RUSCHENBERGER'S SERIES.

FIRST BOOKS OF NATURAL HISTORY.

ELEMENTS OF GEOLOGY:

PREPARED FOR THE USE OF

SCHOOLS AND COLLEGES,

BY

W. S. W. RUSCHENBERGER, M.D.

SURGEON IN THE U. S. NAVY; FELLOW OF THE COLLEGE OF PHYSICIANS; HON.
MEMBER OF THE PHILADELPHIA MEDICAL SOCIETY; MEMBER OF THE
ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA, ETC., ETC.

FROM THE TEXT OF

MILNE EDWARDS AND ACHILLE COMTÉ,

PROFESSORS OF NATURAL HISTORY IN THE COLLEGES
OF HENRI IV., AND CHARLEMAGNE.

TES.

PHILADELPHIA:
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NO. 9 NORTH FOURTH STREET.
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OF HENRI IV., AND CHARLEMAGNE.

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PREFACE.

The eighth in the series of "First Books of Natural History," comprises the Elements of Geology.

The volume has been compiled chiefly from the work of F. S. Beudant, and that of Milne Edwards, and Achille Comte. The works of other writers have been consulted, and freely used; amongst them, Ansted, Lyell, Mantel, Murchison, Trimmer, Buckland, Bakewell, De la Beche, Lea, Parkinson, Phillips, Dana, Percival, Charles T. Jackson, Henry D. Rogers, Morton, Conrad, &c., &c.

The numerous illustrations, to the execution of which we particularly invite attention, were engraved by Mr. G. Thomas, of Philadelphia. We believe better wood-cuts have never been engraved in the United States for any work of the kind, and as a sample of the art, they are creditable to our country.

The explanations and etymologies of technical words are given as they occur, either in the text, or in foot-notes; and in many, if not in all cases, the pronunciation of these words has been indicated by accents. An ample glossary, which will be found sufficiently copious for the general reader, is also appended. When it occurs, the Greek *omega* has been marked thus (*ô*), and italics have been substituted for Greek characters, because, it is presumed, many who may use this volume are unacquainted with the dead languages.

It is believed this small volume contains all that is requisite for acquiring a knowledge of the Elements of Geology, except the desire and consequent labour of the student, essential elements in the acquisition of knowledge of every kind. Without labour, knowledge cannot be obtained; to reach the goal, the road must be travelled, no matter how smooth and easy it may be made; there is no royal path to learning. When the student is master of the information contained in this book, he will be fully prepared for reading, advantageously, voluminous treatises, and the various geological reports and papers almost daily issuing from the press.

All knowledge is necessarily communicated from one person to another, through the medium of words, or signs. When branches, or parts of knowledge, or ideas, become familiar and common, the words representing them cease to be difficult. Then the complaint about "hard words" ceases. Few persons acquainted with the instruments, complain that the words *Thermometer*, or *Barometer*, are "hard;" the first is familiar to all, even to those ignorant of its construction and numerous practical uses. The names *Quadrant* and *Sextant* are not "hard words" to the most unlettered seaman, and we may remark, in passing, that the science of navigation would not be rendered of more easy acquisition, if those instruments were designated by the more familiar names of Bob and Bill. The votary of music does not find the numerous terms, such as *clef*, *minim*, *semibreve*, *crotchet*, or *sonata*, *overture*, *aria*, or *pianissimo*, *crescendo*, *forte*, &c., obstacles in acquiring a knowledge of the science. The same is true of all human sciences. Each has its technicalities and significant names, which cannot be changed without injury, or taken away without increasing the difficulties of acquiring knowledge.

The names and terms employed in Natural History are very numerous, but most of them are very significant and appropriate. It is true, some are of doubtful or remote meaning, and might have been better. The fashion of naming natural objects after distinguished individuals, might be safely abandoned. All who are so fortunate as to discover a new genus, or species, should carefully select a name for it significant of some prominent quality or attribute, so that the generic and specific names would be together descriptive, as far as possible, of the object.

Hard names are no real obstacles to the acquisition of science, and no benefit would arise by departing from systematic nomenclature in elementary works. One great object of such works, is to explain the meaning of the names and terms employed. Nursery, or "baby talk," does not facilitate a child in learning to speak, or in acquiring ideas; nor would the study of geology be facilitated by analogous language. Probably Natural History has been made less interesting in our country, and has been less beneficially studied, in consequence of attempts to employ old words, already appropriated to well-known things, to designate new objects.

The writer trusts the above remarks will be sufficient to meet the objections of all those who cavil about "hard words."

Besides being in itself very interesting, forming as it were the blossom and bloom of Natural History, a knowledge of zo'ology and botany being necessary to the study and recognition of animals and plants in the fossil state, Geology is practically useful in a high degree. To agriculture, and many of the mechanic arts, it is of great advantage, and it is not totally useless to any avocation or pursuit. A competent knowledge of Geology better enables the architect to select materials for buildings, as well as sites for their erection; the engineer learns from it where he may run a railroad or canal with the greatest facility, and least cost; the miner is guided in the pursuit of mineral wealth, metals, or coal, with greater certainty of success when assisted by this noble science, which is more unerring than witch-hazel or diving rod; it facilitates the physician in the study of climate, and opens a wide field to the divine for pointing out the wonders of the creation, and the goodness of God.

Before its natural history was explored, at a cost of more than two hundred thousand dollars, voted by the Legislature, vast sums of money were spent in vainly hunting for coal-mines in the state of New York. But after the geological surveyors reported that no coal could ever be discovered in the districts they had examined (because the several formations constituting the surface of these districts were those which are naturally *below* the coal-bearing series), these wasteful speculations were abandoned, although persons unacquainted with Geology complained that, "not satisfied with their inability to find coal themselves, the surveyors had decided that no one else would ever be able to detect any, having had the presumption to pass sentence of future sterility on the whole land." But time will show there was no presumption or guess, but the sentence of the geologists was a positive deduction from their science — a deduction that has saved thousands of dollars to individuals, who would still seek for coal where it does not exist, were it not for a knowledge of Geology.

In order to study Geology with greater facility and success, schools should be supplied with drawings, representing the principal facts in the science. Also, with some living shells, marine, fluviatile, and terrestrial; specimens of coral, turf, and volcanic products, all distinctly labelled; these, after being pointed out, should be left accessible to the pupils.

To teach them the composition of the crust of the earth, there should be drawings of the different stratifications, and collections of fossils characteristic of the several formations, all distinctly labelled. Where fossils cannot be obtained, casts representing them will serve a good purpose. Specimens of the various crystalline and sedimentary rocks should form a part of the teacher's apparatus.

To illustrate the various effects attributable to igneous and aqueous causes, there should be some well-selected specimens, distinctly labelled, of fossil-shells, encri'nites, of echini'deæ, of madrepores, &c., in order to compare them with those now existing. Drawings on a large scale, of faults and crevices, of dykes and injected rocks, of basa'ltic bosses and of erosions attributable to water, should also belong to the school. During and after the lesson referring to a particular part of the subject, these specimens and drawings should be exhibited and explained to the pupils.

U. S. Naval Hospital,
New York, October 16th, 1845.

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ELEMENTS OF GEOLOGY.

LESSON I.

GEOLOGY DEFINED.—*Form of the Earth — its Surface—Internal Heat — Mineralogy defined — Definition of the term Rock — Formations—Strata—The Origin of Strata—Vegetable Earth —Alluvium—Division of the Formations—Plutonic Formations—Neptunian or stratified Rocks—Order of Strata—Temple of Jupiter Serapis—Subsidence and Elevation of Coasts.*

1. GEO'LOGY (from the Greek, *ge*, the earth, and *logos*, discourse), or *science of the earth*, is that branch of Natural History which treats of the physical constitution of our globe.

2. The earth, as is generally known, is in form of a ball, or *spheroid*, slightly flattened at the poles, floating freely in space. Its diameter is about 8000 miles, and its surface is irregular; here it is studded with long chains of mountains, there hollowed by deep depressions; but these inequalities, however gigantic they may appear, when compared with objects surrounding us, are in reality very trifling, in comparison with the mass of the globe; they are proportionally much less than those we see on the skin of the smoothest orange, and if represented on a ball three feet in diameter, the highest mountains would be still so small as almost to require a microscope to perceive them.

3. The deepest excavations of the surface of the globe are covered by great masses of water which conceal them and prevent their examination; but there is reason to believe that the most profound depressions do not much exceed three miles in depth, below the surface of the sea, and we know by exact measurement that the summit of the loftiest mountains is not six miles above the same level.

Mont Blanc, the highest mountain in Europe, is 15,748 feet; Mont Perdu, of the Pyrenees, is 11,168 feet; Peak of Teneriffe, 12,172 feet; in South America, in the Cordillera of the Andes, there are still higher mountains;

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1. What is Geology?

2. What is the form of the earth? What is its size? What is the character of its surface?

3. What is the greatest depth of the sea? What is the greatest height of land above the level of the sea?

Chimborazo, 21,440; Illimani, 24,450 feet; and Sorota, 25,000. The highest mountain in the world is in Asia, the Himalaya, which rises 26,862 feet above the level of the sea.

4. The surface of the earth has not always possessed the same configuration that it now presents; it has been frequently upturned, and there is even reason to believe that the entire globe was a liquid mass, melted by heat, and that it gradually became solid as it cooled.

5. Except at comparatively shallow depths, we cannot examine the nature of the materials constituting our globe, not even by descending into mines, excavated for the purpose of extracting the wealth they contain; for the deepest of these excavations do not exceed 500 yards. But by calculations, it has been inferred that the centre of the earth cannot be occupied, either by water, or by vapour, but by matter as heavy as our heaviest metals, and so hot that it is probably in a state of constant fusion.

6. A great number of facts concur in proving that the earth possesses an internal heat (the remnant of its *original heat*), independent of that which it receives from the sun. Its temperature increases in proportion as we descend to considerable depths; there are some very deep mines in which the workmen can only labour when naked, and wherever the water of a spring rises from a great depth, its temperature is always very high. This increase of temperature has even been measured, and it has been ascertained that the heat of the earth increases about two degrees, Farenheit, for every 70 to 100 feet. In very deep cellars, where the influence of the seasons is not felt, and where the temperature is always the same, the thermometer, at Paris, stands at about 51 degrees, and at a depth of 200 feet below these cellars the heat is about 55 degrees; at a league below the surface, the temperature must be above that of boiling water, and at a depth of less than two leagues, it must be sufficient to melt tin.

7. It appears to be demonstrated, that the globe, at some remote period, was in a state of incandescence, or liquefaction from heat, and that it cooled by degrees; but we must not conclude that this cooling process has continued to the present time, and is still going forward; it has almost, if not entirely, ceased. From the earliest records of history, to the present moment, the temperature of the

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4. Has the surface of the earth always been the same in form and shape as it now is? Is it supposed that the globe has always been in its present condition?

5. What occupies the centre of the earth?

6. Is the temperature of the earth the same at its centre as it is on the surface? What reasons lead us to the conclusion that the earth possesses an internal heat?

7. Is it supposed that the earth is becoming cooler and cooler every day? How is the earth enabled to preserve its temperature?

globe has not sensibly changed, and by the calculations of the learned, it is proved that the surface of the earth receives from the sun during a year a quantity of heat equivalent to that which it loses in the same space of time; the internal heat of the earth no longer influences the temperature of its surface, except in an insensible degree, and to diminish this influence, which is almost none at all, one-half, would require the lapse of 30,000 years.

8. Our knowledge of the central portion of the globe is limited to what we have just said of its weight and temperature; but the solid crust, constituting its surface, has been better studied.

9. This crust is not formed of a single piece, but is composed of a great number of various materials. The study of these various substances, particularly, belongs to *Mineralogy;* the study of their mutual relations and the more or less important part they play in the constitution of the globe, is the province of *Geology.*

10. In general we give the name of *rocks* to mineral substances, which are united in great masses, and apply the term *formations,* to diverse assemblages of rocks which appear to have been formed under the same circumstances.

The word *rock*, as used by geologists, is applicable to all mineral masses, whether hard or soft, and therefore includes in its meaning, sand, marble, clay, granite, &c.

11. When we examine the sides of mountains, artificial excavations, and various other localities favourable to geological studies, we very soon perceive there are a great many different formations, and these formations are in layers or stories reposing one above the other, constituting *strata:* (plural of *stratum*, a Latin word, meaning a bed, couch, or layer; anything spread out or strewed over a surface.)

12. We can be convinced of this by examining the cuts made through hills for the passage of rail-roads and canals in various parts of the United States. By comparing the different materials composing the earth's crust, the geologist will soon be satisfied that these different rocks, in a majority of instances, are not placed one alongside the other, but cover each other, and form a series of layers, of more or less thickness, comparable to the courses or layers in a mass or wall of mason-work. Gypsum, or plaster of paris, for example, rests upon a stratum of coarse limestone, for, in digging wells in the neighbourhood of Paris, at different points, the coarse limestone is always found below the plaster. This

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8. What do we know relative to the centre of the earth?

9. What is the crust of the earth? Does it consist of one piece? What is mineralogy?

10. What are rocks? What are formations?

11. What is meant by stratum?

12. How are rocks placed relatively to each other?

coarse limestone in its turn covers a stratum of plastic clay; in many places where the coarse limestone is not very thick, it has been pierced through, and the plastic clay found beneath it.

13. But it is not necessary to dig wells in order to be certain of the superposition of the different layers formed by these rocks; it is distinctly seen by examination of the declivities of certain hills, or cuts made through them for the passage of roads, &c.; for, when the point of contact of two layers is exposed at one of these localities, we may frequently distinguish, without difficulty, the manner in which one of these layers is continued beneath the other.

14. In other places nothing similar is seen; the rocks show no trace of stratification, but constitute compact masses, such as granite.

To form an idea of the manner in which nature has produced these immense earthy layers, we must study the phenomena which are now taking place at different places on the surface of the earth.

15. The action of rain, of the sun, of frost, and many other causes are constantly tending to change the surface of rocks, even those which are most compact, and to detach fragments from them; these fragments, more or less divided, are spread out over the surface of the soil, mixed with the *detri'tus** of plants and animals, and constitute a kind of movable bed, more or less thin, which covers the whole surface of the globe, and bears, commonly, the name of *vegetable earth*, because it is in this bed that almost all vegetables grow. The mineral substances which enter into its composition are ordinarily sand, clay, or the *debris*, or remains of calcareous rocks.

16. When currents of water pass over movable formations, such as we have just mentioned, they take up a portion and convey to a distance the detri'tus and debris of which they are composed. In this way, when the heaped-up snows on the tops of mountains melt under the influence of the summer's sun, or when abundant rains fall on the same places, impetuous torrents descend towards the plain, and carry with them earth and fragments of stones found in their route, or which they tear up from their resting-places; the

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* DETRI'TUS.—A geological term applied to deposits composed of various substances which have been comminuted by attrition. The larger fragments are usually termed *debris;* those which are pulverized, as it were, constitute *detri'tus.* Sand is the detri'tus of siliceous rocks.

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13. What evidence have we of the superposition of strata?

14. Are all rocks stratified?

15. What are the common causes which tend to change the surface of rocks? What is detri'tus? What is vegetable earth? What is debris?

16. How do currents of water change the surface of the earth?

result is that the water of these torrents is often turbid, and loaded with mud, sand, flints, or even blocks of stone; but when they reach a flat country, or fall into a large basin, their course is much less rapid, and the foreign materials they held in suspension are gradually deposited; the heaviest sink first, and, at length, these materials line the bottom of the river with an earthy bed, whose thickness is continually increasing.

17. The river Po, which is precipitated from a lofty chain of the Alps, and traverses Lombardy, is a remarkable example of this curious phenomenon. This river, and its principal tributaries, have transported, in this way, so much earthy matter from the mountains to the plain, that, since the Roman era, several large lakes and extensive marshes, situated near Parma, Paisance, Cremona, &c., have been filled up and become dry: the bed of these rivers is also gradually filled up, so that they have several times changed their course, and poured over the neighbouring plains. It has been necessary to restrain them artificially, by building up a long dyke on each bank; this has put an end to these disastrous inundations, but has not prevented the bottom of the river from continuing to rise up; every year it is therefore necessary also to raise up the dykes, so that now these rivers flow in a sort of immense aqueduct, and at certain places the surface of their waters is higher than the roofs of the surrounding houses, as at Ferrara, for example.

18. The river Rhone descends on the northern side of the Alps, and passes the Valais too impetuously to deposit the mud and flints with which it is abundantly freighted; but, when it empties into the lake of Geneva, its course becomes so slow as to be almost imperceptible, and its waters, which were at first turbid and muddy, are limpid and transparent, when they escape from the opposite side of this basin to pass through the town of Geneva: the result is that the Rhone deposits in this basin all the matters which it carried, and gradually raises up its bottom, constituting what is termed *lacustrine* formation. This progressive elevation of the soil is so marked at the eastern extremity of the lake, that an ancient town called Port Valais, formerly situated on its margin, is now found about a half a league from it; about eight centuries have been sufficient for the formation of the great earthy bank which now separates this town from the lake, and the deposite which gave rise to it continues to be made at the bottom of that portion of the lake in its vicinity, and continually tends to raise it up more and more, so that in time it may fill the whole of this basin, and transform the lake into a plain which the Rhone will pass through without spreading itself. In passing through Geneva,

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17. Give an example of change produced by currents.

18. What has been the effect of the Rhone passing through the lake of Geneva? What is meant by lacustrine formation?

this beautiful river, as we have already said, is clear and limpid; but a little beyond the town it receives new tributaries, such as the Arve, which pour into it their muddy waters, and little by little it is again loaded with sand and mud, which it rolls on impetuously to the sea; but at its mouth, its course being slow, these foreign materials, the debris of Mont Blanc, of the Alps, of Dauphiny, and the central regions of France, are in their turn deposited, and gradually elevate the soil they cover; the result is new land which advances more and more on the sea.

19. We give the name of *alluvium* (from the Latin, *alluvio*, an inundation, or *alluo*, I wash) to formations caused in this way by the deposite of materials carried by waters, and as these alluvial formations, when deposited at the mouth of a river, often assume the form of the Greek letter Δ *delta*, we designate the new-made land, which in a manner encroaches on the domain of the sea, under the name of *delta*.

20. The delta of the Rhone, to which we alluded above, and that which is found at the mouth of the Po, are very inconsiderable; but, in certain parts of the globe, several are found of very much greater geological importance. One of the most celebrated is the *Delta of the Nile*, which, according to the calculations of some authors, must have grown nearly half a league since the time of Herodotus; and according to the commonly received opinion, its formation began at the foot of the rocks upon which were built the pyramids of Memphis; but the deltas at the mouth of the Mississippi, and the mouth of the Ganges, increase more rapidly, and possess greater interest for the naturalist.

21. Other formations are also produced, so to speak, under our eyes, by the deposite of materials which the waters of certain springs hold in solution, and throw down when they reach the surface of the earth. In different parts of France, near a spring situated at the north of Clermont Ferrand, for instance, we see examples on a small scale, and in many parts of Italy, enormous masses of calcareous stone, known under the name of *Travertin* (from the Italian, *travertino*), are formed.

22. We often behold issuing from the craters of volcanoes, a burning, semi-liquid matter, which spreads over the surface of the neighbouring country, and, on cooling, is converted into a hard compact rock, called lava. Etna has furnished a great number of irruptions of lava, one of which was six leagues in length, and, in 1783, Hecla, a volcano of Iceland, gave origin to a similar current, which extended twenty leagues in length, and twelve in breadth.

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19. What is alluvium? What is a Delta?
20. Mention some examples of Deltas.
21. What is Travertin?
22. What is lava?

23. These different phenomena partly explain to us the manner in which the production of the different formations disseminated on the surface of the globe, must have been effected, formations whose origin date back from an epoch long anterior to that of the creation of man.

24. In fact, the various formations constituting the common portion of the globe differ, as we have already seen, very widely in their nature, in their constitution, and in their mode of arrangement. Now, these differences remind us of those which exist in the modern formations above mentioned, and seem to indicate that, in the ancient formations, some were produced in the midst of the waters by the deposit of solid materials held in suspension or in solution by this liquid, and others by the action of heat on earthy materials susceptible of being melted, and of being afterwards hardened by cooling.

25. Guided by these considerations, geologists have divided the formations into two great classes; namely, the *sedimentary*, or *stratified formations*, and the *massif* or *igneous formations.* On account of the presumed method of their production, they are also designated under the names of *Aqueous* or *Neptunian formations*, and *Igneous* or *Plutonic formations.*

26. The *plutonic formations* have received this name because they appear to be the product of the action of fire; they are generally of a dense crystalline structure, and ordinarily form very immense masses; they are not arranged in regularly superposed beds, nor do they contain the remains of organized bodies. Some of them are formed, as we see, by the action of volcanoes, and others are very analogous to the latter; they contain not only minerals peculiar to volcanic ejections, but sometimes also matters that are produced by the furnaces of our laboratories and workshops. They seem to have formed the primitive crust of the globe; for we find them beneath the neptunian formations, but they are also sometimes spread over the surface of the latter, or betwixt the different beds or strata of which they are composed.

27. The *aqueous* or *neptunian formations* appear to have been deposited by the waters; in general their texture is coarse or compact, rarely crystalline, and they are often composed of grains of sand separate or agglutinated, of heterogenous fragments, or material having the aspect of a kind of indurated mud; they are also frequently called *stratified formations*, and most of them are also termed SEDIMENTARY FORMATIONS. It is in the midst of these for-

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23. Are the various formations all of the same age?

24. In what manner were the various formations produced?

25. How are the formations divided?

26. What is meant by plutonic formations? How are they produced?

27. How were the aqueous formations produced? What are the characters of aqueous rocks?

mations that we find the remains of the different organized bodies by which the earth has been successively peopled.

28. These stratified formations were not all produced at once, but successively, and under the influence of different circumstances; they constitute, as we have before said, distinct beds or strata, and these strata lie one on top of the other, so that those of a more ancient are found beneath those of a more recent formation. By studying them carefully we shall also perceive that different points on the surface of the earth have been successively, and at intervals, left dry, and covered by the waters of the sea, or by fresh water, the sediment from which constitutes these banks, and we see that these banks themselves differ, not only in the nature and disposition of their constituting elements, but also in the nature of the remains of the organic bodies buried in their substance.

29. We distinguish a great number of these stratified formations, and, as might be anticipated from their mode of production, they are everywhere found in the same order of superposition; the formation which, in one locality, covers another formation, can never be found in another place beneath the latter; it may be entirely wanting, so as to leave the latter uncovered, or in contact with a stratum, which in another place it covered; but wherever it exists, it must be on top of or superior to all formations, the production of which dates back to a more remote epoch.

30. For example, we have stated that in the vicinity of Paris, the gypsum rests upon the coarse limestone, this upon the plastic clay, and this plastic clay upon the chalk; in other localities we may find new strata interposed between these various formations, or we may find one of them entirely wanting; for example, the plastic clay being absent, the coarse limestone would be found resting directly upon the chalk; but this coarse limestone, for the reason alone that it is everywhere found resting upon the chalk, must have been deposited after the chalk was formed, and consequently can never be found below it.

31. It is also evident that when these solid beds are slowly

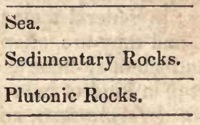

Fig. 1.

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28. Were the stratified formations all produced at the same time? Are all the stratified rocks alike in character?

29. Are the stratified formations always found in the same order of succession? Are all the strata everywhere found?

30. Give an example to show that the strata are always found in the same order of succession.

31. What is the position of sedimentary rocks?

deposited at the bottom of waters, they must have a nearly horizontal position (*fig.* 1), and that they must occupy the steepest parts of the surface upon which they are formed, so that if the surface presents considerable elevations, these may remain uncovered, and show themselves above the level occupied by the new formation (*fig.* 2). Thus when we go from low plains towards mountain chains, and ascend to their summits, we meet, successively, formations more and more ancient as we rise.

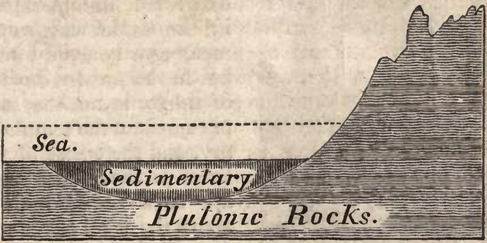

Fig. 2.

32. Sometimes these stratified rocks preserve the horizontal position they had in the beginning; but at other times they become more or less oblique in consequence of their partial depression or sinking, or their unequal elevation. Frequently we see beds which are abruptly raised up, so as to be almost perpendicular; and on the edges of the elevation produced by this overturning of nature, we find other beds which are perfectly horizontal, and we may conclude that the latter were formed subsequently to the elevation of the former; by studying these relations of position we are enabled to determine the geological age of mountains.

33. These great movements of strata sometimes take place suddenly, and are accompanied by earthquakes; but at other times they are effected gradually and without any shock. It appears to be well ascertained that since the time of the Romans, a portion of the coast of Naples sank below the level of the sea, and was subsequently raised up again above this level, without overturning the monuments built on this movable soil. One may be satisfied of this fact by visiting an ancient temple situated near Puzzuoli, called the *Temple of Jupiter Serapis;* this monument, of which three columns remain standing erect, appears to have been built in the third century, and was then very much frequented, on account of its warm baths; but at a subsequent epoch, supposed to be about 1488, the ground sank down, and the temple was covered by the

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32. Do stratified rocks always preserve their original position? What is to be learned by studying the position of strata?

33. How do these great movements of strata take place? Give an instance of the gradual movement of strata.

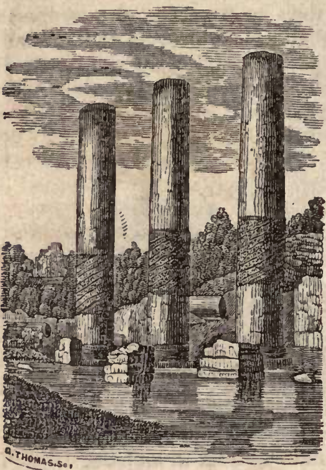

Fig. 3.—Temple of Serapis.

sea to a height of about sixteen feet above the pavement. Marine animals then established themselves on a portion of the submerged columns, and mollusks of the genus Pholas excavated innumerable holes in the same way as they do rocks now covered by the sea; but in the present day the state of things is not the same, the pavement of the temple is again dry, and the traces of the pholades we have just mentioned are at a considerable height above the level of the sea (*fig.* 3). Now, these changes in the relative levels of the coast of Puzzuoli, and the neighbouring sea, cannot be attributed to an alternate sinking and rise of the waters, because movements of this sort must have been accompanied by fearful inundations along the shores of the Mediterranean, and we cannot explain this phenomenon except by supposing that the coast itself, after sinking, was again gradually raised up.

34. At the present time Scandinavia and Chile exhibit an analogous phenomenon. On the coasts of Sweden, for example, we see certain rocks, which were formerly submerged, now above water, and that the steep shore is gradually rising more and more above the level of the sea. For a long time it was observed that the sea abandoned certain parts of the coast, and that the depth of water decreased in several ports of this region; but these changes of level have been ascertained in a more exact manner; more than a century since, marks were made on different rocks on a line with the surface of the water, to serve as points of comparison, and on examining them from year to year, it was found that these marks were successively higher and higher above the level of the sea. In the gulf of Bothnia, this rise appeared to be four feet in a century, but at other places less, and at some points on the coasts of the Baltic, it was nothing, which proves that the change of level does not depend on the subsidence of the sea.

We shall recur to the subject of stratification and the various causes which influence it, after we have studied the characters of the various formations.

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34. What other instances prove the slow movement of strata?

LESSON II.

ORGANIC REMAINS.—*Fossils—How produced.*
FIRST GEOLOGICAL EPOCH.—*Primitive Rocks—Granite—Gneiss—Mica-Schist—Argillaceous-Schist.*
SECOND GEOLOGICAL EPOCH.—*Transition Formation—Cambrian System—Silurian System—Trilobites and other animal remains—Devonian System—Fossil Fishes—Fossils—Limits of the Transition Formation—Strata changed in Position by geological Convulsions.*

1. We find entombed in the different strata of the crust of the globe a great quantity of the remains of organic bodies, which at different epochs have lived on its surface. Those which exist in the present formations, and which have been deposited since the last great revolutions of the earth, generally preserve their primitive composition; but those which have been found in the more ancient strata have been altered in their nature, and passed into the *fossil state;* the gelatinous, fleshy, or ligneous portions, which concurred in their formation, have in part disappeared, and have been more or less replaced by stony particles. By the term *fossil* (formed from the Latin, *fodio*, I dig) is meant any organic body, or the traces of any organic body, whether animal or vegetable, which has been buried in the earth by natural causes.

2. In general, it is the hard parts, those that are capable of long resisting decomposition, which alone undergo this kind of alteration; such as bones, shells, and scales, for example. We never find flesh, nor nails, nor soft fruits, nor other analogous bodies, in a fossil state. Sometimes even these hard bodies disappear, and leave merely traces of their existence in an impression or print in the rock that enveloped them.

3. The organic remains which are found in the most superficial and most recent strata of the crust of the earth, belong in part to species which still exist; but most fossils are derived from animals or plants which have not existed since a period anterior to

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1. In what respects do the organic remains found in the most ancient formations differ from those found in the more modern strata? What is meant by the term fossil?

2. What parts of organized bodies are found in the fossil state?

3. Are the animals and plants found in the fossil state the same as those now existing on the face of the earth? Are all the varieties of fossils distributed through the divers strata without regard to the age of the formations?

historic times, and the species of which are now totally extinct. In general, they differ from species now living, more and more, in proportion to the antiquity of the strata in which they are found, and, in most of the strata of the earth's crust we find certain species which are not met with either in more ancient or more recent formations.

