch; and *therion*, a wild beast;) an animal resembling the modern opossum.

TRACHYTE, (Greek, *trachus*, rough,) a variety of trap rock, sometimes much resembling porphyry in its structure; it has a peculiar rough feel, whence the name.

TRANSITION, a term applied to an extensive series of rocks, properly classed among the Secondary Strata, because they contain organic remains; from the resemblance, however, of their structure to the rocks of the Primary Period, they appear to hold a sort of intermediate position, and to form a passage or *transition* from the one class of rocks to the other, whence their name.

TRAP, (Swedish, *trappa*, a flight of stairs,) igneous rocks, which appear to have cooled and become consolidated under the pressure of deep water; they are composed of felspar, augite, and hornblende; the varieties of trap-rocks arise from the different proportions of these simple minerals, and the manner of their aggregation, or being united together.

TUFA, TUFF. (Italian, *tuffare*, to immerse under water.) *Calc-tuff*, or *calcareous tufa*, is a porous rock, formed by deposits from springs holding lime in solution, commonly called petrifying springs. *Volcanic tufa*, or *tuff* is a porous rock, of an earthy texture, composed of scoriæ, and other loose matter, ejected from a volcano, and cemented together by means of water.

UNSTRATIFIED. Unstratified rocks, or igneous rocks, are such as appear to have been formed by the fusion of the mass of which they are composed, and not (like the stratified rocks) to have been deposited in layers.

UPHEAVE, a term applied in geology to the raising of any stratum, or group of strata, from the position originally occupied.

VEINS, MINERAL, cracks or fissures in rocks, usually filled with substances differing from the rocks in which they occur. They have regular walls or sides, and sometimes a layer of clay between the wall and the vein. Mineral veins, properly so called, are those filled with sparry or crystallized substances, and containing the metallic ores. They are rarely filled with ore in every part; in this respect differing from dikes, and most other similar formations, in which the whole is generally a uniform mass.

VERTEBRATA, VERTEBRATED ANIMALS, (Latin, *vertebra*, any turning point,) a principal division of the animal kingdom, comprising all animals furnished with a back bone.—See p. 106. This division is so named from the joints of the back bone, which are called *vertebræ*, on account of their peculiar construction, which enables the animal to *turn* in every direction.

VOLCANIC ROCKS, VOLCANIC FORMATIONS, lava, cinders, &c., ejected from volcanos.

WEALDEN, (Saxon, *waldé*, wood,) a group of freshwater strata belonging to the Secondary Period.

ZEOLITE, (Greek, *zeo*, to boil,) a simple mineral, usually found in the trap-rocks. There are several varieties, some of which swell or boil up when exposed to the blow-pipe, whence the name.

ZOIC, (Greek, *zo-on*, an animal,) a term applied to rocks containing fossil remains of animals.

ZOOPHYTE, (Greek, *zo-on*, an animal; and *phyton*, a plant;) animals belonging to the Radiata division, so named because, though in their external structure they resemble plants, they are living animals.

INDEX.

The fossils are distinguished by the letter f.

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