4. It is by comparing the fossils with each other, and by combining this study with that of the order of superposition, in which the different strata are found, and with their mode of formation, that we have arrived at a knowledge of the earth at periods long anterior to the creation of man, and are enabled to trace the history of the great revolutions which have successively disturbed and changed its surface.

5. We learn by this study that the physical condition of the surface of the earth, as well as that of the organized beings by which this surface is inhabited, has undergone great and numerous changes. Entire creations of animals and of plants have succeeded each other; after having peopled the waters and inhabited the land for ages, each in its turn has been destroyed by some great catastrophe of nature, and given place to a new creation. But the appearance of a new flora, or a new fauna, the destruction of living beings, and the deposit of enormous beds of rocks, are not the only phenomena which characterize the great revolutions of the earth. At different epochs, total overthrows, of which the most fearful earthquakes and volcanic eruptions of our times can give but a very feeble idea, have raised up the solid crust of the globe, and produced lofty chains of mountains, whose elevation, immense as it appears to us, was even still greater before the valleys and basins that separate them were gradually filled by new deposits.

6. The great revolutions of the earth appear to have been separated by long periods of tranquillity, during which animals and plants multiplied on different parts of the globe's surface, and deposits of solid materials, borne by the waters or drawn from the bosom of the earth, were heaped up, constituting beds of rocks of greater or less thickness, and varying in their nature, in the substance of which were entombed the remains of contemporaneous animals and plants.

7. The natural history of the globe is written in the very rocks of which our planet is composed, and the study of these ancient monuments of the power of the Creator teaches us what transpired long before the existence of man on the earth. These fos-

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4. By what means do we study the geological history of the earth?

5. What are the great facts taught by the study of geology?

6. What seems to have occurred in the long intervals of tranquillity between the great geological revolutions of the earth?

7. Does geology teach us that the earth was always inhabited by man?

sils are truly the medals of creation, medals which are more important and incomparably more ancient than all those of Greece and Rome, or the hieroglyphics of Egypt.

OF THE NATURAL REVOLUTIONS OF THE GLOBE.

8. The history of the globe, like that of nations, is divided into a certain number of distinct periods, during each of which the state of things changed but little, yet it resembles neither that which preceded nor that which followed after it.

9. Geologists designate under the term *formation*, the assemblage of rocks which were produced during each one of these periods comprised in the interval between two of these revolutionary disturbances of the globe.

10. For example, they give the name of *creta'ceous formation* (from the Latin, *creta*, chalk) to the assemblage of rocks which were deposited or derived from the interior of the earth, during a geological epoch, in a part of which *chalk* was deposited; and *juras'sic formation* is the name given to the assemblage of contemporaneous sedimentary rocks composing the most remarkable strata of the mountains of Jura, &c.

Beginning with the most ancient, we will examine these several formations in succession.

FIRST GEOLOGICAL EPOCH.

Primitive, Primary, Primordeal, or Unstratified Rocks.[*]

11. Under the name of *primitive*, or *primary rocks* (from the Latin, *primus*, first, before), we ordinarily designate the different rocks which appear to have been formed before the creation of plants and animals, the remains of which are found in less ancient strata, and seem to be a foundation for rocks subsequently produced.

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[*] Mr. Lyell proposes to designate this system of rocks by the term Hypo'gene (from the Greek, *upo*, under, and *geinomai*, I beget), because they are found under other rocks. He objects to the words primary and primitive, because these terms convey a notion as to the time and age of the formation, and might lead to the error of supposing that they were formed before any other rocks were formed, but the term *hypo'gene* refers exclusively to position.

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8. How is geological history divided?
9. What is meant by the term formation?
10. What is meant by creta'ceous formation? What is meant by juras'sic formation?
11. What is meant by *primitive* or *primary* rocks?

12. As already stated, at its origin our globe must have been a mass kept in a state of fusion by the action of heat, and its surface became solid by slowly cooling. This first crust must have remained for a long time in a soft or pasty condition, and at first its temperature must have been too high to permit water to remain on its surface without evaporating. It must have been split in different directions by the contraction produced by cooling, and then resembled the masses of ice which in our day cover the surface of the polar seas; that is, it presented a very unequal surface, studded with immense fragments heaped up in all directions. In this first geological epoch were formed the massive rocks, such as granite, which serves as the base of all other rocks, and is the result of the solidification of mineral substances previously melted by heat. The cooling of this first crust must have also caused the precipitation of the least volatile matters diffused in the atmosphere, just in the same manner as a cold body placed in a warm moist air is quickly covered by a layer of condensed vapour; and from this cause came new changes in the configuration of the surface of the globe, and the formation of new beds of a crystalline texture.

13. The most ancient portion of the crust of the earth known to geologists is composed chiefly of granite and some other unstratified rocks which appear to be also of igneous origin.

14. We give the name of *granite* to a rock, which is extremely hard, having a rough fracture, which is composed of a confused agglomeration of crystals formed of three distinct materials: some of these crystals have a glassy appearance, and are ordinarily of a grayish colour; they are *quartz*, the same material of which rock crystal is composed; others, often large, opaque, and sometimes rose-coloured, sometimes green, sometimes white or yellow, are formed of a mineral called *feldspar;* and the third variety of crystals, which are composed of *mica*, resemble small brilliant spangles, sometimes black, and sometimes silvery white. Granite then consists of *quartz*, *feldspar*, and *mica*. Certain varieties of granite remain for centuries exposed to the inclemencies of the weather without undergoing any alteration; but other varieties are speedily disintegrated by the action of the atmosphere, and are thus reduced to a kind of grit or argilla'ceous earth. It presents no trace of stratification, and possesses all the characters of a rock of igneous origin.

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12. What is supposed to have been the condition of the earth when first formed? What was the condition of the crust of the earth when first formed? Was it smooth and regular?

13. Of what is the most ancient portion of the crust of the earth composed?

14. What is granite? Of what minerals is it composed? What is the character of granite for durability?

15. Granite, which seems to form the first basis, the foundation stone of the great geological edifice, remains uncovered at various points on the surface of the earth, while in other places it is covered by more or less numerous beds of more recent formations. But all the granitic rocks now scattered over the surface of the globe do not date from an antiquity so remote; for, in different recent epochs, mineral materials in a state of fusion have escaped from the bosom of the earth, which spread over formations then existing, and, on cooling, constituted immense masses of granite similar to that first formed.

16. This rock is met with in different places in all parts of the world, and is employed in the construction of edifices of various description.

17. The beds which are deposited on the first massive crust of the globe are crystalline in structure, and this character is more decided the more ancient they are; they seem to have been exposed to the action of a great heat, without possessing the characters of rocks of igneous origin. They consist principally of *gneiss*, *mica-schist*, and *argillaceous schist*.

18. *Gneiss* is a rock very analogous to granite as respects its elementary constituents, but its structure is foliated and presents a stratified arrangement; it appears to have been formed under water, and seems to be the most ancient of the sedimentary formations, because in certain places on the surface of the globe we find it covered by all the other formations. We often see it naked; it forms vast systems of rocks in which it is often alternated with mica-schist and other ancient rocks. It is used in building and flagging.

19. *Mica-schist* is a lamellar rock composed of quartz ordinarily grayish, and a great quantity of brilliant lamellæ of mica arranged in extended leaves or scales; it commonly accompanies granite and gneiss.

20. *Argillaceous schist* is in appearance an earthy rock, which is easily divided into large laminæ more or less thin, and was evidently formed under water by the deposit of sediment. [Schist, from the Greek *schistos*, slaty, easily split.]

We also find in these primitive strata *compact limestone* of great hardness, and other rocks which more or less resemble the preceding.

21. These different rocks, the origin of which dates from the

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15. Is granite everywhere hid beneath the surface of the earth? Is all granite supposed to be of the same age?

16. Where is granite found? To what uses is it applied?

17. What kind of rocks are found overlying the granite?

18. What is gneiss? How does it seem to have been formed?

19. What are the characters of mica-schist?

20 What is argilla'ceous schist?

earliest period of geological history, constitute a great part of the present surface of the globe, and are often found at great depths, beneath less ancient formations. They present evident traces of great overthrows, and the beds or layers which they form no longer occupy the horizontal position they must have had in the beginning, but are more or less inclined, twisted and fractured, as if at various times they had been broken and their immense fragments irregularly raised up. Those countries in which the primitive rocks constitute the surface are knotted and mountainous, and we find these same rocks in the most elevated points of the globe, where they form the mass of most great mountain chains.

22. The central plane of France, comprising Auvergne, Limousin, Vivarais, and Valais, is formed almost entirely of primitive rocks, most of which are granitic. The same is true of a great part of Brittany and Corsica, Scandinavia and Finland, &c.; these ancient rocks also constitute a large part of the Great Alps, of which Mont Blanc is the highest point, the Eastern Alps from Saint Gothard to Hungary, the Pyrenees, the chain of Erzgeberge, in Saxony, the Grampian Hills of Scotland, the Oural mountains, in Russia, the Alleghanies in the United States, and the Andes in South America.

23. As we have already stated, we find no fossils in the sedimentary formations of this geological period, and it is therefore inferred that in this epoch no living beings existed on the surface of the globe; but it may have been otherwise, and the absence of fossils in these strata depends on some cause, such as their destruction by heat, resulting from their vicinity to enormous masses of igneous rocks, effused near to, or even over and above these non-fossiliferous strata.

SECOND GEOLOGICAL EPOCH.

Transition Formation.

24. The stratified formations which rest on the primitive strata just mentioned, present us with the first traces of the existence of living beings on the surface of the globe, and constitute a particular division, generally named the *Transition Formation*, but designated by Mr. Lyell as the *Primary Fossiliferous Formation*. The most recent name given, however, to these formations, is *palæ'ozoic* (formed from the Greek *palaios*, ancient, and *zôon*, an animal), because they contain ancient animal remains.

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21. Are primitive rocks found only beneath the more recent formations?

22. In what countries do we find primitive rocks at the surface?

23. What fossils are found in the primitive sedimentary rocks?

24. In what formations are fossils first met with? What is meant by palæ'ozoic formation?

25. These formations closely resemble the preceding, and it is often difficult to distinguish them, but they do not appear to have begun to form until the first had been disturbed by some great geological convulsion; for the strata of which they are composed are not parallel to those of the rocks on which they rest, and they differ from them by having fossils entombed in their substance. They appear to have been formed by a slow and continuous deposit of sand, mud, and other materials suspended in water, and they consist chiefly of schists and calcareous rocks. The sea seems then to have covered the greatest part of the known surface of the globe, for we scarcely find a trace of terrestrial plants, and immense depôts of these strata, almost identical in character, are met with in the most distant parts of the earth, as in Germany, England, and America.

26. To judge by the fossils concealed in these formations, the globe was then inhabited by a small number of plants, belonging, for the most part, to the family of fucus, and by a multitude of marine animals, the forms of which differed widely from those now existing. It is also remarked that most of these animals belonged to the inferior classes of the animal kingdom, and, until lately, it was believed no vertebrate animal then existed; but within a short time it has been ascertained there were marine fishes, for remains of them have been discovered in certain rocks whose formation dates back to this remote epoch. (*Fig.* 20.)

27. The most ancient beds of the transition formation contain very few fossils, while other rocks of the same formation are rich in these remains; these differences, which correspond with other peculiarities of stratification, have led geologists to divide this period into three divisions, called the CAMBRIAN, SILURIAN, and DEVONIAN Systems of rocks.

28. The CAMBRIAN (from Cambria, in Wales) or SCHISTOSE SYSTEM. The Cambrian rocks are the lowest sedimentary deposits known. They are composed essentially of schistose grauwackes, which pass through all shades of solidity, lustre and colour; on one side they unite with the mica-schists and gneiss, and on the other with the coarse grauwackes, with which they are found intercalated. These rocks contain slate rocks, conglomerates, dark limestone, and fine-grained slates of various shades of purple, blue and green. In the Cambrian rocks the organic remains consist of a few fossil brachiopods, polypa'ria, or coral animals, &c.

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25. How does the palæ'ozoic formation differ from the primitive rocks? In what manner were the palæ'ozoic formations produced?

26. At the period of the palæ'ozoic formation, what description of organized beings lived on the earth?

27. How is the transition or palæ'ozoic formation divided?

28. How is the Cambrian System of rocks characterized? From what is its name derived? What is the geological position of the Cambrian System?

29. The Silu'rian System (from the *Silures*, or *Siluri*, the ancient Britons who inhabited the region where these strata are most distinctly developed) is next above the Cambrian. It is subdivided into the upper and lower Silurian strata. In its mineral composition it so closely resembles that of the Cambrian that it is often difficult to distinguish them. These strata are entirely of marine origin, and many of the beds (as the well-known Dudley limestone) are composed of shells, corals, crinoidea, and those peculiar crusta'ceans termed *trilobites* (*fig.* 4), held together by a calcareous cement.

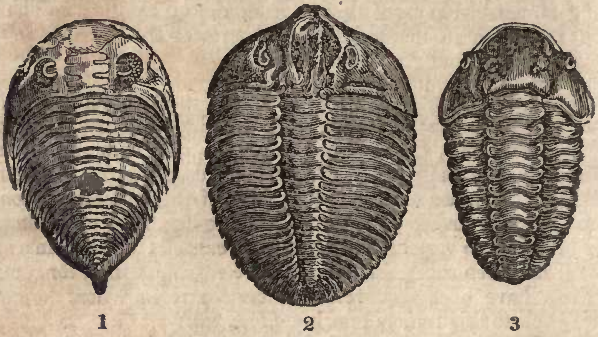

*Fig. 4.—Trilobites.**

30. The presence of these fossil animals is characteristic of the Silurian and Devonian Systems of strata, because they are rarely met with in other situations. They are found entombed in slate and dark limestone.

Trilobites, from their extraordinary form and appearance, have, for more than a hundred and fifty years, been objects of great interest to the naturalist and of wonder to the general observer, and have long been provincially termed *Dudley insects* or *locusts*. The most common examples consist of a convex, oblong body, divided transversely into three principal parts, and longitudinally into three lobes, by two deep, parallel furrows; from this last character, by which the family is recognised among naturalists, the name *Trilobite* (from the Latin *tres*, three, and *lobus*, lobe) has been derived. These fossils are the carapaces, or shells, of crustaceans, belonging to an extinct family, which comprises many genera, and numerous species.

The class of crustaceans consists of two groups, namely: those with eyes

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* *Explanation of Fig.* 4. 1. A'saphus Caudatus.—2. A'saphus Buchii.—3. Caly'mene Blumenbachii.

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29. How is the Silurian System characterized? How does it differ from the Cambrian System? What is the origin of its name? What are trilobites?

30. Of what systems of rocks are trilobites characteristic?

supported on movable peduncles, as the crab and lobster, and those with eyes fixed; the extinct order of trilobites belongs to the last.

The *Caly'mene Blumenbachii* (*fig.* 4, No. 3) is named after the celebrated German naturalist Blumenbach; the generic name, caly'mene (formed from the Greek *kekalumene*, concealed) was devised to express the obscure nature of this genus of trilobites. It is found expanded, with its under surface attached to and blended with the limestone, or coiled up. The head is large, convex, rounded in front, with a broad border, and divided into three lobes by two longitudinal depressions. It has two compound eyes with numerous facets, situated at the back of the head remote from each other. This species is from one to four inches in length. *Mantell.*

"It is a curious fact," says Mr. T. A. Conrad (Palæontologist, State of New York, 1838), "that, whilst the Caly'mene Blumenbachii ceased to exist in New York after the final deposition of the Trenton series, it escaped into remote seas and lived in the era of the Dudley limestone."

In another genus, A'saphus (from the Greek *asaphes*, obscure), the carapace is wide and much depressed (*fig.* 4, Nos. 1, 2); the middle lobe distinct, the cephalic portion rounded in front, and terminating posteriorly in a sharp process on each side. The eyes are compound, and each contains four hundred spherical lenses. Some kinds of A'saphus have remarkably long, pointed, caudal appendages, or tails, (*fig.* 4, No. 1). Some American species of this group are eighteen inches in length. *Mantell.*

31. Besides the trilobites, the remains of other animals are found in the Cambrian and Silurian Systems. They mostly belong to the division of brachiopod mollusks. Among those which are regarded as characteristic of the Silurian System are the *Orthis orbicularis* (*fig.* 5), *Orthis testudinaria* (*fig.* 6): the orthis is a circular shell with a striated surface, and long, narrow hinge; the *Orthoceras* (*fig.* 7), (from the Greek *orthos*, straight, and *keras*, horn); the *Lithuites* (*fig.* 8), of large dimensions; the *Productus*

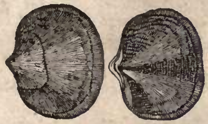
Fig. 5.—*Orthis orbicularis.*


Fig. 6.—*Orthis testudinaria.*

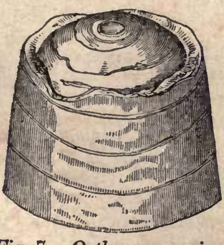
Fig. 7.—*Orthoceras conica.*


Fig. 8.—*Lithuites giganteus.*

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31. Name some of the fossils found in the Cambrian and Silurian Systems. To what division of the animal kingdom do these fossils belong?

(*figs.* 9, 10), (Latin, drawn out, dilated); or *Leptena* (from the Greek *leptos*, slender).

Fig. 9.—*Productus depressus.*

Fig. 10.—*Productus antiquatus.*

"The genus Productus has received its name from a peculiarity observed in several species where the dorsal valve, after having attained a certain magnitude, bends suddenly at right-angles to its former direction, and is then continued irregularly, sometimes being produced (extended) to a considerable length. The whole shell is usually covered with striæ and spines, which in some species are numerous and very long, and which appear to have been movable, doubtless serving a purpose in the animal economy." *Ansted.*

32. The *Spi'rifer* (*fig.* 11), (from the Latin *spira*, a wreath or twisting, and *fero*, I bear), is a brachiopod, closely resembling the terebratula in many important characters, but differing from it in the singular spire of calcareous matter passing across the interior of the shell, and from which the name of the genus is derived. The species are very numerous, and, next to terebratula, are the most abundant of all brachiopod fossils.

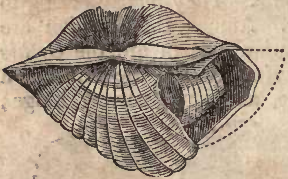

Fig. 11.—*Spirifer trigonalis.*

33. The genus *Terebra'tula* (*figs.* 12, 13, 14), (from the Latin *terebro*, I bore; bored, alluding to the perforated beak). Throughout the whole of the palæ'ozoic formation, certain species of terebra'tulæ are found. This remarkable genus, which has in the present day some representatives in the existing seas, appears to have been created among the very first of the inhabitants of the first formed ocean, and to have retained

Fig. 12.—*Terebratula digona.*

Fig. 13.—*Terebratula octoplicata.*

Fig. 14.—*Terebratula navicula.*

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32. What is the peculiarity of the Spi'rifer?
33. What are terebratulæ?

its place longer than any other. From the incalculable antiquity of their lineage, the terebratulæ have been humorously styled the *Fossil aristocracy*.

34. The genus *Pentame'rus* (*figs.* 15, 16, 17—from the Greek *pente*, five, and *meros*, parts, or cells), contains four known species, all of which belong to the Silurian rocks. In this genus, the lesser valve is divided internally by two parallel walls, or septa, running close together lengthwise along the shell, forming three cells; the other valve also has a septum or wall, which is forked towards the beak of the shell, and divides it into two cells; thus forming the five cells to which it is indebted for its generic name. The casts of these shells (*fig.* 15), often have fissures, produced by the decomposition of the septa; and occasionally these cavities are occupied by calcareous spar.

Fig. 15.—*Cast of the Pentamerus lævis.*

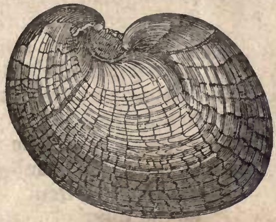

Fig. 16.—*Pentame'rus Knightii.*

Fig. 17.—*Section of same Shell.*

35. Of the polypa'ria or corals which existed when the Silurian rocks were formed, representations of two genera are given. The

Fig. 18—*Cyathophyllum turbinatum.*

Fig. 19.—*Catenipora escharoides.*

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34. How is the genus pentame'rus characterized?
35. Did corals exist in the Cambrian and Silurian rocks?

Cyatho'phyllum (*fig.* 18), (from the Greek, *kuathos*, a cup, and *phullon*, a flower). The abundance of corals of this genus in the Silurian system proves that the seas of that epoch must have teemed with these zo'ophytes. The *Cate'nipora* (*fig.* 19), (from the Latin, *catena*, a chain, and *porus*, a pore). The oval form of the cells when united laterally, and the flexuous disposition of the lamellæ, give rise in transverse sections to elegant catenated markings, from which appearance the fossil has received the name of *chain-coral*. The species figured (*fig.* 19), is common in Silurian limestone, and sometimes forms hemispherical masses more than a foot in diameter.

36. The organic remains of the Cambrian system differ from those of the Silurian system in being less developed; the genera and species of mollusks and corals found in both are alike.

37. The DEVONIAN SYSTEM (so called because it is largely developed in Devonshire, England) forms the superior part of the preceding formation. It appears to be composed

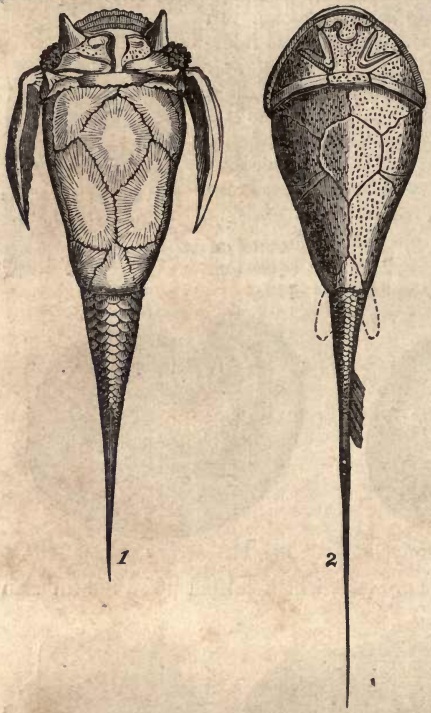

Fig. 20.*—*Fossil Fishes of the Devonian System.*

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* *Explanation of Fig.* 20.—1. Pterichthys cornutus, seen from above—(Pterichthys, from the Greek, *pteron*, wing, and *ichthos*, fish: *cornutus*, Latin, horned. The horned wing fish). 2. Coccosteus oblongus. These figures are restored with great accuracy from the best preserved specimens hitherto discovered. The British species of fossil wing-fishes, of which five or six are known, are all very small, varying in length from one to eight or ten inches. But in the Devonian strata of Russia enormous species occur; the spines of some of them exceed a foot in length. See *Mantell's Medals of Creation*. London, 1844.

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36. How do the fossils found in the Cambrian rocks differ from those of the Silurian System?

at first of pudding-stone, with which it commences, and to pass to sandstone, with which it alternates at different places. Then come sandstone-schists, more or less fine, different species of schist, limestones, alternating with each other, in the midst of which are found beds of anthracite. These various materials are differently developed in different countries: in England the sandstones predominate. They form the *old red sandstone*, comprising strata of clay and marl of different colours. In other places the limestones prevail with different clay-slates, or chloritic schists, sometimes intercalated with schistose quartz, as in Devonshire, and sometimes almost alone, as in Cornwall.

Fig. 21.—*Caryophy'llia fastigia'ta.*

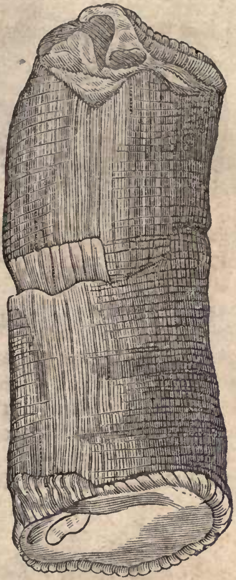

Fig. 22.—*Amplexus coralloi'des.*

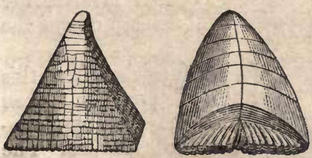

Fig. 23.—*Calceola sandalina.*

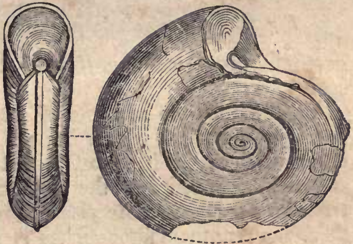

Fig. 24.—*Clyme'nia linea'ris.*

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37. What is the origin of the term Devonian System? What is its geological position? Of what rocks does it consist?

38. This system presents us with depôts of the oldest combustible materials known; and we find in it ferns, ca'lamites, divers species of plants, differing but little from the plants found in the coal formation which immediately follows. We here find also a great many pol'yps more or less analogous to the *Caryophyllia* (*fig.* 21); *Amplexus* (*fig.* 22), by some regarded as polyps and by others as chambered shells, which are found nowhere beside. The *Calceola* (*fig.* 23), so nearly resembling certain productus, appears to be characteristic of the Devonian rocks; and perhaps also the *Clymenia linearis* (*fig.* 24), a chambered shell with aventral siphon. Certain peculiar bivalves are also found (*fig.* 25); some brachiopods, and among others the *Terrebra'tula porrecta* (*fig.* 26).

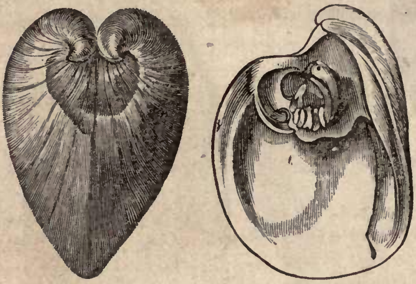

Fig. 25.—*Megalodon cuculla'tus.*

39. Slates, so extensively used for roofs, are furnished from this group of ancient rocks; and on many we find impressions of trilobites. The upper part of the transition strata often contains carboni'ferous materials, sometimes disseminated among the schists, and at others constituting more or less extensive masses, which are generally composed of *anthracite*, though sometimes of bituminous coal.

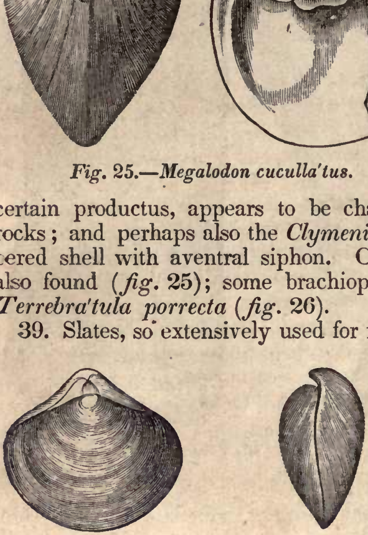

Fig. 26.—*Terrebra'tula porrecta.*

40. These three systems of rocks, namely the Cambrian, Silurian and Devonian, which are not easily distinguished from each other, are found in most countries of Europe, where their assemblage constitutes the greater part of what is named the *transition* or *palæozoic formation.* They abound in Brittany: there the anthraciti'ferous mass forms a stripe along the Loire, extending from Maine to Morbihan, as well as other depôts in Sarthe and Mayenne. These rocks are found through the whole chain

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38. What fossils are found in the Devonian System?

39. What useful material is found in the Devonian System?

40. What systems of rocks constitute the palæozoic formation? Where is this formation met with?

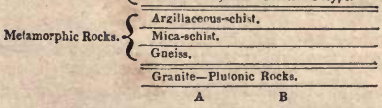
of the Pyrenees, in the southern part of Cevennes, in the mountains of Forez and Beaujolais, and in some parts of Vosges. They form all the Hundsruck, Eiffel, and Ardennes and the southern part of Belgium. They are met with in Hartz, in Saxony, and different parts of Germany, Sweden, and Norway; and they abound in England as well as in the United States. They everywhere offer a matrix for anthracite.

41. Geologists are not agreed as to the natural limit between these strata and those of a more recent order, generally designated under the name of secondary formation; but most authors consider the period of transition to cease beneath the carboniferous rocks and the coal measures.

42. While the different stratified rocks we have spoken of were in progress of formation, there were effusions of granite and other igneous rocks on their surface, and these geological convulsions have produced in the strata elevations and changes of direction, so that many of them are raised up and are very much inclined and in some instances almost vertical. It was during one of these revolutions that the mountains of Westmoreland and Cornwall, in England, were suddenly elevated; a part of those of Brittany, and Bigorre, &c., in France, of the Hundsruck, Eiffel, and Hartz, in Germany, and many other mountain chains. The superior transition strata, which were formed subsequently to this convulsion and rested on the edge of strata thus upheaved, were in turn dislocated and raised up, and according to the observations of a French geologist, Elie de Beaumont, this elevation appears to have been anterior to the formation of more recent rocks than those we have yet mentioned, and to correspond with the eruption of masses of igneous rocks of the mountains of Vosges, known under the name of *ballons* of Alsace and Comté. The elevation of the hills of Bocage, in Calvados and several mountain chains in England, Germany and Poland appears to have occurred about the same time.

The following diagram (*fig.* 27), represents the several strata we have described, in a horizontal position, one lying above the other, and embraces the granite or plutonic rocks below, next the aqueous or metamorphic rocks, and above the whole, the transition formation, consisting of the Cambrian, Silurian and Devonian Systems of strata.

Fig. 27.



41. How is the transition separated from the secondary formation?

42. What is supposed to have happened while the stratified rocks were being formed?

If we suppose the strata to have been in this position at the time of a geological convulsion, such as we have alluded to above, and that the granite should force its way upwards at A or B, we should find perhaps all the relations of the strata changed, presenting something like the arrangement represented in the following figure.

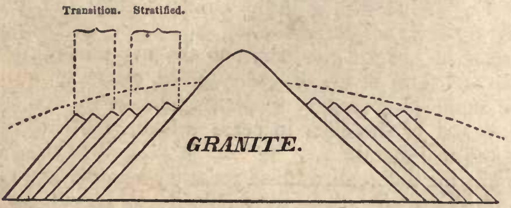


Fig. 28.

The above figure represents the effect of the sudden rising up of a mass of granite, bursting and breaking through all the strata that were lying above it. Instead of a horizontal level surface, as in *fig.* 27, we have a mountain of granite, from the lowest stratum, overtopping all the more recent formations; and the ends of the several strata, where they were broken to give passage to the granite, are brought up towards the earth's surface, represented by the dotted line. In such a case as we here suppose, it would be very difficult for one who had not studied the subject to determine which stratum was first formed: it might seem to him that inasmuch as he finds the granite occupying the highest point, and the transition rocks the lowest, that the granite is of the last or most modern formation.

LESSON III.

THIRD GEOLOGICAL EPOCH.—*Secondary Formation—Carboniferous Formation—Old Red Stone—Fossils—Coal Formation—Fossils—Extent of Coal Measures.*

FOURTH GEOLOGICAL EPOCH.—*New Red Sandstone—Fossils—Triassic System—Bunter Sandstein—Mushelkalk—Keu'per—Ammonites—Fossils.*

FIFTH GEOLOGICAL EPOCH.—*Lias, or Lia'ssic System—Fossils—I'chthyosau'rus—Plei'siosau'rus—Pteroda'ctylus—O'olitic System—Fossils.*

THIRD GEOLOGICAL EPOCH.

Secondary Formation—Carboniferous Formation.

1. After the great revolutions which seem to have terminated the ancient period commonly designated as the transition epoch, the earth appears to have remained in a state of repose for a long time, which permitted new generations of organized beings to multiply on its surface, and mineral substances, carried by the waters, to be deposited in great layers, and to entomb in their substance the solid remains of the exuviæ of contemporaneous animals and plants.

2. The first deposits which took place during this geological epoch, constituted the strata of sandstone, conglomerate, (an assemblage of fragments of rocks and pebbles, cemented together by other mineral matter,) clay, calcareous rocks, &c., and from their union resulted the formation called by geologists the *old red sandstone*, on account of its antiquity and prevailing colour. But this state of things was soon changed, and there was formed, slowly and gradually, at the bottom of the waters, an immense stratum of calcareous rocks, seven or eight hundred feet in thickness; then the sandy sediment alternated with these limestones, and above this great formation, designated under the name of *carboniferous* (coal-bearing) *limestone*, numerous strata of sandstone, schistose clay and coal were accumulated.

3. The fossils of the *old red stone* are somewhat numerous, and belong, for the most part, to marine animals, among which was a fish of strange form, called *cephalaspis*, (from the Greek, *kephale*, head, and *aspis*, shield or buckler,) because its head resembles a kind of buckler (*fig.* 29).

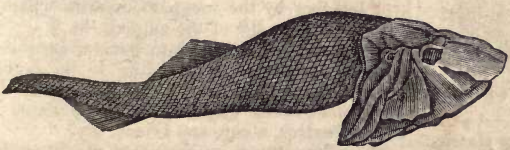


Fig. 29.—Cephalaspis Lyellii.

The remains of the genus *Cephalaspis* (*fig.* 29) are found chiefly in the upper beds of the old red sandstone of Scotland, but also in Herefordshire and Wales. "In this genus, the head is very large in proportion to the body, and occupies nearly one-third of the entire length of the animal; its outline is rounded and crescent-shaped, and the lateral horns slightly incline towards each other, their points being nearer to one another than they are to the round part of the snout. The middle of the head is elevated, and the sides dilated, so as to overlap the body, and extend considerably behind it; but perhaps the head only appears to extend so far, owing to accidents of displacement since the death of the animal. The eyes are placed in the middle of the shield, near to each other, and are directed straight upwards. It is imagined that the pointed horns of the crescent may have been useful

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1. What happened after the termination of the transition period of geological history?

2. What were the first deposits after the transition period?

3. What is the character of the fossils of the old red sandstone? What is the Cephalaspis?

as defences when the fish was attacked by the powerful cephalopods which inhabited the ocean at the period of its existence." The head and body are covered with scales, of peculiar and varied shapes. *Ansted.*

4. The carboniferous limestone, also called *mountain limestone*, and *metalliferous limestone*, affords several varieties of black, bluish grey, and variegated marbles, as well as ores of lead, copper, zinc, &c. It contains a great number of organic remains, such as divers polyparia cyathophylla (*fig.* 18), madrepora, &c., encrinites, which belong to the division of crinoidea (*fig.* 30).

It also contains the remains of a number of mollusks, as the *orthoceras lateralis* (*fig.* 31); *goniatites* (*fig.* 32), which resemble the nautilus; *bellerophons* (*fig.* 33), which, with analogous forms, are not chambered; *euomphalus* (*fig.* 34); *spirifers* and *productus* in great variety, especially (*figs.* 35, 36).

The Crinoideæ, (from the Greek, *krinon*, a lily, and *eidos*, resemblance,) a family belonging to the class of radiate animals, are remarkable for the simplicity of their organization, and the peculiarly complicated structure of their skeleton. The animal resembled a true polyp or coral animalcule; the body consisted of a gelatinous tube, contracted at one extremity, by which it was attached, and furnished at the opposite end with a variable number of delicate contractile filaments placed around the opening which represents the mouth.


Fig. 30.—*Cyathocrinites planus.*

The calcareous skeleton was formed within the tube, and consisted of thousands of regularly-shaped pieces, kept together by the tough membrane which enclosed them during the life of the animal.

The family is divided into genera, according to the form of the stems, or according to its general shape. When the arms or stems are round, it is an *Encrinite*; the *cyathocrinites* (*fig.* 30) takes its name from the Greek, *kuathos*, a cup, and *krinon*, lily.

Many limestones are composed almost exclusively of the remains of species of Crinoidea, as at Lockport, New York; and various genera of this family are found in Alabama, near Huntsville.

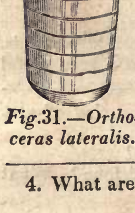
*Fig.*31.—*Orthoceras lateralis.*

The *Orthoceras*, or *orthoceratite*, (from the Greek, *orthos*, straight, and *keras*, horn,) is straight, or slightly bent, cylindrical, slightly conical, many-chambered cell; the chambers are separated by plain septa, which are concave towards the larger end, and pierced with a siphuncle.

Go'niatites (*fig.* 32), (from the Greek, *gônia*, an angle,) is a genus of extinct cephalopods, which inhabited a chambered shell resembling that of the ammonites.

Belle'rophon (*fig.* 33), (from the Greek, *Bellerophontes*, the name of a fabulous hero,) a genus of cephalopods which inhabited chambered shells similar to those of the argonaut and nautilus.

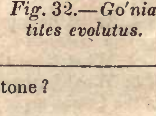
Fig. 32.—*Go'niatites evolutus.*

4. What are the characters of the carboniferous limestone?

The *Euomphalus* (*fig.* 34), (from the Greek, *eu*, properly, and *omphalos* the navel,) was a gasteropod mollusk. The shell is often exceedingly thick, and is divided irregularly into a number of compartments or chambers, provided with a solid tube running through them, entirely shutting off that part of the shell in which the animal dwelt, from the smaller and uninhabited portion. These empty spaces served, no doubt, as floats, rendering the whole mass of the shell and animal sufficiently light to move easily in the water. *Ansted.*

Fig. 33.—*Belle'rophon costatus.*

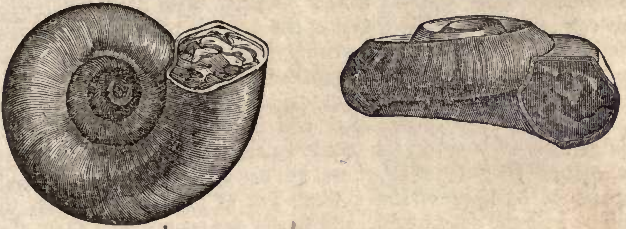

Fig. 34.—*Euom'phalus penta'ngula'tus.*

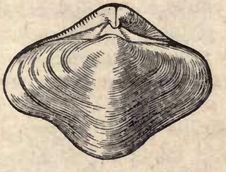

Fig. 35.—*Spi'rifer glaber.*

Fig. 36.—*Productus Martini.*

5. At the period of the *Coal Formation*, the earth appears to have been occupied, in a great part, by a deep sea studded with islands, covered by an abundant and luxuriant vegetation. The then existing plants differed very much from those now living; hundreds of different species are known, but almost the whole of them belonged to the class of vascular cryptoga'mia: they are principally ferns, equisita'ceæ, lycopodia'ceæ, that is, plants of a very simple structure but of gigantic size. The tree-ferns, of which existing species do not exceed 20 or 25 feet in height, even in the torrid zone, and generally not more than 8 or 10 feet, then grew, in localities far beyond the tropics, from 40 to 50 feet high; and other plants, whose representatives of the present time are mere herbs, then rose to 60 feet in height.

6. In that period, there were also insects resembling weevils and neuro'ptera of the present day; scorpions, which differed from the

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5. What was the condition of the earth at the period of the coal formation?

existing species in the number of their eyes; fresh-water mollusks, and very remarkable fishes, which, in certain respects, resembled reptiles, and had their bodies covered by thick solid plates.

7. The debris of the plants of that period, accumulated in immense masses and altered by time and other causes, were transformed into the combustible material, which is so immensely valuable, known under the name of *coal.*

8. The deposits of coal begin, in France, ordinarily with pudding-stones formed of the debris of different rocks from the surrounding country, often comprising gigantic blocks scarcely rounded. Sometimes finer pudding-stones alternate with sandstone, which always constitutes a chief part of the deposit. Very numerous varieties of these sandstones, arising from the size of the grains of quartz and the quantity of argilla'ceous matter entering into their composition, are found; they are frequently micaceous and schistose; they contain beds of clay-slate and bituminous schist, which are sometimes very thick, but rarely calcareous strata. The masses of coal are scattered throughout, but are always separated from the sandstone by beds of slate; these are at first nearly pure, then mixed with the combustible, and finally are represented alone above the deposit.

9. Besides the coal formed by the accumulation of the debris of decomposed plants, the coal-measures contain a great number of the remains of plants which retain their organic characters: the stems and trunks of trees are found in the sandstone; the leaves have left their imprints perfectly preserved in the schists and clays which accompany the coal.


*Fig.*37.—*Pecópteris aquilína.*

10. The impressions of ferns are extremely numerous; among them is the *Pecopteris* (*fig.* 37), of which the leaflets, but little detached from the pedicle, are joined in a single leaf, deeply incised, in which we recognise a principal nervure, from which the secondary nervures arise perpendicularly; the *Sphænopteris* (*fig.* 38), analogous to the preceding, but in which the leaflets are more distinct, deeply lobed, and have the nervures radiate almost from the base; the *Neuro'pteris* (*fig.* 39), which also has the leaflets de-

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6. What animals existed at that period?
7. From what was coal formed?
8. In what kind of rock is coal found?
9. In what do we find impressions of plants?

tached, but entire and rounded, and the nervures arise very obliquely from the middle nervure, and afterwards frequently divide; and a great number of other genera founded on the form of their leaflets and the arrangement of their nervures. We also find various other plants, the families of which are uncertain, such as the *Sphenophyllites* (*fig.* 40), *Annula'ria*, &c. (*fig.* 41), which are very abundant in certain localities.

Fig. 38.—*Sphænopteris Hæninghausi.*

Fig. 39.—*Neuropteris Loshii.*

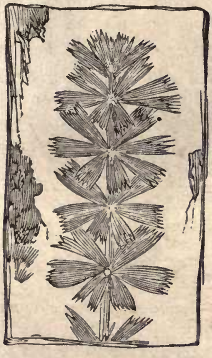

Fig. 40.—*Spheno'phyllum dentatum.*

Fig. 41.—*Annula'ria brevifolia.*

11. True *equisita* appear to have existed in the coal-measures; but we are also led to place in the same family certain stems, grooved lengthwise, with joints at intervals from which branches sometimes spring (*figs.* 42, 43). These stems, called *ca'lamites*,

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10. Name some of the genera of fossil plants found in coal-beds.

are often found, like all the rest of those of which we speak, converted into argillaceous matter, which has become hard, or into carbonates of iron, but rarely into silicious matter. The external vegetable tissue is frequently found to have passed into a carbonous state.

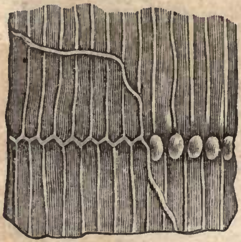

Fig. 42.—*Calami'tes suckovii.*

Fig. 43.—*Calami'tes cannæfo'rmis.*

12. The *Lycopodia'ceæ* embrace various species of *Lepidode'ndrons* (*figs.* 44, 45), of which entire trees have been sometimes found, upwards of sixty feet in height. Their trunks present rhomboidal projections, spirally arranged, which clearly exhibit near the top cica'trices of leaves.

Fig. 44.—*Lepidode'ndron crena'tum.*

Fig. 45.—*Lepidode'ndron e'legans.*

13. The *Sigilla'riæ* (*fig.* 46) seem to range themselves next to the Cyca'deæ; their stems, flattened by pressure, are channelled lengthwise but not articulated, and the cica'trices are arranged in a longitudinal series. The stems, called *stigma'ria* (*fig.* 47), are,

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11. What genera belonging to the family of equisita'ceæ are found in coal-beds?

12. What fossil plants of the family of lycopodia'ceæ are found in coal-measures?

according to Ad. Brongniart, probably only the roots of plants, the body of which is traversed by a ligneous axis surrounded by soft fleshy parts.

Fig. 46.—*Sigilla'ria pachyde'rma.*

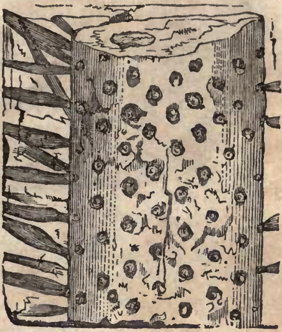

Fig. 47.—*Stigma'ria ficoi'des.*

14. The co'nifers, which, from the consistence of their wood, seem to have participated largely in the formation of carbonaceous matter in different strata, present us, in the different coal-measures, especially in the upper beds, species approximating to the *arauca'ria* in their spirally-arranged sessile leaves. M. Ad. Brongniart refers the whole of them to the genus Walchia of M. Sternberg, of which two species, with their leaves and fruit, are here figured, (*fig.* 48).

Fig. 48.—*a Walchia Schlotheimii.*
b Walchia Hypnoides.

15. Animal remains are not very common in coal-measures; still some are found, and even in great numbers in certain

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13. What are sigillariæ? What are stigmariæ?
14. What genus of conifers is found fossilized?

localities. From the calcareous beds, subordinate to these sandstones, in the environs of Edinburgh, Dr. Hibbert has collected the remains of enormous sauröid fishes, the strong and longitudinally striated teeth of which, as well as the whole osseous system, remind us of the largest sized reptiles. *Fig.* 49 represents, very much reduced, a portion of the lower jaw of one of these voracious creatures, and *fig.* 50 a tooth of the natural size of another species. The limestone in which they are found also contains particular concretions (*fig.* 51) which are considered to be the excrement of these animals, and, on this account, called *coprolites*, (from the Greek, *kopros*, dung, and *lithos*, stone). The family of squalæ was then represented by the division of *cestra'cions*, characterized by teeth adapted for grinding, (*fig.* 52); and by that of the *hybodons*, with conoïdal but not trenchant teeth, the enamel of which is plaited on both surfaces (*fig.* 53). The true sharks, with teeth flattened and trenchant on the edges, (*fig.* 54), did not then exist, and did not appear until very much later in the creta'ceous formation.

Fig. 49.—*Lower Jaw of the Holopticus Hibberti.*

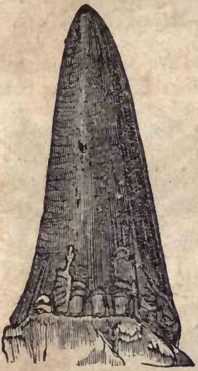

Fig. 50.—*Tooth of the Megalichthys Hibberti.*

Fig. 51.—*Coprolites.*

16. Other fishes are found in the coal-basins of the continent of Europe, either in the bituminous schists, as at Sarrebruck and at Antun, or in kidney-shaped masses of carbonate of iron, as at Saint-Etienne. They belong to neighboring genera of sturgeons, named by M. Agassiz *palæoni'scus*, (*fig.* 56), and *am'blipterus*, and seem to have lived in fresh water.

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15. What animal remains are found in the coal-measures? What are coprolites?

16. Are any other fishes found in coal-beds?

17. Marine shells are rare in coal strata, and are only found in the subordinate limestone of Belgium and England; but at the same time there were some species of *unio* and some small entomostracans which indicate at least an afflux of fresh water to the sea at the points where these particular deposits were made.

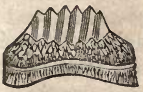

Fig. 52.—Tooth of Cestracion.

Fig. 53.—Tooth of Hybodon.

Fig. 54.—Tooth of true Shark.

18. Extent of the Coal-Measures. It is evident that the coal formation cannot be found except above the Cambrian, Silurian and Devonian strata, which were formed anteriorly to, or about the time of these deposites. If it existed before that period, it must be necessarily concealed by all the strata subsequently formed, and searches have been extended below them at great expense for this combustible. The consequence is, that the coal formation occupies a small portion of the uncovered surface of the earth. All the deposites known in France do not occupy more than one two-hundredth part of the superficies of the territory. England and Belgium are comparatively richer, for in the first the surface of the coal formation is equal to one-twentieth of the whole kingdom, and in the second to one twenty-fourth. All the other States of Europe are much poorer, and some, Sweden, Norway, Russia, Italy and Greece, are almost entirely without this valuable formation. Bohemia is the richest part of Germany in coal, although it does not produce largely. The northern part of the Spanish peninsula seems to contain considerable deposites of coal, and to participate, in this respect, in the wealth of Western Europe.

19. The coal-fields of the United States are numerous and extensive. Coal is found in Massachusetts, Rhode Island, Pennsylvania, Maryland, Virginia, Ohio, Kentucky, Tennessee, Illinois, Alabama, Mississippi, and Indiana; in a word, the coal formation in the United States is greater than in any country or kingdom on the face of the earth, and embraces every variety hitherto discovered.

20. The different layers, constituting the coal-measures, were deposited horizontally at the bottom of the basins they occupy, but they have not remained in this position; at certain places they

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17. What does the existence of the genus unio in the coal-beds indicate?

18. What is the relative geological position of the coal-measures?

19. In what parts of the United States do we find coal?

were raised up, and at others lowered down, so that they became more or less oblique, and often seem to be, as it were, folded on themselves; it is also remarked that frequently a certain extent of the mass formed by these layers has been separated from neighboring parts by a sort of split or cleft, and elevated or depressed to a different level; consequently the beds of coal are suddenly interrupted at these points, and are found further on at a different height. These geological accidents are designated by miners under the name of *faults*, (*fig.* 55).

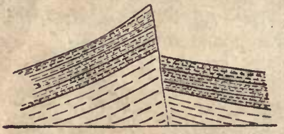

Fig. 55.—Fault.

Speaking of the origin and nature of coal, Dr. Buckland remarks, "The most early stage to which we can carry back its origin, was among the swamps and forests of the primeval earth, where it flourished in the form of gigantic *Ca'lamites*, and stately *Lepidode'ndra*, and *Sigilla'riæ*. From their native bed, these plants were transported into some adjacent lake, or estuary, or sea. Here they floated on the waters, until they sank saturated to the bottom, and being buried in the detritus of adjacent lands, became transferred to a new estate among the members of the mineral kingdom. A long interment followed, during which a course of chemical changes, and new combinations of their vegetable elements, converted them to the mineral condition of coal. By the elevating force of subterranean agency, these beds of coal have been uplifted from beneath the waters, to a new position in the hills and mountains, where they are accessible to the industry of man. From this fourth stage, coal has been removed by the labours of the miner, assisted by the arts and sciences, that have co-operated to produce the steam-engine and the safety-lamp. Returned once more to the light of day, and a second time committed to the waters, it has, by the aid of navigation, been conveyed to the scene of its next and most considerable change by fire; a change during which it becomes subservient to the most important wants and conveniences of man. In this seventh stage of its long and eventful history, it seems, to the vulgar eye, to undergo annihilation; its elements are, indeed, released from the mineral combinations which they have maintained for ages, but their apparent destruction is only the commencement of new successions of change and of activity. Set free from their long imprisonment, they return to their native atmosphere, from which they were absorbed by the primeval vegetation of the earth. To-morrow they may contribute to the substance of timber in the trees of our existing forests; and, having for a while resumed their place in the living vegetable kingdom, may, ere long, be applied a second time to the use and benefit of man. And when decay or fire shall once more consign them to the earth, or to the atmosphere, the same elements will enter on some further department to their perpetual ministration in the economy of the material world."

21. A part of this grand upturning of the coal formation has not disturbed the more recent strata by which it may be covered, and consequently it must have been effected at the close of the geological period whose history we have just studied.

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20. How were the coal-measures deposited? What is meant by a Fault?

21. Has the disturbance of the coal strata affected the strata subsequently deposited abcve them?

FOURTH GEOLOGICAL EPOCH.

(*Secondary Formation Continued.*)

Saliferous Formation—New Red Sandstone—Poïkilitic (variegated) group.

22. The rich vegetation which adorned the surface of the earth during the coal period, seems to have been entirely destroyed or converted into coal, by the geological convulsion which separated this epoch from the succeeding period; this convulsion was followed by the formation of extensive deposits of more ancient rocks and sandy matters, as well as by the effusion of different rocks of igneous origin, such as *porphyries*.

23. These deposits, which are indicative of great movements in the waters, constitute the formation designated by geologists under the names of *red conglomerate*, *new red sandstone*, *rothe-todte-liegende*,* &c. They frequently form layers six hundred feet in thickness, and contain scarcely any remains of organized beings.

24. This *lower new red sandstone*, or *penine* formation of the French, is very abundant in Thuringia. It contains very few organic remains. Above this red sandstone we find, in some places, *bituminous schists*, which are very remarkable, especially in Thuringia, for the ores of copper they contain, which circumstance has gained for them the name of *kupfer-schiefer*, that is, copper-slate. They contain plants which appear to belong to the family of algæ, and a very small number of terrestrial plants, such as the co'nifers. Higher in the series come the compact limestones, the *zechstein* (mine-stone) of the Germans, separated into several layers by marls; then cellular and magnesian limestones, which are more or lses friable, and again, compact limestone and argilla'ceous matter. Such is the assemblage of strata in Thuringia, and in different parts of Germany; but in England the whole series is replaced by the *magnesian limestone*.

25. It was about this geological period that animals belonging to the class of reptiles were created. In this formation we find for the first time the remains of *sau'rians*, in the bituminous schist and in the zechstein, and subsequently in the magnesian limestone of England. These reptiles resemble the living genera of the iguana and monitor. We also find fishes of the genera *palæoni'scus* (*fig.* 56—from the Greek, *palaios*, ancient, and *oniskos*,

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* *Rothe-todte-liegende*—German: red, dead, lier; so named because it is of a *red* colour, *underlies* the metalli'ferous strata, and is *dead*, or worthless, as far as any metallic produce is concerned.

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22. What became of the plants which flourished on the earth previous to the time of the coal formation?

23. What formation is next above the coal?

24. What are the characters of the lower new red sandstone? What is kupfer-schiefer?

25. What animals seem to belong to this fourth geological epoch?

a kind of fish), and *ambly'pterus*, (from the Greek, *amblus*, obtuse, and *pteron*, wing), similar to those of the coal-measures; but they are not found in any formation subsequent to that we are now considering.

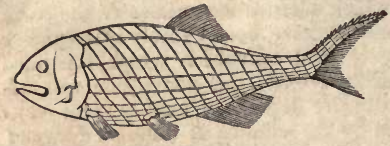

Fig. 56.—*Palæoni'scus*

The *palæoni'scus* is found in the magnesian limestone of England and the kupferzchiefer of Germany. The head is of a somewhat singular form, especially with regard to the anterior portion of the face, which forms a rounded projection above and before the upper jaw, occasioned by the swelling out and prolongation of some of the bones of the skull. The orbit of the eye is surrounded by a series of small narrow bones, and the mouth is usually large, but the teeth so exceedingly small that it is rarely possible to distinguish them. The jaws, however, are powerful, and more especially the lower one, which is larger than the upper. *Ansted.*

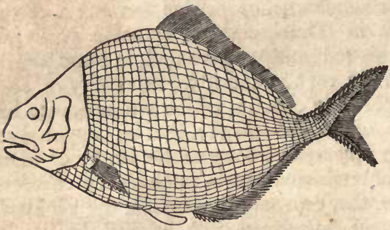

Fig. 57.—*Platyso'mus.*

The genus *Platyso'mus* (*fig.* 57), (from the Greek, *platus*, flat, and *sôma*, body,) which is found in the same strata, differs considerably from the palæoni'scus, as the body is of a trapezoidal form, is much raised, and nearly as high as it is long, while from the position of the scales on the edge of the back and on the belly, it appears to have been flattened.

The head is large in proportion to the size of the body, the extremity of the snout forms a slightly rounded projection, the mouth is small and narrow, the jaws are armed with small but very pointed teeth, the lower jaw is shorter than the upper, and broader in proportion, and the operculum (or bony scale covering the gills) is narrow and much elevated. The whole body is covered with large scales.

One of the most remarkable peculiarities in the structure of this fish is, that although the body is flat, short, and elevated, like that of the recent flat-fish, the tail instead of being, as in the latter, much forked and equally lobed—arrangements which appear, in the present state of things, to be indispensable—retains in the Plátyso'mus the *he'terocercal* character, the upper portion having the vertebral column continued into it, and being much longer and more powerful than the lower portion, which rather resembles a small accessory fin. *Ansted.*

M. Agassiz classifies fishes according to the form of their scales. All those fishes with angular scales *regularly* arranged and entirely covering the skin, constitute the order of *Ganoideans* (from the Greek, *ganos*, splendour). The order of *Placoideans* (from the Greek, *plax*, a broad plate) contains fishes whose skin is covered *irregularly* with plates of enamel, often of considerable dimensions, but sometimes reduced to small points, like the shagreen on the skin of the shark, and the prickly tubercles of the ray. The order of *Ctenoideans* (from the Greek, *kteis*, in the genitive *ktenos*, a comb) is characterized by horny or bony scales, jagged like the teeth of a comb on the outer edge. The *perch*, and many other existing genera, are of this order, which contains but few fossil forms. The order of *Cyclodians* (from the Greek, *kuklos*, a circle) is characterized by having scales which are smooth and simple at the margin, as in the *herring*, *salmon*, &c.

When the vertebral column is prolonged into the caudal fin, the tail is *he'terocercal;* when the vertebral column terminates where the tail is given off, we have the *homocercal* tail, as in most of the recent fishes.

In this same formation we also find *Spi'rifers* (*fig.* 58), and *Productus* (*figs.* 59, 60), and especially the *Productus aculea'tus* (*fig.* 59), which, under the name of *gry'phites aculea'tus*, has been regarded as characteristic of it in Germany; and sometimes, in consequence, the zechstein is called *gryphitenkalk*, which, on this account, has been confounded with the *lias*. Other mollusks, as well as the remains of encri'nites, which seem to be the same as those of the carboni'ferous limestone, are also found.

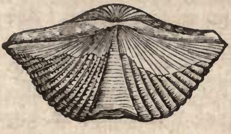
Fig. 58.—*Spi'rifer undula'tus.*

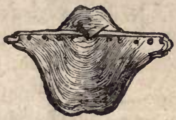
Fig. 59.—*Productus aculea'tus.*


Fig. 60.—*Productus calvus.*

26. Next in order is a layer, known as the sandstone of Vosges, which lies either on the red sandstone or magnesian limestone; or, when these strata are wanting, on some other more ancient rock. After the formation of the several portions of the crust of the globe just mentioned, geological convulsions again occurred, and, as it appears, the mountains of Vosges, the Black Forest, &c., were elevated about the same time. After this movement, new deposits were formed around the base of the hills, constituting the *Trias System* of French and German geologists, so named because it is composed of three kinds of rocks.

27. The TRIAS or TRIA'SSIC SYSTEM (or upper new red sandstone of the English) consists of:—

1. *Bunter Sandstein*, (*gres bigarré* of the French), a quartzose sandy deposit, which usually forms the base of the system, both in France and Germany.

2. *Muschelkalk*, (shell-chalk), a well-marked and highly fossili'ferous limestone, rarely absent in the continental series, but never found in England.

3. *Keuper*, a singular group of sandy marls, of variegated colours, frequently containing salt and gypsum, and remarkable for numerous fossil vegetable remains.

28. The BUNTER SANDSTEIN, or Gres Bigarré, is a fine-grained,

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26. What is the relative position of the Vosges sandstone?
27. What is the trias, or tria'ssic system?

solid sandstone, sometimes white, but more frequently of a red, blue, or greenish tint. The structure of the lower part is tolerably close-grained, and sufficiently compact to form a good building stone; but the uppermost strata are fissile and incoherent, and pass into an earthy clay containing gypsum (plaster of Paris). The intermediate portion is compact, like the lower, but its structure is that of a conglomerate, and is used for making millstones. In many districts the Bunter sandstein contains numerous remains of fossil plants and marine shells, but the latter are rare and confined to particular localities. In this series are found foot-prints, (*fig.* 61), some of which evidently belonged to birds, and others, according to the opinion of certain naturalists, belonged to marsupial mammals, or gigantic batrachian reptiles.

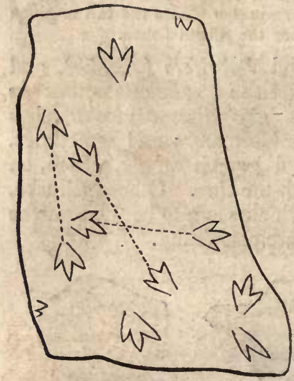

Fig. 61.—*Bird-tracks.*

29. The sandstones and marls of this part of the series are spread over an extensive tract of land in western Europe, more particularly in France, and in south-western and central Germany. On the right bank of the Rhine, in Swabia, there are some districts in which the bunter-sandstein rests immediately on the rothe-todte-liegende, the lower new red sandstone (Vosges sandstone) being absent, and no other representative of the magnesian limestone taking its place.

30. The Muschelkalk (also called conchylian limestone, shell-limestone) is a compact limestone of a grey or greenish-grey colour, and commonly contains, in great abundance, the remains of shells and fragments of radiated animals and fishes. Sometimes the muschelkalk is a bituminous rock, and emits a fetid, disagreeable odour when rubbed or struck with a hammer.

31. Among the characteristic shells are the *Ammoni'tes nodo'sus* (*fig.* 62); *A'vi'cula socia'lis* (*fig.* 63). *Possido'nia minu'ta* (*fig.* 64). In this stratum the *Trigo'nia* (*fig.* 65) is first met with, and species of it are found extending through various subsequently-formed strata to the chalk. A great many *Encri'nites* are also found, especially the species *monilifo'rmis* (*fig.* 66).

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28. What is Bunter Sandstein? What animal remains do we find in the Bunter Sandstein?

29. Where is the Bunter Sandstein met with?

30. What is Muschel-kalk?

31. What shells are characteristic of the Muschel-kalk? What are Ammonites?

The *Ammonites*, (*fig.* 62), or *Co'rnua Ammonis*—so called from a supposed resemblance to the horns engraven on the heads of Jupiter Ammon—are among the most common and well-known fossils. Local legends, ascribing their origin to swarms of snakes turned into stone by the prayers of some patron saint, are still extant in certain parts of England, and perpetuated by the name of *snake-stones*, by which these fossils are provincially known. Several hundred species have been described; they are divided into genera, which are characterized by essential modifications in the direction of the spire, and the inflections of the septa.

Fig. 62.—*Ammonites nodosus.*

The shell of the ammonite is generally thinner and more delicate than that of the nautilus, (to which it bears considerable resemblance), and in some species it resembles the flexible covering of the argonaut; possibly, in these species the animal, like the recent paper nautilus, may have possessed a pair of arms terminating in broad membranous expansions, which secreted the shell, and generally remained in contact with it; otherwise it is difficult to explain how such delicate fabrics should have been uninjured.

The living and extinct species of testaceous cephalopods, "are all connected by one plan of organization; each forming a link in the common chain which unites the existing species with those that prevailed among the earliest conditions of life upon our globe, and all attesting the identity of the design that has effected so many similar ends, through such a variety of instruments, the principle of whose construction is, in every species, fundamentally the same.

"Throughout the various living and extinct genera of these beings, the use of the air-chambers and siphon of their shells, to adjust the specific gravity of the animals in rising and sinking, appears to have been identical. The addition of a new transverse plate within the coiled shell added a new air-chamber, larger than the preceding one, to counterbalance the increase of weight that attended the growth of the shell and body of these animals."—*Buckland.*

The occurrence of the nautilus and its congeners among the earliest traces of the animal kingdom, and their continuance throughout the immense periods during which the family of ammonites was created, flourished, and became extinct, and the existence of species of the same genus at the present time, are facts too remarkable to have escaped notice. To these facts Mrs. Howitt alludes in the following lines to the nautilus:

> "Thou didst laugh at sun and breeze
> In the new created seas;
> Thou wast with the reptile broods
> In the old sea solitudes,
> Sailing in the new-made light,
> With the curled-up ammonite.
> Thou surviv'dst the awful shock,
> Which turn'd the ocean-bed to rock,
> And changed its myriad living swarms,
> To the marble's veined forms."
> *See Mantell's Medals of Creation.*

Fig. 63.—*A'vicula Socia'lis.*

The genus *A'vicula* (*fig.* 63) belongs to the division of bivalve shells, and the fossil species, a great many of which are known, resemble the pearl oyster (*A'vicula Margaritifera*).

Fig. 64.—*Posido'nia minu'ta.*

The genus *Posido'nia*, (*fig.* 64), (from the Greek, *poseidôn*, Neptune), also belongs to the bivalves, and is found in the lower part of the carboni'ferous series.

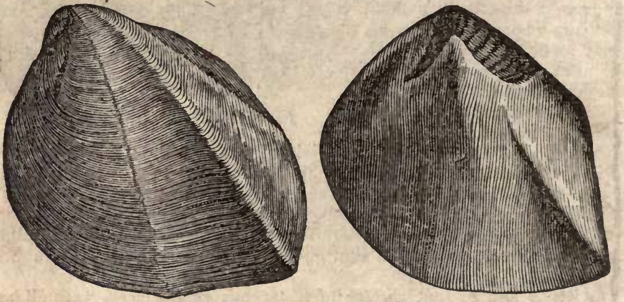

Fig. 65.—*Trigo'nia vulga'ris.*

The genus *Trigonia*, (*fig.* 65—from the Greek, *trigonos*, three-cornered), belongs to the family of *ostracea ;* the only living species known inhabits the seas of New Holland.

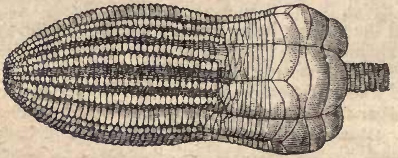

Fig. 66.—*Encri'nites monilifor'mis.*

The *Encri'nites*, (*fig.* 66—from the Greek, *krinon*, a lily), belong to the family of *Echi'noderms.* The skeleton of this animal is said to consist of not less than 26,000 separate pieces. The body of the lily-encrinite was supported on a long and nearly cylindrical column, attached to a rock or some hard substance at the bottom of the sea by an enlargement of its base. This column was made up of a vast number of joints, through which was an aperture, descending from the stomach of the animal to the base of the column.

32. The KEU'PER (a German word) is the name given to the uppermost division of the tria'ssic system, and is often applied to the upper part of the new red sandstone formation. This

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32. What are the characters of the Keuper formation? What organic remains are found in the Keuper series?

group usually consists of a numerous series of mottled marls, of a red, greenish grey, or blue colour, which pass into green marls, black slaty clays, and fine-grained sandstones. Throughout the series, common rock-salt and gypsum are abundant, but the organic remains of animals are extremely rare. Of plants, however, a considerable number are preserved in some localities; and these indicate a wide departure from the carboni'ferous period, and, as well as the shells, seem to possess more analogies with the forms of life determined from the fossils of the secondary period, than with those common in palæ'ozoic rocks. Besides peculiar species of ferns, the trias presents us with fossil plants not previously met with. In the sandstone are particular species of co'nifers which constitute the genus *Volt'zia*, (*fig.* 67), and in the limestone, remains of cyc'adeæ of the genus *mantellia;* this last family is very abundant in the Keuper, in which are found the genus *Nilso'nia*, and the genus *Pterophyllum*, (*fig.* 68). Several species of large saurian reptiles are also found in the trias group of rocks.


Fig. 67.—*Volt'zia hetero'phylla.*


*Fig.*68.—*Pte'rophyllum Pleininge'rii.*

FIFTH GEOLOGICAL EPOCH.

Lias, or Lia'ssic System—Jura'ssic Formation—O'olitic System.

(*Secondary Formation Continued.*)

33. Up to this period of its geological history, we have seen the earth was inhabited only by plants, some inferior animals, such as zo'ophytes, mollusks and fishes, and lastly, by some reptiles. During the period at which we have now arrived, this state of things changed, and there was created a new fauna composed of most remarkable animals, characterized especially by a multitude of reptiles, of strange form and gigantic size.

34. The formation of the Lias—so called from a barbarous provincial word, supposed to be a corruption of *layers*, and to allude to the riband-like appearance of the rock when seen in section—the Lias consists of strata, in which an argilla'ceous character predominates throughout, but which are also remarkable for a quantity of calcareous matter mingled with the clay, and forming occasional bands of argilla'ceous limestone. A few beds of sandstone also alternate with the clay and marl, and are sometimes mixed with the latter, forming a marly sandstone of a white or greenish colour.

35. The inferior layers of the lia'ssic system are characterized, according to M. Leymerie, by the presence of the *Pecten lugdune'nsis* (*fig.* 69), and different species of *echi'nidæ* of the division *diade'ma* (*fig.* 70).

Fig. 69.—*Pe'cten lugdune'nsis.*

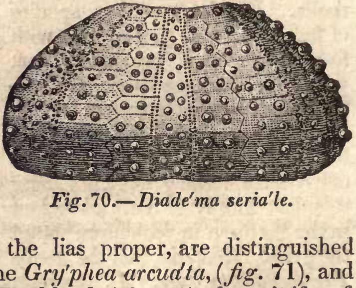

Fig. 70.—*Diade'ma seria'le.*

36. The middle layers, or the lias proper, are distinguished especially by the presence of the *Gry'phea arcua'ta*, (*fig.* 71), and the ammonite named after Dr. Buckland, (*fig.* 72), the spi'rifer of

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33. What is remarked of the animals in the early geological periods?
34. Of what is the Lias formation constituted?
35. What animal remains characterize the inferior beds of the Lias?
36. How is the Lias proper characterized?

Walcot, (*fig.* 73), the last of the race, the giant *plagio'stoma*, (*fig.* 75), and the spinous *plica'tula*, (*fig.* 74).

Fig. 71.—*Gry'phea arcua'ta.*

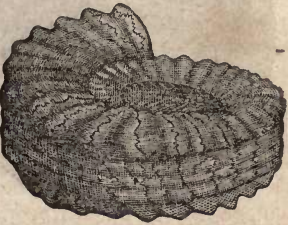

Fig. 72.—*Ammonites Buckla'ndii.*

*Fig.*73.—*Spi'rifer Walcoti.*

*Fig.*74.—*Plica'tula Spino'sa.*

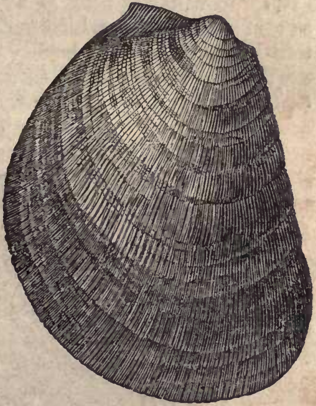

Fig. 75.—*Plagio'stoma giga'nteum.*

37. The superior part of the lias contains a great number of *belemnites*, (*figs.* 76, 77), the *ammonite* named after Walcot, (*fig.* 78), and an *a'vicula* with unequal valves, (*fig.* 79), &c.

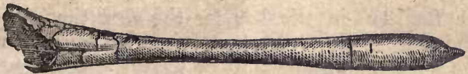

Fig. 76.—*Bele'mnites pistillifo'rmis.*

Fig. 77.—*Bele'mnites Sulca'tus.*

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37. What fossils belong to the upper part of the Lias?

Fig. 78.—*Ammonites Walcoti.*

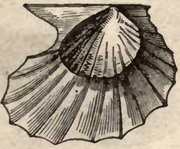

Fig. 79.—*A'vicula inæquiva'lvis.*

38. We also find in this group various species of ***Trigo'nia***, (*fig.* 80), which appear to have existed in all parts of the deposit; but the species, which perhaps furnish very important characteristics, have not yet been studied sufficiently in relation to the grouping. They extend through the o'olitic series to the chalk formation.

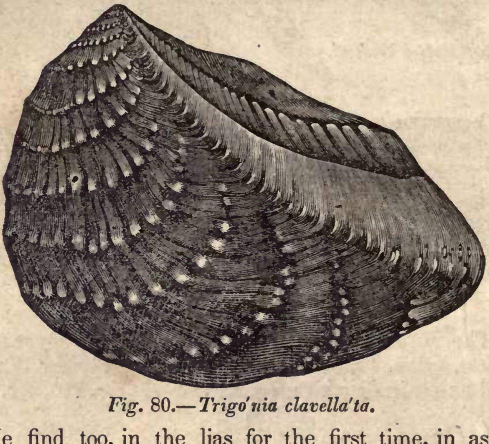

Fig. 80.—*Trigo'nia clavella'ta.*

39. We find too, in the lias for the first time, in ascending through the crust of the earth, those singular saurians whose skeleton at the same time reminds us of lizards, crocodiles, fishes and mammals; their feet, which are in form of paddles, show they were aquatic in their habits: such are the *Ich'thyosau'rus*, (*fig.* 81), some of which were twenty-five feet in length; the *Plei'siosau'rus*, (*fig.* 82), some species of which are nearly fifteen feet long.

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38. Are any species of Trigo'nia characteristic of any part of the Lias?

39. What is an Ich'thyosau'rus? What is the lowest stratum in which it is found? What is the Plei'siosau'rus?

The I'CHTHYOSAU'RUS (from the Greek *ichthus*, a fish, and *sauros*, a lizard —*fish-lizard*—*fig.* 81), must have resembled some huge fish, having an exceedingly large head and very powerful tail. The spine consisted of 120 vertebræ or joints, besides those of the neck, which were united into a mass of solid bone. The eye was an extremely powerful organ, "capable of adapting itself," says Dr. Buckland, "to great changes of distance, and great alterations in the amount of light in which it could be used; giving to its possessor the power of discerning a far-distant object, as well as one near at hand, and of pursuing its prey in the darkness of night, or the dim obscurity of the depths of the ocean, as well as in the day-time or on land." This animal had a wrinkled skin, like the whale, without scales.

Fig. 81.—*I'chthyosau'rus communis.*

Fig. 82.—*Plei'siosau'rus dolichodeirus.*

The PLEI'SIOSAU'RUS (from the Greek *plesion*, near, and *sauros*, a lizard or reptile—resembling a reptile—*fig.* 82) may be described as exhibiting the head of a lizard, attached to a neck whose length was three, or, in some species, even more than four times that of the head. The body appended to this head and neck was comparatively small and fish-like; the extremities were large paddles, and the tail like that of the crocodile. The neck consisted of upwards of thirty vertebræ or joints, and was very long and flexible. *Ansted.*

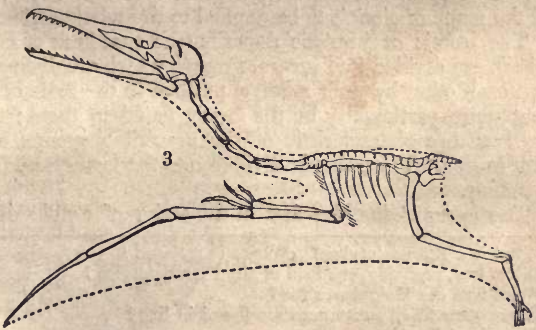

Fig. 83.—*Pteroda'ctylus longiro'stris.*

40. We also find, for the first time, in the lia'ssic group, the *pterodac'tylus* (from the Greek *pteron*, wing, and *daktulos*, finger—

fig. 83), a flying saurian, whose head and neck gave it the semblance of a bird, and its tail was like that of a mammal, while its extremities were analogous to those of a bat; it was capable of walking and flying, and, perhaps, of climbing steep rocks in pursuit of food.

41. With the remains of these singular animals are found, in the lias of Lime-Regis, on the coast of Dorset, England, an immense quantity of coprolites (from the Greek *kopros*, dung, and *lithos*, stone), which probably belonged to them: sometimes their intestines are found in their skeletons; and we also find, in these, the remains of fishes and other reptiles, clearly showing how the aquatic species were nourished. The remains of insects are found with those of the pteroda'ctyli at Solenhofen, in Franconia, also showing what was the food of these animals.

42. Saurians resembling crocodiles were much less abundant in this epoch, although we find, in the lias, remains which prove their existence. The *me'galosau'rus* (from the Greek *megas*, great, and *sauros*, reptile) partook of the nature of the crocodile and monitor, and must have been from fifty to sixty feet in length.

43. Ink-bags of considerable size (*fig.* 84), analogous to those of the cuttle-fish, are also found. In the lias of Lime-Regis, the dorsal bones of the calmar are also met, with other traces of this genus, as well as of belemni'tes. The ink or *se'pia*, which may be obtained from these fossils, is as good as that prepared from the recent cuttle-fish, and has been used.


Fig. 84.—*Ink-bag.*

44. The Jura'ssic or O'olitic System.—O'olite (from the Greek *ôon*, an egg, and *lithos*, a stone), is a granular variety of carbonate of lime, frequently called *roe-stone*, from its resemblance to a fish-roe, or egg-bag. The frequency of the occurrence of this particular form of limestone in a great series of deposits, has caused the name of *o'olitic* to be applied to the whole series.

45. The o'olitic or jura'ssic deposits (the Jura-kalk of German geologists), are divided into several groups, which are distinguishable from each other by their relative position in the scale of elevation, but more particularly by the fossils found in them; the remains which are characteristic of the preceding groups, are not met with in this. The o'olite is divided into the lower, middle, and upper o'olites.

46. The *lower o'olite*, the first in the series of o'olitic deposits,

40. What is a Pteroda'ctylus? Where is it found?
41. What was, probably, the food of the Pteroda'ctylus?
42. What was the Me'galosau'rus?
43. What other fossil substances are found in lias?
44. What is o'olite?
45. How is the o'olitic system divided? How are the divisions recognised?
46. Of what does the lower o'olite consist? By what fossil is it characterized?

consists at first of layers of marl intermixed with sand, then layers of ferru'ginous o'olites, and strata of compact limestone and clays, more or less pure and fitted for the purposes of the fuller, and hence named *fullers' earth.* The first of these marly deposits joins with the marls of the lias, but is characterized by a new species of *gryphæ'a* (*fig.* 85), which is not found in the preceding layers.

47. Above these deposits are found fissile marls, limestone, with ferru'ginous o'olite; to which succeed earthy deposits, the great o'olite, which consists of a variable series of coarse shelly limestone (locally called "rag"), alternating with beds of fine soft freestone, devoid of fossils, and admirably adapted for building purposes. Above these again come marls, sands, clays, and limestones, some of which are full of shells. They are known under the names of *Bradford clay*, *Forest marble*, and *Cornbrash.* In spite of the number of fossils, often broken and in the state of moulds, found in this group, it is difficult to designate those which are certainly characteristic of it.

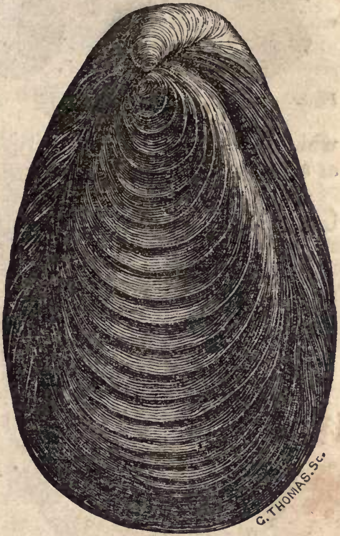

Fig. 85.—*Gryphæ'a cym'bium.*

48. To the *Gryphæ'a cym'bium* (*fig.* 85), which is characteristic of the first group of the o'olitic deposit, and forming, as it were, a new geognostic horizon, we may add the *O'strea acumina'ta* (*fig.* 86),

Fig. 86.—*O'strea acumina'ta.*

Fig. 87.—*Terebra'tula digo'na.*

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47. What is found above the lower o'olite?

which is found in the upper marls, or limestones sometimes met with in their place: different species of *Terebra'tula* (*figs.* 88, 89),

*Fig.*88.—*Terebrat. globa'ta.*

*Fig.*89.—*Tereb. spino'sa.*

*Fig.*90.—*Ammonites Brongnia'rtii.*

which seem to belong more particularly to the lower o'olite, as well as a small globose species of ammonites (*fig.* 90).

49. In the limestones proper, different species of ammonites (*fig.* 91) are found; various species of *pleurotoma'ria* (*fig.* 92),

Fig. 91.—*Ammonites stria'tulus.*

Fig. 92.—*Pleurotoma'ria conoïdea.*

which seem to be characteristic, and a great number of shells of divers kinds, are met with. Encrini'tes, frequently very numerous, which are chiefly referred to the pyriform species, *apiocri'nites*, are sometimes found on the very spot where they lived, attached to the solid materials forming the bottom of the sea of that epoch, and covered by successive deposits of the earthy matter of which it was constituted.

50. An important fact is connected with the marls and fissile limestones which form the first of the o'olite system: the first, or most ancient fossil mammals, were discovered in Stonefield slates.

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48. What fossils are characteristic of the o'olite?

49. What fossils are found in the limestone proper of the o'olite series?

50. What important fact is connected with the fissile limestone and marls of the lower o'olite?

These small animals, the lower jaw of one of which is represented (*fig*. 93), belong to the marsupials; that is, one of the most imperfect orders of the class.

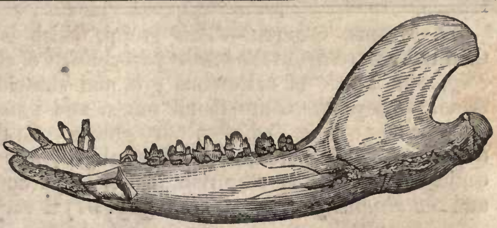

Fig. 93.—Jaw of the Dide'lphus Buckla'ndii—(twice the natural size).

Bones of large animals, thought to belong to the order of ceta'cea, are also found in the o'olitic strata.

51. Con'ifers, which are but rarely found beyond the shell-limestones, are abundantly met with in the o'olite series, of particular genera (*fig*. 94), with Cyca'deæ (*fig*. 95)—ferns of different species, differing from all those met in more ancient strata, and finally a true equisetum (*fig*. 96).

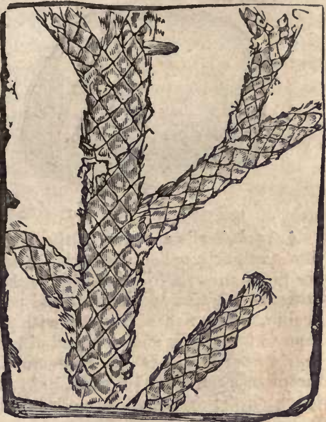

Fig. 94—Brachyphyllum.

Fig.95.—Ptero'phyllum Williamso'nis.

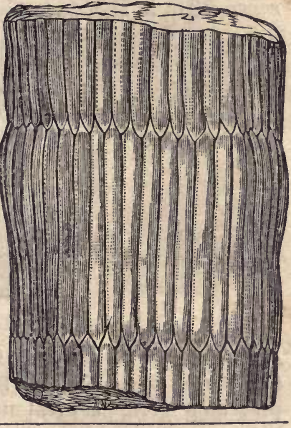

Fig 96.—Equisetum columna're.

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51. What fossil plants are found in the lower o'olite?

52. MIDDLE O'OLITE.—This group, which is less complicated than the preceding, at the lowest part consists of clay, called *Oxford clay*, with layers of calcareous grit, and stratoid masses of limestone. Above these are found sands, and limestones which are more or less o'olitic, and often ferru'ginous. In this group we find deposits of o'olitic iron, which had already appeared in the preceding series. It is very rich in fossils, particularly ammonites; and the *Ananchy'tes bicorda'tus* (*fig.* 97) is very common.

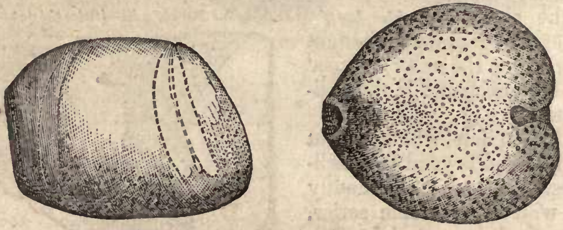

Fig. 97.—*Ananchy'tes bicorda'tus.*

Ananchy'tes is a genus of the family of Echini'deæ, or sea-urchins, sometimes vulgarly called sea-eggs. The family contains thirteen genera, which are distinguished from each other by the form and size of the ambula'cra, (*alleys*)—the narrow longitudinal portions of the shell of the echinus or sea-urchin, which are perforated with a number of small orifices, giving passage to tentacular suckers, and alternate with the broad tuberculate spine-bearing portions (*see fig.* 70)—and also by the position of the vent, and of the mouth. Figure 70, *p.* 54, exhibits the ambula'cra, between the tubercles to which the spines are attached in living species.

53. What especially characterizes the Oxford clays is the presence, often in abundance, of a new species of Gryphæ'a (*fig.* 98),

Fg. 100.—*Terebra'tula Thurma'nni.*

Fig. 98. *Gryphæ'a dilata'ta.* *Fig.* 99. *O'strea Ma'rshii.* *Fig.* 101. *Terebra'tula impre'ssa.*

the *O'strea Ma'rshii* (*fig.* 99), which already commenced in the preceding group, a great number of different terebra'tula, among

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52. Of what does the middle o'olite consist? What fossils belong to it?
53. How are the Oxford clays especially characterized?

which we find in the upper part of the series, the *Terebra'tula Thurmanni* (*fig.* 100), and the *Terebra'tula impressa* (*fig.* 101). The moulds of these shells are frequently silicious, and we find, in the upper layers, beds of silicious balls of loose texture, sometimes enclosing silicious moulds of shells.

54. The upper group of the middle o'olite, called coral o'olite, consists almost entirely of limestone; it is divided into different thick layers, which are distinguishable from each other by their structure. The first or lowest layers are ordinarily compact, greyish or yellowish, filled with polypa'ria or corals of a sac'charoïd structure, or those which have passed to the silicious state: this constitutes the *coral rag* of English geologists. Some of the succeeding layers are o'olitic, frequently of large irregular grains, mingled with fragments of rolled shells; others are compact, passing into chalk or even marl of greater or less solidity.

55. The numerous polypa'ria contained in this group present to us caryophy'llia (*fig.* 21), a'strea, meandri'na, madrepores of a great number of species, resembling more or less those of coral reefs, and a great many other genera. Among the shells, ammonites are less common; but above the o'olite, where all the organic remains are broken, the lowest layers contain a great quantity of various shells, among which are *neri'nea* (*figs.* 102, 103). The superior strata contain a great quantity of *astartes* (*figs.* 104, 105), the most characteristic of which is the *astarte minima.*

Fig. 102.—*Neri'nea Goodhallii.*

Interior of the shell, showing the plicæ of its columnella.

Fig. 103.—*Neri'nea mosæ.*

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54. What are the characters of the upper group of the middle o'olite? What is coral rag?

55. What genera of corals are found in the middle o'olite? What fossil shells do we find in this group?

Fig. 104.—*Astarte mi'nima.*

Fig. 105.—*Astarte elegans.*

Among other shells, we may cite the *Dice'ras arieti'na* (*fig.* 106); and among the echi'noderms, the *cida'ris corona'ta* (*fig.* 107).

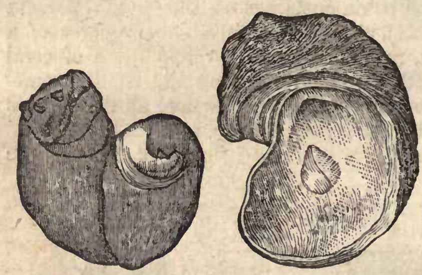

Fig. 106.—*Mould and shell of the Dice'ras arieti'na.*

Fig. 107.—*Cida'ris corona'ta.*

56. Upper O'olite.—This group is divided into *Kimmeridge clay*, and *Portland o'olite.* Kimmeridge clay, (so named because it is well exhibited at Kimmeridge Bay, and near the village of the same name, in the isle of Purbeck), is of a blue, slaty, or greyish yellow colour. Above this is the Portland stone, which, with alternations of compact, marly, sandy or o'olitic limestones, terminates the Jura'ssic or o'olitic system.

57. The organic remains which characterize this group are of the genera ostrea, and ex'ogy'ra of particular species (*figs.* 108, 109), sometimes in great abundance. With a few ammonites, we also find mya (*fig.* 111), Pholadomy'a (*fig.* 110), and Terebra'tula (*fig.* 112), which are also equally characteristic. Certain beds of this formation contain Paludi'næ, or He'lices, consequently indicating that streams of fresh water emptied into the seas of that period.

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56. How is the upper o'olite divided? What is Kimmeridge clay? What is found above the Kimmeridge clay?

57. What fossils are characteristic of the upper o'olite?

Fig. 108.—*O'strea deltoïdea.*

Fig. 109.—*Ex'ogy'ra vir'gula.*

Fig. 110.—*Pholadomy'a a'cutico'sta.*

58. The lithographic stone of Solenhofen, in Bavaria, is referred to the upper strata of the Jura'ssic system; in it are found an immense quantity of fossils, reptiles, particularly, pterodactyls, fishes, insects, plants, &c. In some parts of upper o'olite are beds of a highly bituminous shale (locally known as Kimmeridge coal); in the latest calcareous beds of the Portland group are found *cyca'deæ* (*fig.* 113).

Fig. 111.—*Mya rugo'sa.*

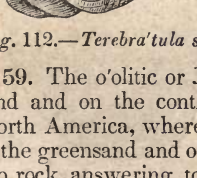

Fig. 112.—*Terebra'tula sella.*

Fig. 113.—*Za'mia feneo'nis.*

59. The o'olitic or Jura'ssic system of rocks is met with in England and on the continent of Europe, but is not represented in North America, where the transition from the new red sandstone to the greensand and other rocks of the creta'ceous period is abrupt. No rock answering to the Lias has yet been discovered in the United States.

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58. To what geological group does the lithographic stone of Solenhofen belong? What is Kimmeridge coal?

59. In what part of the world is the o'olitic system of rocks found? **Is** it known in the United States?

LESSON IV.

SECONDARY FORMATION *Continued.*

SIXTH GEOLOGICAL EPOCH.—*Creta'ceous Formation—Lower Creta'ceous System—Fossils—Wealden Deposit—Greensand—Gault—Fossils—Upper Creta'ceous System—Fossils—Extent of Creta'ceous Formation—Table of Formations.*

SIXTH GEOLOGICAL EPOCH.

CRETA'CEOUS FORMATION.

(*Secondary Formation Continued.*)

1. Next in order above the Jura'ssic system we find, in discordant stratification, immense creta'ceous deposits in a great many localities; these deposits may be divided into several others, according to the discordance of stratification observed in some of their divisions. The creta'ceous formation (from the Latin, *creta*, chalk) may be divided into the upper and lower chalk.

2. The LOWER, or INFERIOR CRETA'CEOUS system: Neocomian of the French; the Shanklin, or Lower Green Sand of the English. The first deposits formed above the o'olite are composed of marls, then a yellowish limestone, characterized by great numbers of genus *Spata'ngus* (*fig.* 114), with a multitude of the remains of shells and polypa'ria of different genera. This limestone is sometimes in continuous layers of considerable thickness, some-


Fig. 114.—*Spata'ngus retusus.*


Fig. 115.—*Exo'gy'ra subplica'ta.*


Fig. 116.—*Lima elegans.*

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1. What is found next above the Jurassic formation? Why is it termed creta'ceous? How is the creta'ceous group divided?

2. How are the first deposits above the o'olite characterized? What is lumachella? What is found next above the yellow limestone?

times only in masses agglutinated to each other by mud and sand; sometimes it is entirely wanting. Above it are clays which contain, often in great quantity, ex'ogy'ra (*fig.* 115), and oysters, among which is distinguished the great species, named *Ostrea Leymerii;* the *Lima elegans* (*fig.* 116) is also found. Among these clays are met large calcareous masses, a good deal flattened, filled with the same fossil shells, presenting *lumachella** or conchilians, which have been confounded with the Portland group, formed by an accumulation of the *ex'ogy'ra vi'rgula* (*fig.* 109). Next we have, at least in parts of France, sands and clays, sometimes variegated in colours, among which are masses of iron ore, commonly o'olitic. The remains of shells seem to give place here to ferruginous masses.

3. These last deposits seem to be wanting in other localities, in which we find, instead, great layers of limestone, more or less compact, sometimes white, sometimes coloured, which enclose hippuri'tes, spheruli'tes, and even nummuli'tes, which have been long regarded as belonging to the tertiary formation. We also find here a fossil which is very characteristic; it was at first compared to the *diceras* (*fig.* 106), but is now called *Chama ammonia* (*fig.* 117). This species of shell, which is often very abundant, is always so imbedded in the mass of rock, where it is distinguished by the sinuosities it forms, that it is very difficult to detach it entire. Various species of ammonites, gigantic hamites, several species of Crio'ceratites (*fig.* 118—from the Greek, *Krios*, a ram, and *Keras*, horn) and belemnites. The trigo'niæ, which are still met with and continued to the greensand, present here new species (*fig.* 119), which seem to be characteristic.

Fig. 117.—*Cha'ma ammo'nia.*

Fig. 118.—*Cri'oceratites Durva'llii.*

4. In the south of France and in the Pyrenees the chalk formation

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* Lumachella—an Italian word, formed from *limacea*, a snail, which is derived from the Latin, *limax.* The word is used to designate a mass formed of the remains of snails, &c. with their nacre, united by gluten—It is also called conchilian marble.

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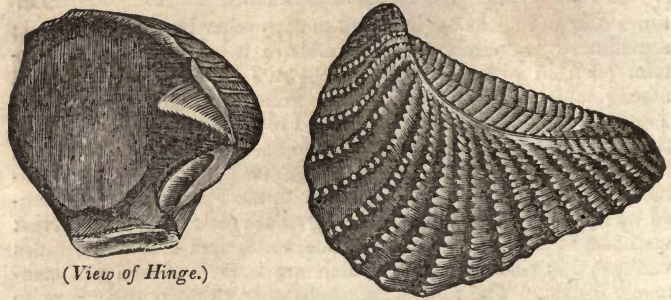
3. Are sands and clays everywhere found above the yellowish limestone? What fossils are found in these limestones of the creta'ceous group?



(*View of Hinge.*)

Fig. 119.—*Trigo'nia a'læfor'mis.*

possesses peculiar characters, both in relation to the organic remains contained in it, as well as its mineralogical relations. We there find a great many shells, very remarkable for their form and peculiar structure, which are called hippuri'tes (*figs.* 120, 121), and spheruli'tes (*fig.* 122). Many nummuli'tes (*fig.* 123), of which some deposits are formed exclusively, are also met with. It is not determined precisely to what part of the lower chalk these deposits should be referred, but

Fig. 120.—*Hippuri'tes bio'culata.*

Fig. 121.—*Hippuri'tes orga'nisans.*

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4. How is the chalk formation characterized in the south of France? What are Hippurites?

they seem to represent a part of the *neocomian* (or Shanklin) formation. In the Pyrenees the layers are often of a deep colour, and separated by argilla'ceous schists, which seems to make them a part of the transition formation; but, on the contrary, in the north part of the basin of the Gironde, they belong to the chalk.

5. The neocomian, which was not at first distinguished from other parts of the chalk formation, is now recognized in a great part of France, Switzerland, and different parts of Germany, Poland, and even to the Crimea. Here and there deposits of gypsum of greater or less extent are met with, sometimes isolated, and sometimes associated with crystalline rocks.

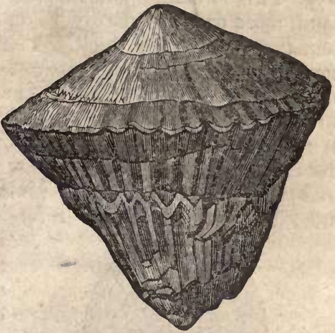

Fig. 122.—Spheruli tes ventricosa, or, Radioli'tes turbina'ta.

Fig. 123.—Nummuli'tes from the chalk.

6. The Wealden Deposit.—We frequently meet in the first deposits of the chalk formation the remains of organized bodies, which appear to belong to paludi'næ, clearly showing there was here and there an afflux of fresh water to those seas in which these remains accumulated. We also find in the same situations deposits of combustibles, which have always been known under the name of lignite (from the Latin, *lignum*, wood), probably formed from con'ifers (as dicoty'ledons did not then exist), which were doubtlessly carried by rivers: such are those in the environs of Orthez, in the department of Landes; of Bellesta and of Saint-Girons, in the department of Ariege; of Irun, in Guipuscoa (Spain), &c. But all these local deposits are nothing compared to those which have long been described in England, in parts of the counties of Kent, Surrey, and Sussex, under the name of *wealds*, from which is derived the term *wealden formation.*

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5. What is the Neocomian deposit? What is its extent?
6. What is meant by Wealden formation? Why is it so called?

7. This formation is composed of alternate layers of limestone, sand, more or less ferru'ginous, and clay, the deposits of which are sometimes extremely thick. There are entire beds of limestone composed of paludi'næ, constituting what is named *Purbeck limestone.* The laminæ of argilla'ceous matter are often covered by *cy'clades* and *anodo'ntæ*, and we find disseminated a great number of small *cypris.* There are many species of fresh water fishes, the remains of fluviatile tortoises, mingled with marine and terrestrial saurians, among which is the monstrous *i'guanodon*, which must have been thirty feet in length, to judge from the size of its bones. In this formation are found also, in the *dirt* of the Isle of Portland, the sili'cified stems of cyca'deæ (*fig.* 124), standing erect in the midst of the earth, of which the deposit consists; various species of con'ifers, equisita'ceæ, and ferns are also met. The remains of birds of the order of gra'lleæ (waders) also exist, but no mammals, although we have seen them in the marls of the o'olite (*figs.* 81, 82).

Fig. 124.—*Mante'llia nidifo'rmis.*

8. It is believed that the clays in the environs of Boulogne, which seem to be continuous with those of England on the southern side of the Channel, may be referred to the wealden deposit, as well as those of Forges and of Savigny in the country of Bray, where paludine limestones like those of Purbeck have been found. It is very certain, according to the observations of M. Leymerie, these deposits are connected with those in the department of Aube, and form part of the superior neocomian clays: if there are indications of fresh water deposits, they prove the connection between the wealden formations and those of this epoch.

9. According to English geologists, the wealden formation is below the neocomian, and is, consequently, older and not precisely contemporaneous with it.

10. Above the neocomian and wealden formations there is a group of deposits generally termed *Green Sand*, consisting of two arena'ceous beds, with a parting of clay called *gault.* The green sand formation receives its name from the prevalence of small green particles of si'licate of iron distributed through the sand. It is found in New Jersey. In England it is divided into lower green sand, gault, and upper green sand. This group consists of white

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7. What is Purbeck limestone?

8. What is the extent of the Wealden formation?

9. Which deposit lies above, the Neocomian or Wealden?

10. What is found next above the Wealden and Neocomian? From what does green sand obtain its name? How is it divided?

and yellowish sands, which are frequently ferru'ginous, containing masses of limestone, clays, and sandstones of more or less compactness: it also comprises the *quadersandstein* and *plæner-kalk* of German geologists.

11. *Gault* is a stiff clay of a blue colour, and the inferior portion of it in England abounds in iron py'rités, while the upper part contains green particles of the si'licate of iron. Various nodules and concretions are found throughout, which are sometimes fossili'ferous, but more frequently obscure and of doubtful origin. *Gault* is a provincial term, used originally in the middle of England to designate the brick-clay, which there belongs to the creta'ceous system.

12. Above the green sand formation, the calcareous part becomes more abundant; at first it is mixed with sandstone, and then, little by little, becomes isolated, and now contains only green particles of si'licate of iron, which, from being at first very abundant, gradually disappear: this is the *chloritic* chalk, which is sometimes friable, and at others solid. The green particles having totally disappeared, the limestone is found alone, sometimes in form of pure chalk, of more or less solidity, and occasionally becomes very compact; here we have argilla'ceous or arena'ceous limestone, and finally sands, or nearly pure sandstone. From these result the *chalk marl*, or representatives of it.


Fig. 125.—*Ex'ogy'ra sinua'ta.*

13. Organic remains are very abundant in these deposits, and in species and even in genera are very distinct from those of the preceding formations. Immediately above the wealden is a marly bed, characterized by the presence of a species of Ex'ogy'ra (*fig.* 125) five or six inches in diameter, not known in the neocomian. According to M. Leymerie, the *nu'cula pectina'ta* (*fig.* 126) is a characteristic shell of the gault or blue marl. Belonging to the green sand

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11. What is gault? What is the origin of the name?
12. What succeeds the green sand formation? What is chloritic chalk? What is chalk marl?
13. What organic remains are found in these deposits?

formation generally, the characteristic shells are the *inoce'ramus conce'ntricus* (*fig.* 127), the *plica'tula placu'nea* (*fig.* 128), several species of ammonites, and particularly the *ammonites monilé* (*fig.* 129), which is quite characteristic.

Fig. 126.—*Nu'cula pectina'ta (shell and mould).*

Fig. 127.—*Inoce ramus conce'ntricus.*

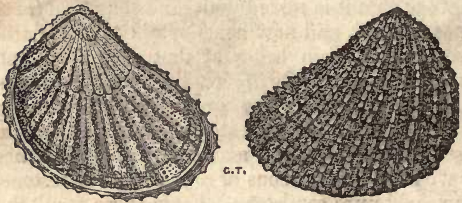

Fig. 128.—*Plica'tula placu'nea.*

Fig. 132.—*Scaphi'tes e'qualis.*

14. We find in the chalk marl the *baculi'tes* (*fig.* 130), and *turrili'tes* (*fig.* 131), different species of the first of which are found in the highest part of the chalk formation. To these may be added the *scaphi'tes* (*fig.* 132), some particular species of ammonites (*figs.* 133, 134), the *Ex'ogy'ra columba* (*fig.* 135), the *O'strea carina'ta* (*fig.* 136), the *terebra'tula octo'plica'ta* (*fig.* 137), which continue in the chalk.

Fig. 129.—*Ammonites monilé.*

Fig. 130.—*Baculi'tes.*

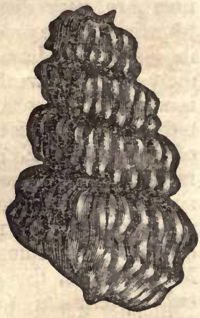

Fig. 131.—*Turrili'tes costa'tus.*

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14. What animal remains are found in the chalk marl?

Fig. 133.—*Ammonites varians.*

Fig. 134.—*Ammonites rothomage'nsis.*

Fig. 135.—*Ex'ogy'ra columba.*

Fig. 136.—*O'strea carina'ta.*

Fig. 137.—*Terebra'tula octo'plica'ta.*

Nu'cula (from the Latin, *nux*, a nut) is an inequilateral bivalve shell; the hinge is narrow, and has many teeth like those of a comb: several species are known.

Scaphi'tes (from the Greek, *scaphe*, a boat) is an eliptical, many chambered shell, somewhat resembling the ammonites.

Ba'culites (from the Latin, *ba'culum*, a stick) is a multilocular, straight, or slightly bent, and slightly conical shell; the chambers are separated by septa, pierced by a marginal siphuncle.

Turrili'tes is a spiral, turriculated, multilocurlar shell; the chambers are separated by winding septa, which have the si'phuncle in their disks: the aperture is round. This fossil must not be confounded with the *Turrite'lla*, which is a univalve, found both recent and fossil.

15. The *Upper Chalk Formation.*—In this we find chalk with and without flints. The layers of flint are frequently almost the only indications of stratification afforded by the mass. It is frequently soft, and susceptible of solution or suspension, as in Spanish whiting, which contains an immense quantity of microscopic shells, belonging to the group of *foraminifera.* In some cases it is arena'ceous, and sometimes very compact. Although often white, we find it in some places coloured grey, yellow, red, &c.;

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15. How is the upper chalk formation characterized?

sometimes it is o'olitic in character, and becomes almost crystalline, even magnesian, and in localities remote from crystalline materials which might affect it. The inferior part of this formation is frequently soiled with clays—*chalk marl*. Above it is more pure, and contains a great many nodules of flint or silex. Though this character is very common, it is wanting in a great many places. At its upper part the chalk formation becomes very sandy, as in the neighbourhood of Maëstricht.

16. Excepting the ba'culites found at Maëstricht, the remains of cephalopods are not found in the upper creta'ceous formation; but belemni'tes (from the Greek, *belem'non*, a dart) of particular species, such as *fig*. 138, and many other organic remains not met with in the chalk marl, are found: among them are the *plagio'stoma spino'sum* (*fig*. 139); the *o'strea vesicula'ris* (*fig*. 140);

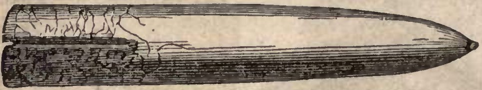
Fig. 138.—*Belemni'tes mucrona'tus.*

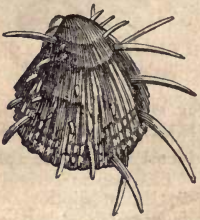
Fig. 139.—*Plagio'stoma spino'sum.*


Fig. 140.—*O'strea vesicula'ris.*

the *Ca'tylus Cuvieri* (*fig*. 141), the structure of which is fibrous; the *Terebra'tula Defra'ncii* (*fig*. 142); the *ana'nchytes ova'tus* (*fig*. 143); the *Spa'tangus cor-an'guinum* (*fig*. 144).

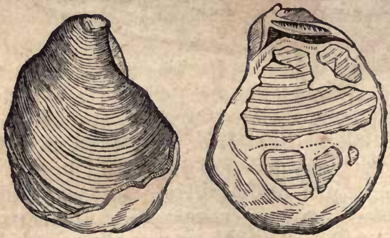
Fig. 141.—*Ca'tylus Cuvieri.*


Fig. 142.—*Terebra'tula Defra'ncii.*

16. What organic remains are found in the chalk formation?

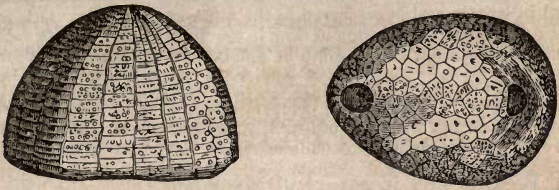

Fig. 143.—*Ana'nchytes ova'tus.*

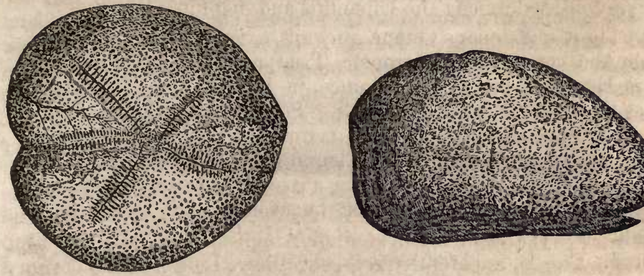

Fig. 144.—*Spa'tangus cor-an guinum.*

17. In the upper part of these deposits we find, among many other fossils, an enormous saurian, called the Mosasaurus (from the name of the river Meuse, and the Greek, *sauros*, lizard), originally found on the banks of the Meuse, in the celebrated quarries of St. Peter's Mount, near Maëstricht (*fig*. 145). Organic remains of a Mosasaurus have been found in New Jersey.

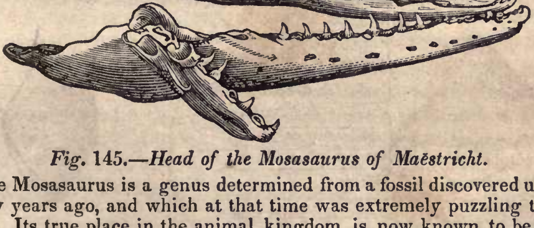

Fig. 145.—*Head of the Mosasaurus of Maëstricht.*

"The Mosasaurus is a genus determined from a fossil discovered upwards of sixty years ago, and which at that time was extremely puzzling to naturalists. Its true place in the animal kingdom is now known to be among the Lacertian Saurians; but the animal appears to have been perfectly marine in its habits. The head, the only part at first discovered, measured

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7. Where is the Mosasaurus found? From what is its name derived?

four feet in length, and is preserved in the museum at Paris. Other parts have also been found from time to time in the Maëstricht quarries, and some fragments in the chalk of the south of England." *Ansted.*

The whole length of the animal was probably not less than twenty-four feet, a magnitude which must be compared with that of the lizards of the present day, and not with the crocodilians, whose structure is totally different.

18. We also find in the chalk formation ceta'ceous mammals, which are classed among the lamantins and dolphins.

19. The CRETA'CEOUS GROUP prevails extensively in England and on the continent of Europe. True white chalk exists not only in England, but also in France, in Denmark, in Poland, in central Russia, and in the Caucasus. Semicrystalline rocks of the creta'ceous epoch also exist in the central plains of Asia Minor. Beds of the creta'ceous period are found in New Jersey, and other parts of the United States; but they rest on the oldest secondary rocks, without the intervention of the o'olite. The formation is extremely calcareous, in places chiefly arenaceous, but no true chalk has yet been discovered in America; nor has o'olite been found. Fossils, apparently creta'ceous, have been recently obtained from south-eastern India.

☞ This brings us up to the close of the secondary formation. As far as we have studied our subject, we find the earth's crust to consist of a series of formations, as represented in the following diagram (*fig.* 146).

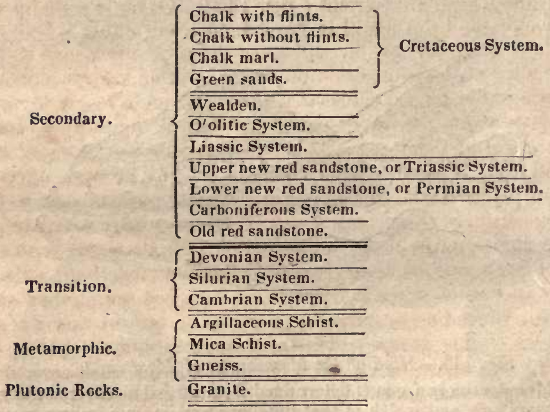

Fig. 146.

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18. What mammals are found in the chalk formation?

19. What is the extent of the creta'ceous group? Has chalk been found in the creta'ceous formation of the United States?

The study of the creta'ceous rocks brings us, as it were, to the termination of that period in the history of the earth's structure to which the character of antiquity belongs. In the succeeding period, we shall find all the fossils are either resemblances or types of existing organic creatures.

LESSON V.

SEVENTH GEOLOGICAL EPOCH.—*Tertiary Formation—Eocene beds—Paris Basin—Fossils—Anoplothe'rium—Paleothe'rium—Miocene beds—Dinothe'rium—Lignites—Pliocene beds—Fossils—Bone Caverns.*

SUPERFICIAL DEPOSITS.—*Drift—Diluvium—Megathe'rium—Boulder Formation—Alluvium—Big Bone Lick.*

EIGHTH GEOLOGICAL EPOCH.—*Modern Formation.*

SEVENTH GEOLOGICAL EPOCH.

TERTIARY FORMATION.

1. Ordinarily, geologists designate under the collective name of SECONDARY FORMATION, the long series of systems of rocks, commencing above the transition formation with old red sandstone and coal (*fig.* 146), and terminating above with the chalk; and they give the name of TERTIARY FORMATION to those strata which are more recent than the chalk, and consequently superior to it, but still more ancient than the strata of the present or modern epoch.

2. During that period the seas were very much less extensive than they were in the more remote geological ages, and consequently the sedimentary deposits formed in those waters are of less extent and more isolated. Moreover, their formation was effected at different points of the globe, and at different periods, and to follow their history in chronological order, it is necessary to subdivide them into three groups. At the period contemporaneous with the deposit of each one of these series of formations, there existed particular species of organized creatures, mingled with other species like the preceding or succeeding periods; but the fauna of all the divisions of this period possesses certain common characters, and among the most remarkable of these is the existence of a great number of mammals.

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1. What is understood by secondary formation? What is meant by tertiary formation?

2. How did the seas of the tertiary epoch differ from those of more remote geological ages? What is the most remarkable characteristic of the tertiary formation?

3. The Tertiary Formation is divided into the older, middle, and newer tertiary groups, which have been conveniently designated by Mr. Lyell under the names of Eocene, Miocene, and Pliocene.

The first, EOCENE (from the Greek, *eôs*, dawn, and *kainos*, recent), designates the older tertiary strata, in which there appears, as it were, the first dawn of existing species.

The second, MIOCENE (from the Greek, *meiôn*, less, and *kainos*, recent), is applied to the middle tertiary strata, because in them we find more recent species than in the preceding group, but still *fewer* recent than extinct species.

The third, PLIOCENE (from the Greek, *pleiòn*, more, and *kainos*, recent), is given to the newer tertiary beds, because there is always a greater number of recent than of extinct species found in them.

4. The *Eocene, or older tertiaries.*—The beds thus designated are a very variable series, consisting, in England and Belgium, of stiff clays alternating with sand, and resting on coarse sand and gravel; and, in Paris, of a number of limestones and marls, alternating with gypsum and silicious strata. They are deposited in basin-shaped depressions in the older rocks, and in England some portion of them has been so greatly disturbed, that the beds are actually vertical.

5. The older tertiaries of England are chiefly confined to three masses, contained in trough-shaped basins, called respectively, the London, the Hampshire, and Isle of Wight basins; a stiff clay predominates in them, and, from being very abundant near London, is known as the "*London clay.*" The London clay often, but not always, rests on a series of sandy and gravelly beds, inclosing bands of potters' clay, to which the name of *Plastic clay* has been given.

6. The greatest development of eocene strata in the United States occurs in Virginia, North and South Carolina, Georgia, and Alabama. In Virginia these beds consist of greenish sands, nearly identical in appearance with a portion of the creta′ceous series, and of the same mineral composition; and a little further to the south a continuous formation of white limestone ("Santee limestone") occurs, which is of no great thickness, and which varies in hardness, and is composed of comminuted shells, but so closely resembling certain creta′ceous beds of the secondary period in New Jersey, as to have been frequently mistaken for them. But this resemblance does not extend to the fossil contents of the beds,

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3. How is the tertiary period divided? What is meant by Eocene? What by Miocene? What by Pliocene?

4. What are the characters of the Eocene beds? How are they deposited?

5. What are the chief localities of Eocene beds in England? What is London clay?

6. In what parts of the United States do Eocene strata exist?

which are in many instances analogous, or the same as those of the eocene formations in other parts of the world.

7. The geological position of the city of Paris resembles that of London, each being situated upon an extensive and important group of tertiary strata, which occupies a depression or basin in the underlying chalk. The nature of the two deposits is, however, totally different, the deposit being characterized in England by great accumulations of argillaceous matter, which form the *London clay*, while in the neighbourhood of Paris there is a varied series of limestones and marls, alternating with important beds of gypsum and silicious matter.

8. The depression in the chalk forming the celebrated Paris basin so frequently named by geologists, which is filled up by these strata, is nearly one hundred and eighty miles in its greatest length, and about half that in breadth. The surface of the chalk is usually covered by broken and rolled flints, often cemented by a silicious sand into a kind of breccia; and these flints seem to mark the action of the sea upon reefs of chalk before the commencement of the tertiary epoch.

The order of stratification of the Paris basin is represented in the following table.

8. Upper marine sands. 7. Upper fresh water sands.
6. Green marls.
5. Gypsum.
4. Calcaire siliceux, or Fresh water limestone. 3. Calcaire grossier, or Marine limestone.
2. Plastic clay.
1. Chalk.

9. Above the chalk we find, first, deposits of *plastic clay*, so called because varieties of it are well suited for the manufacture of pottery. In the neighbourhood of Montereau on one side, between Houdan and Dreux on the other, it is remarkable for its whiteness and purity, and is used in the fabrication of the finest porcelain. Around Paris it is coloured and impure, and suitable only for coarse pottery. These clays contain lignite, in which we see, perhaps for the first time, mingled with numerous co′nifers, phanero′gamous monocoty′ledons, true palms, and some dicoty′ledons. Marine, as well as fresh water shells, are found in its upper part.

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7. In what respects does the geological position of Paris differ from that of London.

8. What is the extent of the Paris basin?

9. What lies next above the chalk in the Paris basin? What are the characters of plastic clay? To what uses is it applied?

10. Above the plastic clay we find thick deposits of marine limestones, more or less arenaceous in structure, the different beds of which may be easily distinguished by their characters. These limestones contain a prodigious quantity of *mil'liolites* (*fig.* 147) — extremely small shells—the most of which do not attain .03937 of an inch in size, and yet they constitute a great number of genera. These serve, in a manner, as paste to an immense number of shells of different genera, which are more analogous to creatures now living than any we have hitherto mentioned: three per cent. of them are even identical with species now existing in the neighbouring seas. The cerithia are here so abundant that the formation is sometimes known by the name of *cerithia limestone*, although these same fossils are found in many other deposits. There are certain species which are characteristic,—that is, they are always found wherever these deposits exist: such, for example, is the *Ceri'thium giga'nteum* (*fig.* 148),

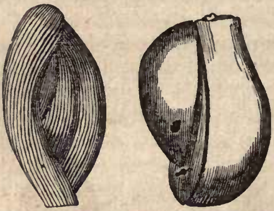

Fig. 147.—*Mil'liolites (greatly magnified).*

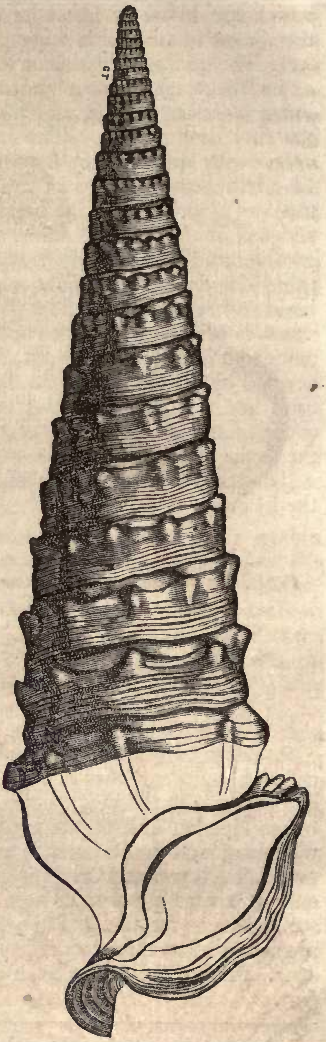

Fig. 148.—*Ceri'thium giga nteum (very much reduced).*

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10. What lies above the plastic clay? What are mil'liolites? What proportion of fossil shells found in eocene strata resemble living species? What is Cerithia limestone?

Fig. 149.—*Turrite'lla imbricata'ria.*

sometimes twenty-seven inches in length, the extremity of which is almost always worn or broken by the friction and knocks occasioned by the movement of the animal. Among other shells, of which there are a great many species, it is difficult to name any which are absolutely characteristic; among the most common are the *Turrite'lla imbricata'ria* (*fig.* 149); the *ampulla'ria acuta* (*fig.* 150); the *terebe'llum fusifo'rmé* (*fig.* 151); the *mitra scabra* (*fig.* 152); the *crassate'lla sulca'ta* (*fig.* 153); the *car'dium porulo'sum* (*fig.* 154). With these species are found a great many others, which have been described and figured in a great many books on the environs of Paris; there are species which are much more com-

Fig. 150—*Ampulla'ria acuta.*

Fig. 151.—*Terrebe'llum fusifo'rmé.*

Fig. 152.—*Mitra scabra.*

Fig. 153.—*Crassate'lla sulca'ta.*

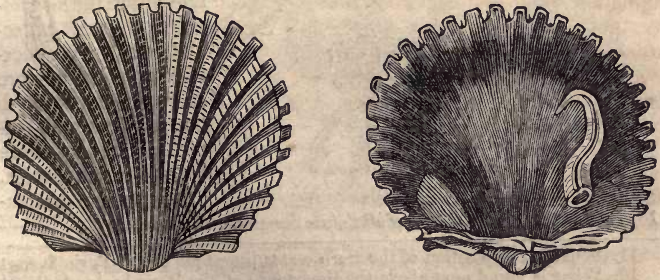

Fig. 154.—*Car'dium porulo'sum.*

mon than thôse named, but some of them are not found everywhere, and others are seen first in the superior formations.

11. Above the marine limestone, or rather parallel with it, we find what is named fresh-water or silicious limestone, so called because there is mingled in it a considerable quantity of silex, sometimes uniformly disseminated, and at others forming here and there more or less voluminous masses (*fig.* 155), which constitute the *millstone without shells*, which is wrought into millstones. Fluviatile shells are found in the lower parts of this bed, such as lymnea and planorbis.

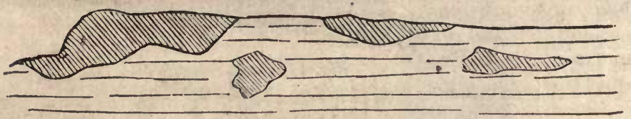

Fig.* 155.—*Fresh-water limestone, with masses of millstone without shells.

12. The next group in the general series of Paris basin rocks consists of white and green marls, with a considerable quantity of gypsum, the latter being chiefly developed in the centre of the basin. The upper parts both of the marine and fresh-water limestone alternate occasionally with marls; but the latter form, on the whole, a distinct overlying group of fresh-water origin, and contain land and fluviatile shells, fragments of wood, and great numbers of the bones of fresh-water fishes, of crocodiles, and other reptiles, of birds, and even of quadrupeds, the latter being usually isolated and often entire. The gypsum beds having been extensively quarried for the manufacture of "plaster of Paris" (obtained by burning the gypsum), they have yielded a multitude of these mammalian remains, which formed the base of the great discoveries of Cuvier—so that the investigation of them by that anatomist may even be considered to have laid the foundation of the science of Palæonto'logy, so far as it is dependent on sound principles of analogy. It is chiefly in the lower parts of the gypsum that these extinct quadrupeds are found. Such, for example, are the *anoplothe'rium* and *paleothe'rium*, pachydermatous animals, more or less approaching to the rhinoceros and tapir, of which there were several species. The common *anoplothe'rium* (*fig.* 156—

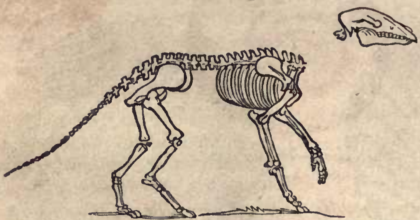

Fig. 156.—*Skeleton of the Anoplothe'rium communé.*

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11. What is the position of the fresh-water limestone of the Paris basin?

12. What is found next above the limestones of the Paris basins? What is plaster of Paris? What fossils are found in the gypsum? What is the Anoplothe'rium?

from the Greek, *a*, without, *oplon*, arm, and *therion*, animal), was of the size of an ass, of a heavy form, and with thick short legs and a long tail; some species had slender legs, and must have been swift and active; and others of the size of a hare, and even of a guinea-pig, which were nevertheless adult.

13. The *paleothe'rium* (*fig.* **157**—from the Greek, *palaios*, ancient, and *therion*, a beast), was of the size of a horse, and form of a tapir; species of various size, both large and small, existed.

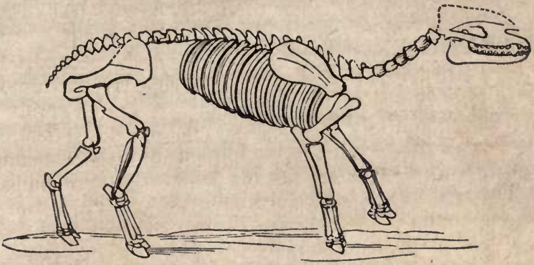

Fig. 157.—*Skeleton of the Paleothe'rium magnum.*

14. Above the gypsum we find another more modern group, consisting of two formations, one marine and the other fresh-water. They are composed of marls, mica'ceous and quartzose sands, and layers of flint. These beds of sand are often of great thickness, and are at first coloured by oxide of iron, and then white and pure: they frequently form masses of sandstone, sometimes without organic remains, or only rolled shells of the marine limestone; sometimes, on the contrary, they contain the casts or impressions of shells. On these sandstones repose new lacu'strine deposits, forming sometimes *shell millstone*, filled with *lymneæ* (*fig.* 158), *plano'rbis* (*fig.* 159), and seeds of *chara*, or *gyro'gonites* (*fig.* 160).

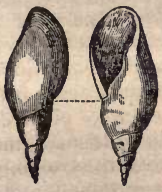

Fig. 158.—*Lymnea longisca'ta.*

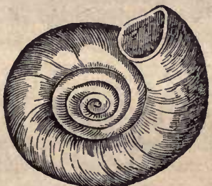

Fig. 159.—*Plano'rbis cuom'phalus.*

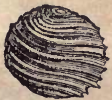

*Fig.*160.—*Chara medicage'nula* — (*greatly magnified.*)

15. The *Miocene, or middle tertiary period.*—During this second part of the tertiary period both terrestrial and aquatic ani-

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13. What is the Paleothe'rium?
14. What lies above the gypsum?

mals became more numerous, and more like those of our own times; then there existed a great number of mollusks, belonging to species which still inhabit the seas of the present epoch.

16. In England the miocene tertiary is represented by a thin and variable heap of gravelly strata, called the "crag formation," which is divided into three parts. The lowest is called *coralline crag*, because a great many coral remains are found in it; the next is the *red crag*, distinguished by its deep ferru'ginous stain; the uppermost is named *Norwich*, or *mammali'ferous crag*, which is of more recent origin than the red crag, and contains bones of large mammals, and occasionally fresh-water shells.

17. An extensive series of miocene beds occupies the whole surface of both shores of the Chesapeake Bay, a hundred miles north and south, and fifty miles wide. A similar series occurs in Virginia. The lowest beds of the Chesapeake series are argilla'ceous, and the uppermost are sandy; both series abound in fossils, and when met on the side of a river they are sometimes found to consist of little else than shells and the remains of zo'ophytes, often in a high state of preservation.

18. The miocene tertiaries prevail extensively on the continent of Europe in various river basins. They occupy a considerable portion of the west of France, filling up the basins of the Loire and Garonne; they fill up also a great part of the valley of the middle Rhine, and the whole of the great valley of Switzerland, between the Alps and the Jura chain; and from Switzerland they extend towards the north-east, following the course and partly filling up the valley of the Danube. From point to point they may here be traced spreading out into extensive series near Vienna, and in Styria, and occurring again in the plains of Hungary; they are also found in Poland and Russia; they appear both in northern and southern Italy, and on the shores and islands of the Mediterranean.

19. The miocene beds of the basin of the Loire are chiefly developed near the city of Tours, and in the Touraine district, where they consist for the most part of broken shells; these beds, however, sometimes afford a building stone, the comminuted shells being mixed with sand and gravel, and cemented by calcareous matter. In Switzerland there is a series of tertiary sandstones of the miocene period; and between the lakes of Geneva and Lu-

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15. What is remarked of the miocene period, as respects animals?

16. How are the miocene beds represented in England? What is coralline crag? What is red crag? What is Norwich crag?

17. In what part of the United States do we find examples of miocene beds?

18. Where do we find miocene beds in Europe?

19. What is the nature of the miocene beds in Switzerland? What is molasse?

cerne these beds consist of a coarse conglomerate, called "nagelfluhe," passing into a finer sandstone (the "molasse" of French geologists), which is usually soft and incoherent, but sometimes sufficiently hard to be used as a building stone. Various beds of lignite and marl are irregularly distributed through the molasse, which are evidently of fresh-water origin.

20. The marine deposits of the miocene strata, although abounding in shells, do not contain as great a number of species as the marine limestone of the Paris basin; yet, eighteen per cent. of these species are identical with those now living in the neighbouring seas. There is often the strongest analogy between these new deposits and the lower limestones, with which they have been confounded; yet, if we do frequently observe a common aspect, and often find the same shells in both, there is, nevertheless, essential differences between them. In one case, we no longer find species characteristic of the lower deposits; there is no *ceri'thium giga'nteum*, no *car'dium porulo'sum*, &c.: in the other, we find new remains which we did not meet with before, such as the *Bala'nus cra'sus* (*fig.* 161), the *Rostella'ria pespelica'ni* (*fig.* 162), the *Pe'cten pleurone'ctes* (*fig.* 163), &c., which are never found in the Paris basin, but exist in the subapennine formation.

Fig. 161.—*Bala'nus crasus.*

Fig. 162.—*Rostella'ria pespelica'ni.*

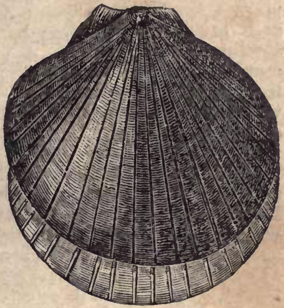

Fig. 163.—*Pe'cten pleurone'ctes.*

21. The strata belonging to this period of the tertiary formation contain divers species of *paleothe'rium*, but differing from those found in the Paris gypsum. Here we also find several other species of animals, which constitute genera, no trace of which is met with in the preceding formation, and which totally disappear in the succeeding epoch. Here we find the remains of *ma'stodons* (from the Greek, *mastos*, a nipple, and *odous*, tooth), animals analogous

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20. What is the character of the fossils of these beds? What proportion of them resemble recent or living species?

Fig. 164.—*Tooth of a ma'stodon* (*reduced*).

to the elephant, but whose teeth (*fig.* 164) have crowns studded with conical or nipple-like points, instead of being flat. On the miocene beds we also find the gigantic *Dinotherium* (from the Greek, *dinos*, circular, and *therion*, a beast), an animal resembling the tapir, which is remarkable by having the tusks turned downwards (*fig.* 165). It was first found in Hesse, afterwards near Auch by M. Lartet, who subsequently found in the same place the bones of monkeys.—Remains of the rhinoceros, of the hippopo'tamus, and of the castor are also found in these deposits.

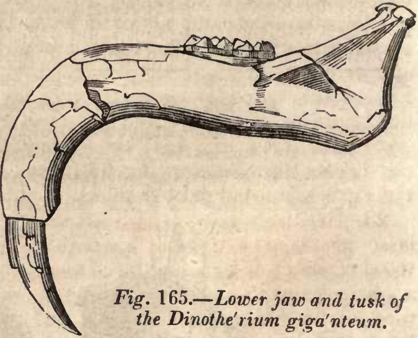

Fig. 165.—*Lower jaw and tusk of the Dinothe'rium giga'nteum.*

"The Dinothe'rium is the largest of the terrestrial mammalia of whose existence we have any positive knowledge, but as it is not a matter of absolute certainty at present of what nature its extremities may have been, we are hardly in a condition to speak very decidedly of its general appearance or habits. It is chiefly known by the fragments of the head and teeth, which exhibit a near approach, the former to the ceta'cean tribe, and the latter to the tapir; but there is a remarkable and very striking anomaly in the existence of two large and heavy tusks placed at the extremity of the lower jaw, and curved downwards like the tusks in the upper jaw of the walrus. It is probable, from the size and position of these tusks, as well as from the structure of the bones of the head, that the animal was aquatic in its habits, living almost entirely in the water, and feeding on such succulent plants as it could there obtain.

"The length of the Dinothe'rium is calculated to have been at least as much as eighteen feet, and its proportions were, probably, very much the same as those of the great American tapir. It was provided with a trunk, which seems to have been short, but extremely large and powerful, and capable of being employed to tear up the food which the tusks, acting like pick-axes, may have loosened." *Ansted.*

22. The miocene is very rich in combustible material; to it belong the lignites of Languedoc, of Provence, Switzerland, and most of those of Germany—as well as the masses of earthy com-

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21. What fossil animal remains are found in these beds? What is the Dinothe'rium?

bustible in the neighbourhood of Cologne. All these lignites appear to have been formed chiefly from con'ifers, the structure of which (*fig.* 166) may be recognised in the mass of combustible itself, or in the wood disseminated through various deposits.

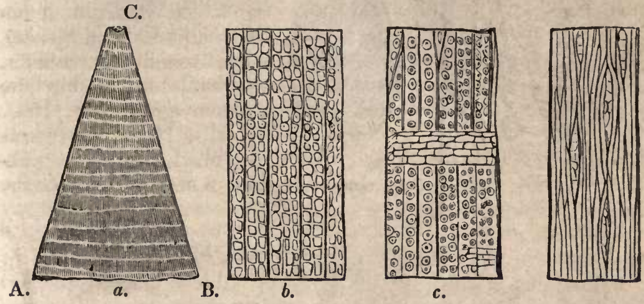

Fig. 166.—*Structure of the wood of con'ifers.*

a. Part of a transverse section of natural size.
b. Part of the same section seen under a microscope.
c. Longitudinal section, in the direction from B to C, also magnified.
d. Section in the direction from A to B.

23. But the tertiary sandstones of the miocene period (the molasse) also contain a great quantity of dicoty'ledonous plants, the wood of which is here and there found disseminated, sometimes in a silicious state, and clearly exhibiting the proper tissue or structure of this class of plants (*fig.* 167), particularly characterized by the presence of large longitudinal vessels. We also find leaves,

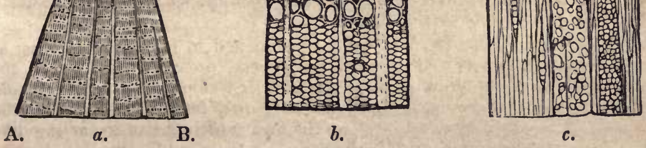

Fig. 167.—*Structure of the wood of dicoty'ledons.*

a. Part of a transverse section of natural size.
b. Part of the same section, seen under the microscope, showing the large vessels.
c. Longitudinal section in the direction from A to B, showing the structure of the medullary rays, and that of a large vessel.

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22. What is lignite? From what family of plants were these lignites probably formed? How is this family of plants recognised?

23. What description of plants exist in the tertiary sandstone of the miocene period?

Fig. 169.—*Comptonia a'cutilo'ba.*

Fig. 168.—*Leaf of an undetermined elm.*

often in great numbers, in the clays which accompany the lignites, in the characters of which we distinctly recognise existing dicoty'ledons, such as walnuts, maples, elms, birches, &c. (*figs.* 168, 169). Even fruits are found which re distinguished, often with difficulty, from those now growing.

24. We also find in this formation, either in the midst of deposits of combustible—, as in those of Liblar near Cologne, or in the argilla'ceous or sandy matter of the formation, the remains of monocoty'ledonous plants: there is wood presenting the structure of the palms, that is, an assemblage of woody fasciculi (bundles), longitudinally arranged, without regard to regularity, in the middle of cellular tissue, as seen (*fig.* 170). Leaves like the representation (*fig.* 171) are also met with. We find, too, in the miocene gypsum of the same nature as that of the Paris basin, which has led to the supposition that they were of the same epoch; but besides this section of country being formed of the "molasse," the organic remains are not of the same species.

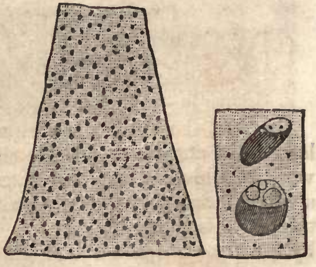

Fig. 170.—*Structure of the wood of palus.*

Fig. 171.—*Palmacites Lamanonis.*

Towards the close of the miocene, or second epoch of

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24. How do we recognise the previous existence of monocoty'ledonous plants from their fossil remains?

the tertiary period, a new upheaval appears to have taken place in the region of the Alps. A part of this complicated chain of mountains had then long existed. Thus the Alps of Provence and of Dauphiny, which belong to a system of which Mont-Viso is the most remarkable point, date from the interval elapsed between the deposit of the inferior and upper layers of the creta'ceous system; other portions of the Alpine region were raised up at the same time as the Pyrenees, that is, after the creta'ceous period; for example, the neighbourhood of Castel-Gomberts, and in the mountains which connect the Alps to the Jura, we perceive traces of an upheaval contemporaneous with that of Corsica, which occurred after the deposit of the eocene, or first period of the tertiary formation; but the greater part of this majestic barrier between Italy and the north seems to have acquired its present configuration, and to have attained the immense height we now observe, in more recent times. The chain of the western Alps appears to have been upheaved after the deposit of the miocene or second series of the tertiary; and the chain extending from Valais towards Austria appears to be of still more recent origin.

Dating from the geological convulsion which gave to the western Alps their existing prominence, and at different points produced the elevation of the "molasse," and other tertiary strata of the miocene period, as well as those of more ancient epochs, Europe presented a great continental space; and during the period of tranquillity which followed this catastrophe, marine deposits did not take place except on the shores or in gulfs not far from the centre of this region, as in the subapennine hills, in some parts of Sicily, and on a portion of the coast of England; but sedimentary deposits occurred in the basins or valleys of still existing rivers, and in some lakes of fresh water which a more recent geological revolution has caused to disappear.

25. The *Pliocene, or newer tertiary.*—In Europe the pliocene is chiefly represented in south Italy, in the Morea, and in the islands of the eastern archipelago; and important contemporaneous beds exist in the valley of the lower Rhine, near Bonn, and a portion of central France, as well as in southern Russia.

26. The pliocene beds are not all, however, of the same age, and the beds so called must have been in the course of formation for a very long period. Those of Italy admit of being subdivided into two groups, the older of which is called the sub-apennine, and attains a great thickness near Parma, exhibiting a considerable number and variety of fossils. These beds consist for the most part of greyish, brown, or blue marls, containing calcareous matter, and overlaid by thick sandy beds. The Sicilian beds are distinctly newer than these, and are equally extensive. Marls, with occasional limestone, form the great mass of the materials of these strata. Like the subapennines they are richly fossili'ferous, but are chiefly characterized by their shells. A fresh-water bed of the newer period is found at Œningen, on the lake of Constance, and contains numerous remains of fishes, and some fragments of land animals.

27. From the eocene, or deposits of the Paris basin, there is a

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25. In what parts of Europe are the pliocene beds represented?

26. Are all pliocene beds of the same age? What is the character of the Sicilian beds?

progressive increase in the number or proportion of recent species found: in the Paris basin three per cent. of the fossil shells are analogous to the shells now existing; in the miocene, eighteen per cent., and in the pliocene fifty per cent. of the fossil shells resemble existing species. There is scarcely any analogy between the shells of the Paris basin limestone and those of the subapennine hills. Besides the *Balanus crasus* (*fig.* 161), and the *Rostella'ria pespelica'ni* (*fig.* 162), we may cite the *Pleuro'toma rota'ta* (*fig.* 172), the *Buc'cinum prisma'ticum* (*fig.* 173), the *Volu'ta Lambe'rti* (*fig.* 174), &c., and almost all the shells of the Mediterranean.


Fig. 172.—*Pleuro'toma rota'ta.*


Fig. 173.—*Buc'cinum prisma'ticum.*


Fig. 174.—*Volu'ta Lambe'rti.*


Fig. 175.—*Murex alveola'tus.*


Fig. 176.—*Astarte Basteroti.*


Fig. 177.—*Cy'prea coccinelloïdes.*

The deposits alluded to also contain masses of lignites, which are advantageously worked in different localities. Some offer regular layers of a sort of compact coal (brown coal), accompanied by fresh-water shells, indicating a tranquil deposit in lakes; but the greatest number contain only irregular masses of wood, some of which present the texture of the con'ifers. A great number of leaves, analogous to those of existing dicoty'ledons, are also found.

27. What proportion of fossils found in the eocene, miocene, and pliocene respectively, resemble species now living?

28. The pliocene beds of the United States seem to belong chiefly to a very modern period; they exist to a great extent in several localities. At the mouth of the Potomac, in Maryland, is a series of clay beds, alternating occasionally with sand. All the fossils found in these beds are identical with those species found living on the neighbouring sea-coast, a positive indication of the newness of these beds. Similar beds exist at Niagara and in Kentucky, and in other parts of North America; in all cases the recent deposits are very striking.

29. While these lacu'strine deposits were tranquilly forming beneath the waters, the then uncovered surface of the earth was inhabited by hyenas, cavern bears, hairy elephants, ma'stodons, rhinoceroses, hippopo'tami and other animals belonging to genera still in existence, but the species of which are now lost; they appear to have been destroyed in the geological revolution which raised up the principal chain of the Alps, and gave to these mountains their present configuration, and its present shape to the European continent. It is probable, too, that the same revolution destroyed the multitude of animals whose bones are found at the bottom of certain caverns or fissures in the rocks, where they are buried in a sort of calcareous cement, ordinarily of a reddish colour.

30. Bone Caverns.—The most ancient caverns, celebrated for the remains of mammals which they contain, are those of Harz and of Franconia; but since Dr. Buckland has shown the propriety of removing the mud, sands, rolled flints, stala'gmites, &c., which often cover the bone collections, these remains have been found everywhere, even in places where they had not been previously supposed to exist.

31. Most of these caverns appear to have had one or more lateral openings, affording easy entrance to the animals that frequented them, as places of refuge, to devour their prey, and finally they came to them to die. Here their bones accumulated through a great many generations, and we now find them buried in a dark earth, in or on which we recognise their dejections. Often we find among the bones of a certain genus of animals other bones, having upon them the print of teeth, showing they had been the prey of the first. The greater number of these bones belong to the bear tribe, two species of which were larger than any now existing; or to the hyena tribe, also larger than those now known. Sometimes one, and sometimes the other of these genera predominates; a species of wolf abounds in the bear caverns of Galenreuth in Franconia: other carni'vora, of the genus dog, and those of the genus cat, including species of cougars, are everywhere in small

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28. In what parts of the United States do pliocene beds exist?

29. What kind of animals inhabited the land while these lacu'strine deposits were being formed?

30. What are bone caverns?

31. What are the features of bone caverns?

numbers. The remains of rodents, of ruminants, also of large pachyderms and of birds, which have been dragged as prey to these resorts, are also found.

SUPERFICIAL DEPOSITS.

"The regularly stratified deposits, of whatever geological period they may be, are in most parts of the world covered up, more or less, by a considerable mass of heterogeneous material derived from the degradation of the more ancient rocks. This mass is generally unstratified, and deposited in irregular heaps, partially filling up valleys, covering low tracts of level country, and sometimes even capping low hills, but almost always bearing marks of having been transported from a distance over ranges of high land, although not without some reference to the present physical features of the country over which it has travelled.

"Occasionally the fragments which have been thus conveyed are of large size and angular, and in this case they are called "boulders," or "erratic blocks;" but such masses have not generally travelled to any very considerable distance from the parent rock. The transported fragments are much more commonly of small size, and rounded, as if by mutual attrition, at the bottom of the sea; and in this state they have been often carried to very great distances, and are found many hundred miles from the place whence they seem to have been derived. They are then called 'gravel,' and are not unfrequently mingled with bones and fragments of bones of large quadrupeds." *Ansted.*

32. These superficial deposits are termed DRIFT, and comprise deposits of water-worn, transported materials, consisting of gravel, boulders, sand, clay, &c.

33. Drift is divided into DILU'VIUM, or ancient drift, and ALLU'VIUM (from the Latin, *alluo*, I wash upon), or modern drift.

Fig. 178.—*Skeleton of the Megathe'rium.*

34. The DILU'VIUM (formed from the Latin, *diluo*, I wash away) covers up the tertiary deposits, and contains fossils whose origin dates back to a period not very long antecedent to the present. In fact the dilu'vium, to a certain extent, unites the tertiary with the recent period. It contains the bones of large mammals, both of extinct and recent genera and species. Among them we may perhaps place the enormous megathe'rium (*fig.* 178 — from the

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32. What is meant by drift?

33. How is drift divided? What is the difference between dilu'vium and allu'vium?

Greek, *megas*, great, and *therion*, beast), which was not less than eighteen feet long and nine feet high. The skeleton is analogous to that of animals of the order edentata. The thigh-bone in the megathe'rium is nearly three times as great as the largest known elephant; the bones of the instep and those of the foot are of corresponding size, the heel-bone projects back nearly eighteen inches, and the small bones of the foot advanced as much forwards. The third toe is provided with a socket to receive a claw, the sheath of which measures thirteen inches in circumference, and the core on which the nail was attached is ten inches in length. The fore limbs were well adapted for grasping the trunk or larger branches of a tree. This animal was slow in its movements, and probably fed on roots, which its teeth were admirably adapted for grinding.

35. To the diluvial drift are also referred the great collections of bones of the Icy ocean, on the coasts of Siberia and on the neighbouring islands: there a number of enormous animals, their flesh preserved through thousands of years, lie buried in sands consolidated by perpetual ice; in the same situations have been found stags and horses, the elephant and rhinoceros, covered with hair, seemingly indicating that the species which then lived in northern climates were enabled to bear, from being clothed in fur, lower temperatures than those with naked skins which now inhabit southern Asia and Africa. The tusks of these elephants of the ancient world are sought for the ivory they afford, and compete, in commerce, with those of modern elephants.

It is perhaps to the dilu'vium we must refer those immense masses of rolled debris which contain gold, platina, and the diamond, in Brazil, in Africa, in India, and in the Oural mountains, as well as the arena'ceous veins of tin in Cornwall and Mexico.

36. The **Boulder Formation**, or **Erratic Block Formation**, also, is regarded as a part of the diluvial drift. A great part of the plain of Switzerland is covered at intervals by fragments of rock, measuring about a cubic yard, which strew the plain, and dot the sides of the Alpine ravines, and rise on the opposite side of the Jura range, even to an elevation of several thousand feet above the sea. The most concentrated distribution of these blocks seems to be near the town of Neuchâtel, but similar masses are also found on the summit of the Mont Saléve, behind Geneva. It is very remarkable that a belt of fragmentary masses (not few or small, but countless and gigantic), differing entirely in character from the formation on which they rest, should be found lying on a steep, almost precipitous slope of nearly bare or thinly-covered rock. One of the blocks behind Neuchâtel, eight hundred and fifty feet above the lake, is of granite, and measures between fifty

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34. What is the position of diluvial drift? What is the megathe'rium?
35. What other fossils are referred to the diluvial drift?
36. What is the nature of the Boulder formation?

and sixty feet in length, by twenty feet broad, and forty feet high, while between the Jura and the Alps blocks still larger are in many places to be found—one, out of a great number together in the canton of Berne, measuring 61,000 cubic feet.

37. Erratic blocks and gravel cover the plain of central Europe and the steppes of Russia. Almost the whole surface of North America, as far as it has been examined, has been found covered with gravel, pebbles, and boulders, varying greatly in thickness, and obviously of the same origin as similar deposits in Europe; and a region which has been called the great Atlantic plain, extending between the Alleghany mountains and the Atlantic ocean, together with the lower part of the great valley of the Missisippi, appear to be the districts where it conceals the underlying deposits to the greatest depth.

On the borders of Lakes Erie and Ontario there are very decided marks of the great drift which has elsewhere overspread North America, and the boulder formation, containing marine shells, extends into the valley of the St. Lawrence, as far down as Quebec, and at a height of at least three hundred feet above the sea-level. Below Quebec there are large and far-transported boulders in beds, both above and below these marine shells, and wherever the contact of the drift with hard subjacent rocks is seen, these rocks are smoothed and furrowed on the surface, as they are in similar positions in northern Europe.

38. ALLU'VIUM, or MODERN DRIFT.—In many parts of North America the valleys are filled up to a depth of twenty or thirty feet with unconsolidated beds of earth of various kinds, and the heteroge'neous mass contains in it abundant remains of large pachyde'rmatous animals, not now living in the country, but associated with, and overlaid by other and similar beds, in which occur the bones of buffaloes, that have within a few years been driven westward by the advancing steps of civilized man. These beds all belong to the same geological period, or nearly so, and a description of one will be sufficient to give an accurate notion of a multitude of similar bogs and soft meadows in many of the western states. The most remarkable is that known as the "Big Bone Lick" in Kentucky.

39. The Big Bone Lick occupies the bottom of a boggy valley, kept wet by a number of salt springs, which rise over a surface of several acres, and the substratum of the country is a fossili'ferous limestone. At the Lick the valley is filled up to the depth of not less than thirty feet with beds of earth, the uppermost of which is a yellow clay, apparently the soil brought down from the high grounds by rains and land floods. In this yellow earth, along the

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37. Where is the Boulder formation met with?
38. What is allu'vium?
39. What are the characters of the Big Bone Lick of Kentucky?

water-courses at various depths, the bones of buffaloes and other modern animals are often found quite entire. Beneath the clay is another layer of a different soil, bearing the appearance of having been formerly the bottom of a marsh. It is more gravelly, darker coloured, and softer than the other, and in it, or sometimes in a stratum of compact blue clay alternating with it, there are found innumerable bones of large mammals, chiefly ma'stodons, but including also elephants, and extinct species of animals of the ox and deer tribe. In other localities the ma'stodon bones are found immediately below the surface in reclaimed marshes, and they are sometimes extremely perfect, sometimes broken and water-worn. The Big Bone Lick would appear to have been resorted to, not only in modern times by the living races, but more anciently by animals now extinct, for the salt, and perhaps the food produced by the marsh. The buffalo and bison are frequently known to perish entrapped in these licks and swamps, and it seems evident that the ma'stodon and elephant of former times must, from their huge size and unwieldy forms, have been at least equally exposed to the same fate. *Ansted, Rogers, &c.*

40. Up to the present time all geologists agree in saying that in the formations of this period, as well as in the most ancient rocks, neither human bones nor any vestige indicative of the existence of man on the face of the earth has been found, and it is, for this reason, probable that man had not yet been created at the time of the destruction of these animals.

EIGHTH GEOLOGICAL EPOCH.

Modern Formation.

41. New formations are now being made, either by the effusion of igneous matter from the bowels of the earth, or by sediment from waters, and these formations, which are contemporaneous with man, constitute the *modern formation.*

42. Since the last great catastrophe alluded to (the upheaval of the Alps), there has been a general repose, which perhaps will be disturbed one day by some new geological revolution; by the upheaval of some great mountain chain, for example, and by the great rush of waters which must follow such a convulsion, new lands will rise from the bosom of the ocean, and probably enclose remains of the bony frame of man and of animals now existing, just as the ancient formations conceal the solid remains of creatures which preceded us on the earth. Even now we have proof that things must pass in the present time very nearly as they did in

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40. Are human bones found in a fossil state, in the formations thus far studied? What is the inference from the fact?

41. What is meant by modern formation?

42. Are human bones any where found in a fossil state?

ages long gone by; for in certain modern formations, which continue to be formed under our eyes, we find human skeletons imbedded in the substance of the rock, and already presenting the characters of fossils of the tertiary period. One of the most remarkable examples of this kind has been discovered in the island of Guadaloupe.

Thus far we have presented a sketch of the earth's structure as revealed to us by an examination of its crust, only in reference, however, to the order of superposition of its formations, resulting from great geological convulsions, and characterized by the remains of animals found entombed in it. When we reflect on the inconceivable length of time it has evidently required to effect all these changes, and elevate one above another gigantic stories of various rocks, the imagination is startled; when we see entire creations of plants and animals covering the surface of the earth, and inhabiting the waters, disappear after a time, leaving a few mutilated remains as the only trace of their existence, and give place to a new flora and a new population of animated creatures, destined to undergo in turn a similar fate, we are struck with astonishment, and overcome by admiration of the power of the Creator of things so grand and so beautiful.

LESSON VI.

INFLUENCE OF INTERNAL AGENTS ON THE SURFACE OF THE EARTH.

EARTHQUAKES—*Description—Effects of—Changes of level produced by—Upheaval and Subsidence—Constant level of seas—Slow and progressive Subsidence—General conclusions.*

VOLCANIC PHENOMENA.—*Explosion—Eruption—Island of Saint George—Monte-Nuovo—Jorullo—Vesuvius—Definition of a Volcano—Submarine Eruptions—Volcan of Unalaska—Crater of elevation—Formation of Craters—Effects of upheaval——Form of Volcanic Islands—Periods in the formation of a Volcano—Interior of Craters—Kirauea—Solfataras—Volcanic Ashes—Lava Currents—Characters of Lavas—Dykes—Gaseous Volcanic Products—Eruption of Mud—Solid products of Volcanoes—Trachyte—Obsidian—Compact Lavas—Porous Lavas, &c.*

1. We have spoken of formations and of their relative order of superposition, and occasionally alluded to the various causes which affect them. From what we have said it might be inferred that the several formations are so many concentric spheres, enveloping

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1. Why is it that the surface of the globe is not entirely smooth, free from mountains and valleys?

a mass of fire; and such in fact might have been the case had it not been for certain disturbing forces which have fashioned the mountains and valleys, and caused the dry land to be lifted up above the waters. Had it not been for these disturbing forces, phenomena analogous to volcanoes and earthquakes, the whole globe would have remained under water, and man would not have been called into existence. But having seen the general structure of the interior of the earth, we will study the phenomena, the disturbing forces which modify its surface, more particularly than we have yet done.

These disturbing forces are either internal or external; first, of the INFLUENCE OF INTERNAL AGENTS ON THE SURFACE OF THE EARTH.

It has been already stated (page 12) that the centre of our earth is a mass of fire, to the influence of which many phenomena may be referred.

EARTHQUAKES.

2. *Description of Earthquakes.*—Every one has heard of the terrible scourge which in a moment reduces the most flourishing cities to a heap of ruins, and sometimes upturns the neighbouring country. An earthquake is often preceded by rumbling, subterraneous sounds, which are frequently heard some time before the catastrophe. Tremblings more or less violent are perceived during a few minutes or seconds only, which in many instances are often repeated with more or less rapidity and force; in certain cases they even continue, with irregular intervals, during several days, or months, or even entire years. These movements of the earth are of different kinds; sometimes they consist of jerking horizontal oscillations, occurring at irregular intervals, sometimes of vertical shocks, that is, in rapid and successive rising and falling of the soil; at other times of various twisting movements. Frequently all the various motions take place almost at the same moment, and then nothing can escape destruction.

3. Sometimes an earthquake is circumscribed in narrow limits; that which happened on the 2d of February, 1828, in the island of Ischia, was not felt either in the neighbouring islands or on the continent. Frequently, too, it shakes an immense surface: for example, the earthquake of the 17th June, 1826, in New Grenada, was felt over many thousand square leagues. Sometimes it extends enormous distances, as in the case of the famous earthquake of Lisbon, which was felt in Lapland in one direction, and Martinique in another; and, transversely, from Greenland to Africa, where

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2. What are earthquakes? What is the nature of the motions produced by earthquakes? What is the duration of earthquakes?

3. What are the limits of earthquakes?

Morocco, Fez, and Mequinez were destroyed: all Europe experienced its effects at the same moment. From the different histories of earthquakes, many examples of this kind of propagation might be adduced, extending more or less widely. It may be even concluded, from statements of facts, that the shock extends according to a great circle, more or less inclined to the equator, and perhaps over an entire hemisphere.

4. *Effects of Earthquakes.*—Earthquakes, when violent, not only overturn entire cities, and the most solidly built edifices, but they cause important modifications in the ground itself. Those of Calabria, in 1783, furnish examples, which are the more important because the facts were observed by the most distinguished men of the times, such as Vicenzio, physician to the king of Naples, Grimaldi, Hamilton, Dolomieu, &c., and also by a commission appointed by the royal academy of Naples. All was overturned in this unhappy country; the course of rivers was interrupted and changed; houses were raised above the level of the country, while others, frequently at no great distance, were sunk down more or less; edifices of great solidity were split from top to bottom; certain parts were raised above others, and the foundations pushed up out of the ground. Every where the surface of the earth partly opened, often in long crevices, some of which were one hundred and fifty yards in breadth; some of these were isolated, sometimes bifurcated—frequently exhibiting other fissures perpendicular to their direction (*fig.* 179); some were in form of rays diverging from a centre, like a broken glass (*fig.* 180). Some opened at the moment of the shock, and immediately closed again, grinding betwixt their parietes the habitations they swallowed up; others invariably remained gaping after the commotion, or, commenced by a first shock, were widened by succeeding shocks. In both cases it was sometimes observed that the borders of the split were on the same plane, or showed a more or less projecting swelling up

Fig. 179. *Fig.* 180.

Crevasses and fissures produced by earthquakes.

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4. What are the effects of earthquakes? What is the character of fissures produced by earthquakes?

(*fig.* 181); sometimes one of the parts is elevated much higher than the other (*figs.* 182, 183), showing that one must have been raised while the other was sunk.

Fig. 181. *Fig.* 182. *Fig.* 183.

Changes of level produced by earthquakes.

Again it happens that a more or less considerable extent of surface is suddenly sunk, carrying down plantations and habitations, leaving yawning chasms, with vertical sides, eighty or a hundred yards in depth. In certain cases an immense quantity of water springs from the bottom of these cavities, forming more or less extensive lakes, sometimes without apparent current, and sometimes giving origin to impetuous torrents. In some instances, on the contrary, rivulets were absorbed by the fissures in the earth, or swallowed for a time, or forever.

But, besides the numerous cracks and divers chasms which intercept the waters, furnishing new springs, and giving them a new channel, it also happens that masses of rocks, falling across valleys, arrest the waters and soon form lakes in the upper part. Now, these accumulated waters make new passages, either by breaking through the sides of the valley, or by enlarging some fissure in the mountain; or, they *degrade*, cut down, the obstacle which retained them, and soon overturn it entirely or in part. Hence arise those fearful outbreaks, those impetuous torrents rolling down enormous masses of rock, the ravages of which are as disastrous as the earthquake itself, and which, excavating new channels, or widening and deepening those that waters before pursued, mark their course by the debris which they roll down and successively deposit.

When the principal effects of earthquakes took place on the continent between Oppido and Soriano, the phenomena extended as far as Messina, across the straits; more than half the city was destroyed, and twenty-nine hamlets or villages were swallowed up. The bottom of the sea was sunk, and disturbed at various points; the shore was rent, and the whole ground along the port of Messina was inclined towards the sea, suddenly sinking several yards; the whole promontory which formed its entrance was swallowed in a moment.

5. *Upheaval and Subsidence.*—The earthquakes which occurred on the coast of Chile in 1822, 1835, and 1837, have produced effects not less remarkable. Different parts of the coast, from Valdivia to Valparaiso, that is, an extent of more than two hundred leagues, were evidently elevated above the waters, as well as many neighbouring islands as far as those of Juan Fernandez; the bottom of the sea to a considerable extent participated in this phenomena. On the coast, rocks which had been previously under water were raised two or three yards above its level, with the mol-

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5. Give some examples of upheaval and subsidence produced by earthquakes.

lusks which lived on their surface; rivers emptying on the coast became fordable where they had been navigable by small vessels; well-known anchorages were diminished in depth to a corresponding extent, and at different points, shoals now oppose the passage of vessels of large draught where they readily floated before.

Analogous circumstances occurred in India in 1819; a hill, fifty miles long and sixteen broad, was raised up in the midst of a flat country, barring the course of the Indus. Further to the south, on the contrary, but parallel to the same direction, the country sank, carrying down the village and fort of Sindré, which nevertheless remains standing, half submerged. The eastern mouth of the river became more shallow in many places, and portions of its bed which had been fordable suddenly ceased to be so.

The history of all times and of all places furnishes us with facts of exactly the same nature. Everywhere we are told of fissures in the earth, of profound chasms, in which cities and even entire countries are swallowed, from which flow mephitic gases, enormous masses of water, sometimes cold, sometimes hot, sometimes even flaming. Also of plains suddenly transformed into mountains, of shoals raised in the midst of the ocean, of mountains rent and overturned, of mountainous regions, of hundreds of leagues of rocks all at once levelled and replaced by lakes. Of water-courses changed, swallowed in chasms of the earth; of lakes which dry up by breaking through their bounds, or suddenly lost in subterraneous conduits, instantaneously formed. In opposition, we also learn of enormous springs producing new streams, suddenly rising through a fissure of a rock, without any knowledge whence the waters come: of thermal springs which have become instantaneously cold; of others, on the contrary, appearing where they did not exist before. All these phenomena are so many indications of fissures in the earth, which afford new channels to waters which might have circulated there before.

6. Relatively to the sea-coasts, these phenomena are often mentioned by authors in a peculiar manner; rarely do we see it explicitly announced, there is an elevation; but the event is stated in other terms, referring the effect to the most moveable element. In this way authors speak of the sea having retired more or less, leaving its bed dry, either permanently or only for an instant: sometimes, on the contrary, they mention that the sea suddenly overflowed more or less elevated coasts. Geologists translate these indications by the term *oscillation*, if the phenomenon be momentary, and by the terms *upheaval*, or *subsidence* of coasts, if it be permanent, because they refer these effects to the solid parts of the globe, and not to the sea, the level of which does not vary. Nevertheless it must be borne in mind that, if these transitory phenomena may sometimes be attributed to *oscillations of the earth*, they may also arise from a real impulse communicated to the waters of the sea, and possibly partake of both causes. We know, in fact, that during earthquakes the sea is sometimes violently agitated, that its waters, elevated to considerable heights, occasionally make fearful irruptions on the land, advancing and

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6. What is meant by oscillation? What is meant by upheaval? What by subsidence?

retiring again, carrying devastation over a greater or less extent. These impetuous movements of advance and retreat, accompanied by sudden dislocations caused by subterraneous commotions in the solid crust of the globe, may occasion frightful havoc. The history of the Grecian archipelago, of the islands of Japan, and of a multitude of places, is full of disasters produced by these catastrophes.

The various effects produced by earthquakes under our eyes, and those cited in the most authentic narrations, tend to confirm what is transmitted to us from the most remote times, although we might state the facts in other terms. Who dares formally to contradict Pliny, relating, according to the historians, that Sicily was separated from Italy by an earthquake; that the island Cy'prus was separated from Syria by the same means; and that of Eubœ'a (Negropont) from Bœotia, &c.? We would not even positively deny the existence of the Atlantis, swallowed by the waters, according to Egyptian tradition, in a day and a night. Let us rather declare, that the assemblage of observations we have, evidently shows that immense upheavals and subsidences have for a long time formed part of the mechanism of nature, in bringing the surface of the earth to the configuration we now observe.

7. *Constant level of seas.*—We have just admitted the *subsidence* and *upheaval* of coasts, and laid down the principle that the level of seas is invariable: but this last assertion being contrary to opinions commonly received by the world, it is necessary to support it by demonstration. The laws of hydrostatics teach us that a mass of liquid cannot be permanently elevated or depressed at one point of its surface, but that a level must be established after oscillation, great or small, ceases. Hence it follows that the level of the sea cannot be stationary at one point, without its being so throughout, and that the waters cannot be elevated or depressed in one spot, without similar changes being experienced at all points of the same basin. Now we know thousands of localities where the surface of the sea has not undergone the least variation since the most remote historic times; therefore the level has not changed, and its constancy is the most positive fact we are aware of, because it has been subject to the proof of all ages. On the other hand, if we could be led to suppose, like the inhabitants of Chile, seeing the manifest change on their coast, that the sea has subsided there, we must also conclude, with the inhabitants of California, Peru, Brazil, &c., that in those places it underwent no variation. It must also be admitted that the sea has risen at the bottom of the Gulf of Arabia, as it has done, in different epochs, on the coasts of Portugal, in the Straits of Messina, &c. All these circumstances are incompatible with each other, and opposed to the laws of hydrostatics; and hence we conclude, that instead of the immutability of the ground, which an error, analogous to the idea of immobility of the globe, has created, we must admit immu-

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7. Does the sea always maintain the same level? What reasons lead to the opinion that the level of seas is always the same?

tability of the seas, by acknowledging that the solid surface of our planet is susceptible of elevations, depressions, and all kinds of disturbances.

The *slow upheaval of Sweden* has already been noticed (p. 20).

8. *Slow and progressive subsidence.*—There is no doubt that, for four centuries past, the western coast of Greenland is continually sinking, through an extent of two hundred leagues north and south; ancient buildings, both on the low islands and on the continent, have been gradually submerged; and it has been frequently necessary to move various establishments built near the shore, farther inland. Subsidence of certain islands in the South Seas has been indicated; but in those places, so rarely visited by geologists, the facts are not yet clearly established.

9. *General conclusion.*—It must now appear to be well established, that earthquakes are capable of producing great modifications of the earth's surface, since, within our times, vast tracts of country have been elevated sensibly above the level of the sea. It is not less evident there is a slow power in operation, in virtue of which, different parts of our continents may also be successively raised; and that it also produces gradual sinkings as well as sudden subsidences, which are doubtless correlative phenomena.

All these circumstances, however remarkable, are, nevertheless, not very astonishing, when we reflect on the enormous disproportion which exists between the thickness of the solid crust of the globe, and the mass of melted matter it envelopes. Is it surprising that such a crust, a mere rind, relatively almost as thin as a coating of gold-leaf on an orange, should be disturbed in every manner by the least movement of the subjacent mass, particularly if we bear in mind that similar movements doubtlessly have been taking place ever since the first pellicle was consolidated on the surface, and all the successive crusts must have been rent in every direction, and therefore their mass could not afford the resistance of a continuous envelope?

VOLCANIC PHENOMENA.

10. *General notion—Explosion—Eruption.*—Volcanic phenomena are closely connected with earthquakes; they are, in a manner, the final results of them. When, by the shaking and elevation of the ground, the terrestrial crust is deeply broken, a temporary or permanent communication is established between the interior and exterior of the globe, through which various kinds of matter are disengaged from the bosom of the earth. Through the crevices escape gases of different kinds, waters hot or cold, simple

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8. Is there any evidence of the slow and gradual subsidence of land?

9. Why is it believed that earthquakes modify the earth's surface?

10. What are volcanic phenomena? Give some instances of volcanic phenomena.

or sulphurous, and loaded with mud, are the most simple transitory results. But frequently there are, also, through the upheaved and broken ground, amidst violent detonations, explosions which eject, to a great distance, all the debris of the formation, as happened at Saint-Michel, in the Azores, in 1522, where the debris of two hills covered the whole city of Villa-Franca. It most frequently happens, at the same time, that more or less considerable eruptions of incandescent matters take place, consisting of scoriæ, pumice, &c., in a melted state, which are either projected to a distance, or run on the slopes, or accumulate on the spot to a greater or less height; this has occurred in a great many localities.

Eruption of the island of Saint George.—In the month of May 1808, in the island of Saint George, one of the Azores, the soil in the midst of cultivated fields after being upheaved opened at many points with a fearful noise. It first formed a vast cavity, or *crater*, of 100,000 square yards, then a smaller one at the distance of a league, and finally twelve or fifteen little craters on the broken surface. An enormous quantity of scoriæ and pumice was projected to a distance, and the ground was covered a yard and a half deep over an extent a league wide and four leagues long. For more than three weeks afterwards currents of melted matter flowed from the principal crater to the sea.

Monte-Nuovo.—Monte-Nuovo, formed in 1538, at the bottom of the bay of Baia, on the coast of Naples, is another example of a similar eruption. Violent earthquakes had continued during two years: *on the 27th and 28th September they did not cease either day or night; the plain found between Lake Averne, Monte-Barbaro and the sea, was then upheaved, and various cracks were evident, &c.* (Pietro Giacomo di Toledo). *Then a great extent of ground was elevated, and suddenly assumed the form of a growing mountain; in the night of the same day this little mountain of earth opened with a great noise, and vomited flames, as well as pumice, stones and cinders* (Porzio). The pumice came from the upheaval of the soil, which consists of this material throughout Campa'nia; and the stones and cinders came from the eruption which occurred at the moment: we still see on the south side of the mountain a ridge of scoriæ, and on its summit the crater which produced them. The eruption lasted seven days, and the matters projected and ejected partly filled Lake Lucrin. From that time the most perfect tranquillity has prevailed.

Jorullo.—There was something analogous, but under peculiar circumstances, in what happened in Mechoacan, near the town of Ario, on the 29th September, 1759, after an earthquake of two months duration. In the midst of a plain covered with sugar-cane and indigo, and traversed by two rivulets, there formed in a single night, says M. Humboldt, a gibbosity (bunching up) 160 yards high near the centre, covered by thousands of small smoking cones, in the midst of which were raised up six great hillocks, arranged in one line (*fig.* 184), in the direction of the volcanoes of Colima and of Popocatapetl. The highest of these hillocks, called *Jorullo*, was more than five hundred yards in height above the plain; from its sides escaped a great quantity of lavas.

Vesuvius.—Something similar must have occurred in Vesuvius, for Strabo describes the mountain so called by the ancients without in any way alluding to the remarkable cone which now exists (*fig.* 185), and which he would not have failed to mention. It is evident this cone did not then exist; but the crests which rise in semicircles on the north, forming what is now called the *somma*, probably constituted part of a complete circle; the

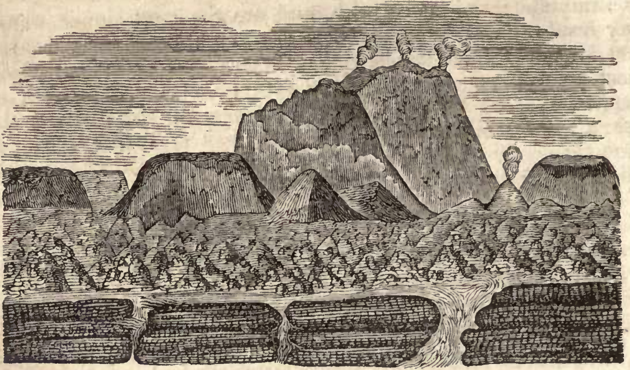

Fig. 184.—*Volcan of Jorullo.*

south half, which was much more arched, and separated from the other by a diametrical split, only offers now a trace at the east, and an indication at the west by the pumice tufa of Salvatore. The mountain, which is probably represented in fig. 186, *was*, says Strabo, *very fertile on its slopes; its summit was truncated, in a great part united, entirely sterile, of a burnt aspect, exhibiting cavities filled with cracks and calcined stones; from which it may be conjectured that these places were formerly burning craters.* All leads to the belief that the cone, which alone bears the name of Vesuvius now, all the products of which differ from the rocks of the *somma*, was not formed till long afterwards, and probably at the time of the famous eruption in the year 79, which cost the life of the Roman naturalist; it then, without doubt, formed a permanent conduit in the midst of the matters which are raised in form of a dome, and which has been enveloped by subsequent scoriæ. This catastrophe seems to have produced but little lava, but a horrible upheaval, *which precipitated a great part of the mountain into the sea* (Pliny the younger), and buried Herculaneum and Pompeii, not under torrents of melted matter, as commonly said, but under avalanches of pumice which previously existed on the slope of the mountain, for Vesuvius itself has never produced an atom. If the whole south slope turned towards the sea is now occupied by lava, it is evident that before the formation of the permanent volcan it was covered with pumice tufa, traces of which are still seen at different points, the same as now on the external slope of the somma, and in all Campa'nia.

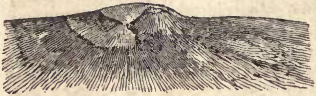

Fig. 185.—*View of Vesuvius as it now is.*

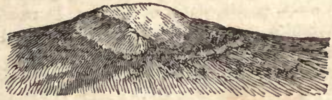

Fig. 186.—*Vesuvius in the time of Strabo.*

11. *Definition of a Volcan.*—In those events, it often happens that the rent, which has given rise to observed effects, is obstructed or closed at a considerable depth, and tranquillity is entirely restored, as at *Monte-nuevo.* Under other circumstances, on the

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11. What is a vo'can, or volcano?

contrary, the rent forms a permanent conduit at once, or after several shocks in the same place. In this case there is sometimes established a continuously active furnace, from which gaseous matter in abundance is disengaged, or from which lava continuously boils, and from which there is an incessant projection of scoriæ; this has been the case at *Stromboli* from the remotest antiquity. At other times the conduit is temporarily obstructed at its upper part; but the least effort is sufficient to remove the obstruction, or to produce a new opening in the vicinity, through some fissure which communicates with the principal conduit (*fig.* 187). In all cases, the result is a centre of easy communication between the interior and exterior of the earth, and it is this which is called a *volcan* or *volcano*.

*Fig.*187.—*Volcanic conduits.*

This facility of communication is probably a preservative against the violence of earthquakes; indeed it has been observed that, from the moment an eruption takes place anywhere, the shocks which had been felt up to that time, become fewer and weaker, and even cease altogether. The earthquake of Caraccas, in 1812, terminated by the eruption of the volcan of Saint-Vincent, in the Antilles; the eruption of *Jorullo*, and that of *Monte-Nuevo*, terminated the earthquakes which desolated the surrounding countries. On the contrary, when a volcano becomes inactive, it seems to announce earthquakes; in 1797, when the volcan of Purace, near Popayan, had ceased to emit flame and smoke, the valley of Quito was agitated by violent shocks. Volcans, therefore, seem to be natural vents, designed by Providence to prevent a complete destruction of the globe, and its inevitable rupture into fragments, which, launched into space, might there describe new orbits.

12. *Submarine eruptions.*—It is not only on land that volcanic phenomena occur; they also take place under the sea, as might be naturally anticipated. In our own times, we have had formed in this manner the island of Julia, in 1831, on the south-west of Sicily; Bogoslaw, in 1814, in the Aleutian Archipelago; Sabrina, and another one not named, in 1811, in the Azores, where, previously, at different epochs, others were formed, according to the most authentic histories. The same thing occurred, at different times, around Iceland; and various accounts indicate that in the islands of Sunda, the Philippines and Moluccas, throughout the Pacific, in the Kuriles, Kamtschatka, &c., similar phenomena took place.

Volcan of Unalaska.—One of the most striking examples is furnished by the island, which arose in 1796, about ten leagues from the northern point of Unalaska, one of the Aleutian islands. At first a column of smoke rose above the surface of the sea; then a black point appeared, the smmit of which launched forth sheets of fire and stones with violence. This phenomenon continued for several months, during which the island grew successively in extent and height; later, smoke only issued, which ceased altogether four years afterwards. Still the island continued to enlarge, and to rise

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12. Do volcanic eruptions take place on land exclusively?

without any apparent ejection; and, in 1806, it formed a cone which might be seen from Unalaska, and upon it were four other smaller ones, on the north-west side.

Santorin.—The Mediterranean also furnishes a fine example of submarine eruptions, in the midst of the space comprised between the islands of *Santorin*, *Teresia* and *Aspronisi* (*fig.* 193), which, according to the ancients, appeared above the water several centuries before the Christian era, in consequence of violent earthquakes. In this circuit, *Hiera* arose first, 186 years before our era, which subsequently grew by little islets rising on its borders in the years 19, 726, 1427; then, in the same way, *Micra-Kameni*, in 1573, and *Nea-Kameni*, in 1707, were formed; and successively growing in 1709, 1711, 1712, &c. No crater was formed in either of these islands, and we only have there the appearance of volcanic matter in form of a *dome*, which seems to have covered the orifice through which it escaped. There was no volcan there, according to the terms of our definition, but a tendency to form one at some future time. The islands of *Milo*, *Argentiera*, *Polino*, *Policandro*, *Poros*, &c., are formed of the same materials, and probably had the same origin.

13. *What passes in these phenomena.*—These submarine phenomena are announced by incandescent matters ejected above water; by scoriæ and pumice, which float on the surface; by burning rocks, which appear in the midst of waves of vapour, and by the boiling of the sea, the temperature of which becomes very much increased. All these things occurred in our own times, at Julia, at Sabrina, &c., and are such as authors mention in detail, in all their accounts. Father Gorée has given us a history of the upheaval of Nea-Kameni, of Santorin, in 1707; and all the circumstances he relates agree with what Strabo, Pliny, Plutarch and Justin tell us of the appearance of Hiera, in the midst of flames, and a violent ebullition of the sea.

But the circumstances we have just spoken of are not always all present at the same time. Sometimes no solid rock appears above water; this was the case at Kamtschatka, in 1737, where jets of vapour, great ebullition of the sea, and pumice-stones floating on the surface, were all that was perceived; but when the spot could be approached, there was found a chain of submarine mountains, where there had been previously a depth of more than a hundred fathoms. In certain cases there is not even a jet of vapour, and the phenomenon is manifested by the heat of the water only; this happened in 1820, at the island of Banda, among the Moluccas, where the bay, which was upwards of fifty fathoms deep, was filled by the tranquil elevation of compact basa'ltic matter, probably pre-existing, which formed an elevated promontory composed of large blocks piled one on the other; and its appearance was manifested by the heat of the water only. It also seems, that after eruptions, there is often a peaceful and slow upheaval, as in the island formed before Unalaska, and at Santorin, according to the observations of M. Virlet. Indeed, between Micra-Kameni and the port of Phira, where there is an abrupt submarine mountain, there was, at the beginning of the present century, fifteen fathoms of water above the highest part; but there were only four fathoms in 1830, and little more than two in 1834. It is presumed a new island, that is, the summit of a new cone, will appear in the gulf, and the appearance will, probably, be accompanied by such phenomena as we mention.

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13. What phenomena occur in submarine eruptions?

Let us add that islands which rise to the surface of seas do not always remain. Many of them disappear after a longer or shorter period, either by being washed down by the waves, as is supposed to have been the case with the island of Julia, or by their mass sinking into an abyss formed beneath them; the last circumstance doubtlessly happened to an island which was elevated in 1719, near Saint-Michael (Azores), and disappeared in 1723, leaving in its place a depth of seventy fathoms. In the same region there was an island in 1638, where there is now a bottomless abyss.

14. *Crater of upheaval, or elevation.*—The first effect of an eruption is to burst, by its violence, the crust of the earth in the direction which matters pent up in the interior have taken to escape. The ground, no matter of what nature, is at first raised to a more or less considerable extent, or arched like a bell, and often cracked in every direction; at once, the explosion occurring, as if by the action of a formidable powder-blast, an opening is made in the form of a funnel, through which often escape gaseous and other matters which caused the event. It is to these initiatory openings, which may be made anywhere, to which the name of *crater of elevation* has been given, from the necessity of distinguishing them from all that may subsequently occur in the series of volcanic phenomena. The hillock itself which is produced on the soil, by the first effect, is called the *cone of elevation*, to distinguish it from analogous hillocks which are often formed also by the accumulation of incoherent materials ejected from the volcano.

15. *Character of these openings.*—What characterizes craters of elevation, and enables us to recognise them in places where there is no account of an eruption, is, the disposition or arrangement of the upheaved strata, being very different from what is everywhere else observed. These beds are here found inclined all round the axis of the cone, as in the section (*fig.* 188), rising more and more from the base to the summit, and presenting their abrupt escarpments towards the interior of the cavity. Monte-Nuovo is an example in miniature: the mountain was formed by elevation, hollowed at its summit by ejecting gases and incandescent matters; and the cavity, which can be examined now, has around it, at an inclination of thirty degrees, strata of different formations, which in all the rest of Campa'nia are horizontal. The semicircle of the *somma* presents the same characters in the inclined tables of amphige'nic porphyries, and analogous circumstances exist in many other localities.

Fig. 188.—*Disposition of strata around a crater of elevation.*

16. Another character, not less important, and especially useful when the upheaved matters are not divided into beds, is furnished

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14. What is a crater of elevation? What is a cone of elevation?

15. How are craters of elevation characterized?

us in great craters of elevation by the crevices or cracks which extend from the margin of the escarpment to the external base of the mountain, forming what are named *barancos* in the Canary islands, where they are so remarkable. One of these barancos (or ravines) much deeper than the others, extends from the foot of the mountain to the bottom of the crater, as is shown in the following view (*fig.* 189). This last character is seen almost always in the different localities produced by similar events, as well as in most islands which have been upheaved in our times in the midst of the ocean; frequently there are many valleys of the same kind.

Fig. 189.—*View of the Island of Palma.*

Remarks on the formation of craters.—We have mentioned explosion as determining, definitely, the formation of the crateriform cavity at the summit of the upheaved mass; however, it is not probable that this circumstance, which is applicable to Monte-Nuovo, the island of St. George, &c., is constantly seen in all cases; it seems to be even totally inadmissible in certain craters of vast extent known to exist in a number of places. But this explosion is not even necessary. In fact it is easy to conceive that after a fracture, as in *fig.* 190, which is a correlative result of elevation, it may happen that all the erect, column-like masses, and all the elongated points between the rents, might be tumbled down at the same moment, or by a subsequent action. Hence results an open cavity (*fig.* 191), the margin of which is formed by all the debris, and the depth is in proportion to the sum of the voids or spaces formed by the fractures. On the other hand, it is clear that elevation is produced by some matter, liquid or gaseous, which pushes the crust of the earth and forces it to swell upwards; now, if it happen that this matter should find exit at some other point, or retire again into the bowels of the earth, the upheaved part being left without support may sink into the abyss left beneath it, and consequently cause an immense vacuity in the midst of the gibbosity or hillock, then merely forming a mass

Fig. 190.

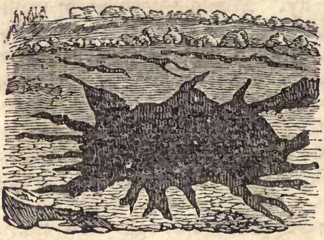

Fig. 191.

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16. How are craters of elevation distinguished when the upheaved matters are not divided into beds?

hollow in the centre, and cracked on the margin. This must have taken place in many cases, and notably in the mass of Etna, (*fig.* 192), the eastern slope of which presents a vast excavation, called *Val del Bove*, which is bounded by high ridges, cracked at various points.

Fig. 192.—*Plan of Etna and its environs, according to the relievo of M. Elie de Beaumont.*

This comment need not be regarded as a simple theoretic speculation; there are many examples of similar excavations, independent of the effects produced by earthquakes. At the summit of Mount Etna there is one of 1300 feet in depth, which dates from 1832, and many others which were produced at the end of the last or beginning of the present century. Frequently lakes are formed on a sudden, sometimes of boiling water, by the sinking of the land consequent on volcanic eruptions, as in 1835, near the ancient Cesarea in Cappadocia; in 1820, in St. Michael's (Azores), &c. It has also happened that high volcanic mountains have at once sunk, their place being at once filled by deep lakes, as the volcano of Papadayann in Java, in 1772, which carried away with it forty villages built on its sides: as also, in 1638, the peak of the Moluccas, which could be perceived twelve leagues at sea. We know that the summit of Carguaraizo which rivalled Chimborazo in height, crumbled in 1698, and the same occurred to Capac-Urcu, also situated on the plane of Quito, a short time before the arrival of the Spaniards in America. Many other facts of a similar kind could be adduced in support of the theory advanced.

17. *Effects subsequent to elevation.*—The crateriform cavities we have spoken of sometimes remain the same as when first produced; often, however, various volcanic phenomena subsequently occur at different times and in various ways. In this manner it was that the cone of Vesuvius (*fig.* 185) was formed in 79 in the ancient crater of the *Somma* (p. 104); that the peak of Teneriffe is found in a circle, the vertical walls of which rise from 600 to 1200 feet; that the volcan of Taal, in Luzon, one of the Philippine islands, is in the centre of a basin filled with water, and sur-

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17. Do craters of elevation always remain the same as when first produced? Give some examples of the secondary effects of eruptions.

rounded by elevated rocks, having a single opening only for entrance &c.

Islands which have been elevated in the midst of the sea frequently exhibit phenomena of the same kind. Thus the islands of Santorin, Theresia, Aspronisi, (*fig.* 193), which were elevated long before the Christian era, present the appearance of a vast crater of elevation: their slopes are gentle (*fig.* 193) externally, but abrupt, on the contrary, towards the centre of the circle of which they form the margin. The ground is composed of various strata, inclined outwardly, among which are limestone and argillaceous schist. In the middle of the circle, the depth of which is considerable on the borders, all the subsequent volcanic phenomena were produced, and here the three summits of cones successively appeared, which constitute three modern islands, and are still preparing new eruptions.

Fig. 193.—*Section of Santorin and adjacent islands.*

Something similar is seen in the Gulf of Bengal, on the Island of Barren, discovered in 1787. It is a vast circle (*fig.* 194) formed of high mountains, into which the sea penetrates by a single opening, and has a volcan in the centre which was in full activity at the time of the discovery.

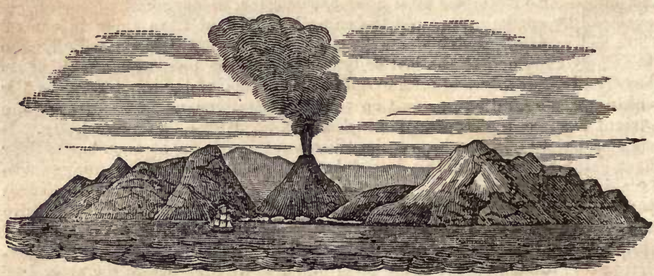

Fig. 194.—*View of the Island of Barren in the Gulf of Bengal.*

18. *Similarity of configuration in Volcanic Islands.*—Different volcanic islands which have been formed under our eyes, as it were, in the midst of the ocean, are entirely analogous to those we have mentioned. The island of Sabrina, at the moment of its appearance, presented a crater which opened to the south, (*figs.* 195, 196), and terminated by an opening, through which issued a current of boiling water: according to the accounts, the island of Julia must have been somewhat analogous; and the history given by Captain Thayer, reported by Poeppig, shows such to have been the case. On the 6th September, 1835, to the north of New Zealand, this navigator almost witnessed a submarine eruption, which presented

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18. How do volcanic islands differ from each other in form?

Fig. 195.

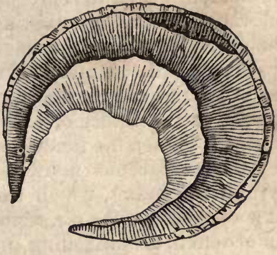

Fig. 196.

Appearance and form of certain volcanic islands.

an annular rock, almost on a level with the surface of the sea, in the midst of which was a lagune having a single outlet, and in which the water was burning. Now, these islands appear to be nothing more than points of domes upheaved, like those in the gulf of Santorin, either instantaneously or slowly, and having the summit broken, like Monte-Nuovo. These are true craters of elevation or of explosion, as we would call them; and as such they may consist of solid rocks, or of various tufas, or even of scoriæ accumulated on their borders. The archipelago of the Azores, which have so often witnessed rising from the sea similar islands, which time has destroyed, presents us one which seems to have escaped destruction, to exhibit to us how all those were formed which have disappeared. This is the rock of *Porto de Ilheo*, which presents a vast circle, into which vessels enter for shelter; its sides rise 400 feet and are composed of volcanic tufa.

19. These phenomena explain to us the origin of a great many islands found in the ocean (*fig.* 197), both by the analogy of their form to those we have named, and their nature. Some are in the form of a horse-shoe, having a more or less expanded opening, which gives access to the middle of the deep basin they enclose, and in the centre of which isolated volcanic hillocks are occasionally found. Others are entirely circular, having some of the points of the circle more or less broken, or groups of small islands arranged in a circle, which are more or less prominent above the water.

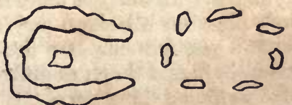

Fig. 197.—*Disposition of certain islands in the South Seas*

20. *Different periods of the formation of a volcan.*—We may often distinguish in the mass of a volcanic mountain, several dif-

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19. How do volcanic phenomena explain the origin of certain islands?

ferent parts, each of which corresponds to a particular mode of formation. The first gibbosity or hill is, in general, the effect of elevation of the pre-existing soil, which may be of any kind or nature. Afterwards, sooner or later a fissure is formed, which produces either a crater of elevation or a dome of pasty matter, as at Jorullo, clearly detached from the first hillock; and, as a last result, in the midst of one or the other a permanent chimney is formed. Often the formation of the terminal cone then commences, by the scoriaceous matters raised by the melted lava filling the primitive conduit, which overflows the margin of the aperture, or it is ejected into the air, from which it falls again around the centre of eruption, accumulating in cones with a maximum slope of from 30° to 35°. These loose scoriæ melt on the side towards the interior of the chimney, which they narrow more and more by the successive cornice-like projections they form, and in this way conceal the true diameter of the crater.

21. It is rare that these three kinds of formations are all found in the same volcano; but we always find the gibbosity produced by elevation, and one or the other of the secondary domes. At Teneriffe there is a broken dome which was upheaved in the middle of a crater of elevation. At Vesuvius, from the constant solidity of the base, and other circumstances, we may infer the existence of a central nucleus, produced in the same way as a dome, in the year 79, afterwards enveloped in loose materials, and bearing on its summit a true cone of scoriæ. At Etna (*fig.* 198) we clearly distinguish the primitive hill or gibbosity, showing sheets or coats of ancient upheaved lavas, on the middle of the slightly-arched surface, which all this part of the island presents; it is terminated by an almost level surface, the *Piano del Lago*, in the midst of which rises the terminal cone of scoriæ, regularly circumscribed on all sides, and clearly separated from the base on which it was formed. On the slopes are small cones of eruption, formed here and there, at different times, which have since contributed to the swelling up of the whole of the surrounding land.

Fig. 198.—*View and profile of Etna, and the surrounding country.*

22. It is clear, that the cones of scoriæ constructed in the manner just mentioned, at the bottom of volcanic gulfs, cannot be very solid; they often change their form at every eruption. Sometimes the edifice rises more and more; sometimes, on the contrary, it

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20. Are volcans always characterized by the same kind of formations?

21. Do we always find in one volcano all the kinds of formation? What one is always found?

22. What are the characters of cones of scoriæ found at the bottom of volcanic gulfs?

crumbles into more or less considerable shreds, and hence cones are deeply broken in all manners of shape. Sometimes the whole mass is swallowed at once in the abyss it covered, and is reconstructed by subsequent eruptions. This took place in the terminal cone of Etna, which has several times disappeared entirely, leaving an immense aperture, without parapet, in the midst of a little plain which crowned the original gibbosity or hill. At Vesuvius only the upper part of the cone has ever been modified.

23. *Interior of craters.*—Contrary to the expectation of all those who visit volcanoes, the interior of craters seldom possesses much that is worthy of observation. After great eruptions, during which they cannot be approached, these cavities (which are of conical form, and have a more or less extensive diameter at the top, with a bottom apparently formed of a sheet of consolidated lava, which covers the principal chimney) ordinarily present for observation merely jets of sulphurous vapours, escaping here and there from fissures in the soil, from interstices in blocks of crumbled scoriæ, or a greater or less number of small cones raised up in different places. Occasionally we see one or more gulfs, sometimes filled with vapours which escape continually, and sometimes revealing the incandescent lava in the depth; sometimes silent and dark, inspiring with terror, but without possessing the least interest for observation. In long intervals of crises, traces of volcanic action often entirely disappear; in certain instances even the sides of the crater become covered by vegetation, as is related of Vesuvius before the eruption of 1631.

24. There are, however, some observations worthy attention. The crater of Stromboli, which has been in continuous activity from the most ancient times, still presents phenomena identical with those recorded by Spallanzani, in 1788. It is constantly full of melted lava, which alternately rises and sinks in the cavity. Having reached to twenty-five or thirty feet of the edge, this lava swells, is covered with large vesicles or blisters, which speedily burst with a noise, permitting the escape of an enormous quantity of gas, and projecting scoriaceous matters on all sides. It immediately sinks, after an explosion, then rises again, to produce the same effects, which are in this way repeated at regular intervals of some minutes.

25. If the lava of Stromboli were less fluid, it is conceived, that having reached to its highest point, it would there stop, assume an arched form, and become consolidated into a more or less elevated cone; and then, if an explosion occurred at a certain instant, a new conical crater would be found in the middle of the old one. This

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23. What is found in the interior of craters?

24. What is remarked of the crater of Stromboli?

25. What would probably be observed, if the lava of Stromboli were less fluid than it is?

explains what frequently takes place in volcanoes, and, for example, at Vesuvius (*fig.* 199), where domes have been raised which remained for a long time, and were subsequently broken, giving passage to lavas, and finally sank into abysses left beneath them. Certain craters, having a widely extended bottom, often contain hills of considerable height, which have had an origin such as we have described; either the lava is arrested at a certain height, in form of a cap, or swelled up at different points, or elevations took place in different matters which had filled the cavity.

Fig. 199.—*Adventitious Crater, in the middle of Vesuvius, in* 1829.

26. Sometimes, in place of lava, there is found at the bottom of craters boiling sulphur, as was seen at Vulcano, and, on a larger scale, at the volcan of Taal, in the island of Luzon, and at that of Azufral, to the north of Quito, in the Andes; hills, and even domes of sulphur, are also mentioned, as M. Boussingault observed at the volcan of Pasto.

A crater now often mentioned by voyagers is that of Kirauea, on the island of Hawaii, one of the Sandwich group. This vast cavity is three and a half miles long and two and a half wide, and over a thousand feet deep: Captain Wilkes, in his narrative of the United States Exploring Expedition, states that "the city of New York might be placed within it, and when at its bottom would be hardly noticed. A black ledge surrounds it at the depth of 660 feet, and thence to the bottom is 384 feet. The bottom looks in the

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26. Is anything found at the bottom of craters besides lava?

daytime like a heap of smouldering ruins. The descent to the ledge appears to the sight a short and easy task, but it takes an hour to accomplish.

"All the usual ideas of volcanic craters are dissipated upon seeing this. There is no elevated cone, no igneous matter or rocks ejected beyond the rim. The banks appear as if built of massive blocks, which are in places clothed with ferns, nourished by the issuing vapours.

"What is wonderful in the day, becomes ten times more so at night. The immense pool of cherry-red liquid lava, in a state of violent ebullition, illuminates the whole expanse, and flows in all directions like water, while an illuminated cloud hangs over it like a vast canopy."

27. *Solfata'ras.*—There are a great many craters which for a long time have not given exit to any lava, and are reduced to disengaging, in greater or less abundance, sulphurous gas, which escapes by a multitude of fissures in the soil, and often accompanied by aqueous vapour. Hence the name of *Solfata'ra* has been given to those places where these phenomena are more or less developed. There are some craters which seem to have been always in this state. Such, for example, is the Solfata'ra of Pouzzoli, in the kingdom of Naples, which is a vast crater of elevation, at the bottom of which are found broken volcanic rocks, daily decomposed by the vapours. This solfata'ra is of the highest antiquity, and appears never to have presented other phenomena than those now observed. When in repose, volcanic craters become more or less active solfata'ras.

28. It is not uncommon to find one or more lakes, frequently of great depth, at the bottom of craters and solfata'ras. The waters they contain are sometimes quite pure, but they are often charged with various salts, or sulphurous or sulphuric acid, as was seen in the volcan of Teschem, in the island of Java, prior to 1817, the year when this mountain was entirely destroyed by the action of gas.

29. *Commencement of eruptions.*—Continuous emissions of gas or scoriaceous matter from certain volcans, must not be confounded with eruptions, which are sudden events, fortunately transitory, often bringing desolation over an entire country. When an eruption is about to take place it is ordinarily preceded by earthquakes, after which it suddenly occurs with more or less noise. If a volcan already exist in the country, an eruption begins by pouring out abundant *fumes*, composed of various gases and aqueous vapour, then pulverulent matter called *volcanic ashes*, the quantity of which is sometimes immense; then follow directly, when they do not appear from the beginning, fragments of red-hot porous stones, called *rapilli* or *lapilli* and *pouzzolani*, more or less considerable blocks of solid matter, which are sometimes ejected to great dis-

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27. What are Solfata'ras?

28. What is the character of the water of lakes found in craters?

29. How is the commencement of eruptions characterized? What are volcanic ashes? What is rapilli? What are volcanic bombs? What is tu'fa?

tances; and lastly, portions of melted matter torn from the lava filling the crater, and becoming rounded by their motion through the air, form what are called *volcanic bombs.* From all this we have, amidst violent detonations, immense bundles or masses of various matters projected to great heights, lighted by reflection from the melted lava, part of which fall at greater or less distances, according to their weight and the force with which they are impelled. Ashes, rapilli, or pomice then produce in the vicinity of the volcan, sometimes even at a distance, considerable deposits, which becoming solid by their weight and by water, form what is termed *volcanic tufa,pumice tufa*, and various *conglomerates.*

The vapours and ashes ejected from volcanoes sometimes form enormous clouds, frequently dense enough to intercept the light of day, and shroud the whole neighbourhood in darkness. These clouds, driven by the wind, are sometimes carried to the distance of twenty, fifty, and even two hundred leagues. This happened in 1812, when the ashes of Saint Vincent, in the Antilles, were carried to Barbadoes, and so darkened the air that persons could not see their way. The ashes of Vesuvius were carried in 1794 to the end of Calabria; and it was found even in Procopus, that during the eruption of 452 they were conveyed as far as Constantinople.

What occurs at the bottom of seas during eruptions is not seen; but it is clear that the ejection of earthy matters, rapilli, and pumice, are not less abundant, because we find at these times on the surface enormous quantities of them, and in land upheaved, there are seen distinctly deposits of volcanic tufa, pumice tufa, and conglomerates, precisely like those formed on land.

30. *Appearance of melted matters.*—The phenomena mentioned are sometimes the only effects of an eruption; but most generally they are only the precursors or sequents of the expulsion of melted matter, which soon appears under different forms. Sometimes these matters, most frequently in mass, rise in *cones* or *domes* above the very orifice from which they issued, sometimes entire, sometimes vertically perforated in the centre, sometimes susceptible of being pushed further out. This happened at Jorullo, and again and again in the gulf of Santorin, and the same must occur in a great many other localities.

31. Under other circumstances, the crater first formed at the summit of a volcan is completely filled with melted matters; these soon break a passage at a greater or less depth, pouring out torrents, which furrow the side of the mountain, and run to the plain, where they spread more or less.

32. *Form of currents.*—If fissures or cracks of eruption be formed at the foot of a volcano in a flat country, the lava escaping from it at once forms broad horizontal sheets in the middle of the plain. This occurred in Iceland in 1783; crevasses formed in the plain at the foot of Skaptar-Jokul, a high volcanic mountain of the

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30. What is the form of melted matters ejected from volcanoes?
31. How are lava-currents formed?
32. What is the form of lava-currents?

country, and an immense volume of melted matter escaped from them. This immediately spread over the soil, covering eighty square leagues, filling up all depressions, and forming a vast lake of fire of considerable depth.

33. But this is not always the case; the current often forms on more or less inclined slopes, and the lava forms true currents on their surface, of greater or less length, a part of which adheres to the land in consequence of cooling, and in evidence of its passage. After its exit from the bosom of the earth, the melted matter soon cools on the outside, solidifies, wrinkling and cracking in every direction, and thus acquires a crust, ordinarily porous, the thickness of which becomes more or less considerable. This crust prevents the liquid or paste it envelopes from spreading, and confines the current to a certain thickness; also, from its slight faculty of conducting heat it prevents the interior lava from cooling, which, from this cause, goes on very slowly. Lavas have in fact remained liquid or pasty, and preserved a high temperature for a very considerable time; some are cited as still running on very gentle slopes, ten years after their ejection, and others which gave off vapour twenty-six years after their exit from the bosom of the earth.

34. If after the external cooling the volcanic spring continues to furnish melted lava, the current takes place in a kind of consolidated sack which is formed; a sack which then strives, as it were, in all directions, is broken and mended successively; this causes the twisting and various irregularities in the current of lava. When the source is stopped, the matter which escaped from it does not continue to flow the less in the sack enclosing it, but the latter successively flattens, and the middle is effaced, leaving a more or less elevated roll or ridge on the margins. This is first seen at the upper part of the current, then successively to a point where the liquid matter, becoming more and more viscid, has not sufficient force to drag after it the solid parts formed, to break or push them forwards. The lava then stops at the bottom of the sack, terminating in a club-like mass (*fig.* 200). The form, direction, and extent of these lava-currents vary according to circumstances, such as the degree of inclination of the mountain sides, and the nature of the lava itself. Some volcanic products are so pasty they cannot run, but remain over the aperture, as occurs with certain trachytes, which then form more or less elevated domes. Others, such as various obsidians, which seem to cool and harden quickly, are sometimes arrested in form of great tears,

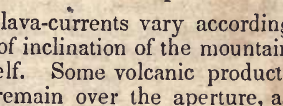
Fig. 200.—*Lava-current arrested on a slope.*

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33. Do lava currents cool rapidly under all circumstances?

34. Is the form, direction, and extent of lava-currents always the same?

even on steep slopes, as at Teneriffe. On the contrary, stony lavas which cool slowly and long remain fluid, are not arrested except on a horizontal plain.

35. *Various characters of the same lava.*—From what has been stated, it is certain that lavas cannot accumulate to a great thickness, or spread in sheets, except on a horizontal plain. The structure of lava depends, in a degree, on its external arrangement. The vein, which is behind the current, on a very steep slope, is, in parts, thin, scoriaceous, corded, and always very porous. On less steep slopes, the surface of pieces is more united, the pores are smaller; on descents, at an angle of from three to five degrees, the dislocated parts are in plates of greater or less thickness, the structure of which presents a certain uniformity, and the centre is sometimes a little more compact, if the thickness is sufficient. In great flows, causing great accumulations on plains, where the depressions are filled up, all the inferior part becomes a compact, and, more or less, crystalline mass, which is porphyritic, because then it cools slowly and tranquilly; in this case it is frequently divided, through its whole height, into columnar masses, generally normal on the cooling surfaces, and porous at the upper part only; this is seen at Vesuvius and Etna, where the lava is very thick, and at Iceland in the immense deposit formed by the eruption of 1783.

36. *Veins of Lava, or Dykes.*—It frequently happens, that in volcanic eruptions there is formed, on the sides of the mountain, crevices of greater or less breadth, through which the lava comes to the surface of the soil. These cracks are remarked for a long time after their formation, either from remaining partly open, or from the rapilli with which they are filled, leaving a kind of ditch, which may be readily followed. They may be also recognised by the partial and crateriform excavations of these debris, which all have the same line of direction; sometimes they are distinguished by rolls of scoriæ on the edges, which escaped while the lava was boiling in the interior; they also exhibit conduits of lava, which unite to each other the different cones of eruption formed on their line of direction. It cannot be doubted that these cracks remain partly filled with the lava to which they gave passage, giving rise to *veins*, or *dykes*. Sometimes the lava flows above the crack or fissure, forming sheets on the surface. Sometimes a coat or bed of lava is found in evident communication with a dyke, which, after having passed up through all the lower deposits, stops in the middle of it (*fig.* 201); and it is not rare to find several beds of lava lying one above the other, each one corresponding with a particular dyke (*fig.* 202), to which, no doubt, it owes its origin; the

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35. Are the characters of lava always the same?
36. What are dykes? Are all dykes precisely the same in character?

most recent of these dykes or veins being the one which has passed up through all the inferior beds or tables, to form the upper one.

Fig. 201.

Fig. 202.

Sheets, or tables of Lava, with their corresponding Dykes.

37. The matter that constitutes dykes is rarely porous, except sometimes on the sides towards the rock encasing it; it is frequently even of a finer grain than the table or bed in which the dyke terminates; its mass is sometimes divided into prisms perpendicular to the sides of the fissure, which were the cooling surfaces. This matter generally resists atmospheric influences, and it frequently happens that the surrounding rock being *degraded*, carried away by external agents, the dyke remains projecting on the side of the escarpment (*fig.* 203), or even rising out of the earth like a wall.

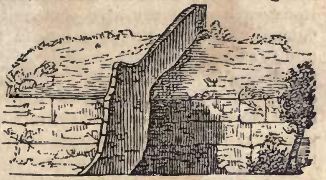

Fig. 203.—*Dyke brought into view by destruction of surrounding rocks.*

38. *Gaseous volcanic products.*—Volcanic phenomena are accompanied by the production of great quantities of various gases, some permanent, others condensable or soluble. These products consist for the most part of watery vapour; but they are found to contain also various acids, and other matters sublimated from the volcano. Most of these gases are fatal when breathed.

Gases, always at a high temperature and mixed with the vapour of water, act powerfully on the solid surrounding matters; they disaggregate and decompose them in all ways, reduce them to powder, to mud, and form new compounds of every kind. This happens in all solfata'ras, where it is often necessary to be cautioned against falling into masses of muddy matter, which is sometimes very hot. But nothing is comparable in this respect to the volcans of Java; the acid and aqueous vapours which are there in great abundance, destroy the rocks and form a paste of them, which speedily becomes incapable of resisting the explosive action of the interior. These fearful eruptions take place, not of lava as in ordinary volcanoes, but of enormous masses of boiling water, charged with sulphuric acid and thick mud, which destroy everything in their way, and cover the whole country with a sulphurous slime the matter of which is called *buah.* This happened in 1822, on the eruption of Gallung-Gung, which, with earthquakes and horrible noises, was considerably sunk, truncated at the summit, and entirely overturned. Torrents of hot sulphurous water and mud issued from rents

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37. What is the character of the matter constituting dykes? By what means are dykes sometimes naturally brought into view?

38. What are the characters of the gaseous products of volcanoes? How do gases affect surrounding solids? Do volcanoes ever eject mud? In what condition is lava when gases are disengaged from it?

in the side of the mountain; and many inhabitants were swept away in the waters, or buried under deposits of mud, during the 8th and 12th days of October.

Muddy eruptions of Quito.—The volcans of Peru, which like those of Java have rarely produced lavas, vomit from their sides torrents of mud called *moya*, sometimes sulphurous like the *buah* of Java, at others carboni′ferous. This happened in 1698, when the volcan of Carguarai′zo crumbled, covering more than 2500 square miles with mud; and in 1797, when the village Pellile′o, near Rio-Bamba, was buried under a mass of black mud, &c. What especially characterizes the eruptions in Peru, and makes them very strange, is that the muddy waters which spring from the bosom of the earth, are filled with small fishes, species of which live in the neighbouring lakes; and the quantity of them has been sometimes so great as to excite epidemic diseases by their putrefaction.

Gases disengaged from Lavas.—It can be readily conceived that gases and matters of various kinds may be disengaged from the bowels of the earth, through fissures communicating with its surface; but what is most remarkable, they are also disengaged from lavas, although on leaving the volcano they have no properties in common. As long as the lava is fluid and at a high temperature nothing escapes from it, but the moment it begins to harden, and consequently to cool, gases are disengaged in more or less quantity. Streams, matters which filled the lowest levels, then constantly emit the vapour of water, hydrochloric acid, sal ammoniac, which are deposited on the surface, to say nothing of realgar, iron, &c., which are sometimes sublimed in the fissures or cracks. Consequently the lava itself must contain these matters, which remain engaged in it, we know not how, while the mass is fluid or pasty, and which are disengaged just in proportion as it solidifies and cools, and in a manner which leaves no after-trace. It is supposed that all these matters give to porous lavas, the power of preserving their fluidity for a much longer time than similar substances artificially prepared.

39. *Solid products of Volcanoes.*—All the solid substances which volcanoes produce in great abundance, belong to the group of si′licates, generally anhy′drous si′licates, and particularly to that division of those confounded under the name of feldspar. These are generally compound rocks, and substances more or less mixed, the principal base of which it is difficult to separate, and therefore they cannot be accurately classified: we are forced to resort to artificial divisions.

1st. *Tra′chyte* (from the Greek *trachus*, rough) is a rock often rough to the touch, as its name indicates, composed of albite or rya′colite, sometimes compact, of a ceröid or vitreo-resinous, and occasionally earthy lustre, sometimes crystalline, the mass being finely porous, containing crystals of the same substances, and often also hornblende and black mica.

Albite (from the Latin, *albus*, white), a mineral so called from its colour, which contains si′lica, alu′mina, and soda. A lamellar variety is found at Chesterfield, Mass., called *Cleavelandite*, in honour of Professor Cleaveland.

Rya′colite (from the Greek, *ruax*, a stream, and *lithos*, stone), is a glassy mineral, of a greyish-yellow to white colour, or colourless. Besides si′lica, alu′mina, and soda, rya′colite contains potash.

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39. What are the general characters of the solid products of volcanoes? What is tra′chyte?

Hornblende (from the German), a kind of dark or black variety of mineral, belonging to the same group as tre'molite, acti'nolite, asbe'stus, &c.

Mi'ca (from the Latin, *mico*, I shine), is a mineral generally found in thin, elastic laminæ, soft, smooth, and of various colours and degrees of transparency. It is one of the constituents of granite and its associate rocks.

40. 2d. *Obsi'dian* (from the Greek, *opsis*, view, or after Obsidius, who first found it in Ethiopia), is a homogeneous, vitreous substance of various colours. By the ancients it was used in place of glass, and is also called volcanic glass. It consists of si'lica, alu'mina, with a little potash and oxide of iron.

This substance is produced abundantly in the islands of Lipari and Teneriffe, the volcans of the Andes, and wherever volcanic apertures open in tra'chyte.

41. 3d. *Compact lava.* A substance with a compact base of a deep colour, most frequently formed of la bradorite, containing crystals of the same substance, or of the feldspa'thic group in general, which in the mass presents a more or less distinct porphyritic structure. Crystals of py'roxene, of am'phibole, black mica and peridote are also occasionally found.

La'bradorite—Labrador spar. A beautiful variety of opalescent feldspar from the coast of Labrador: it exhibits brilliant and mutable tints of blue, red, green and yellow, and is susceptible of a good polish. It is cut into small slabs, and employed in ornamental jewelry. It is a si'licate of alu'mina, lime, and soda, with traces of oxide of iron.

Py'roxene (from the Greek, *pur*, fire, and *zenos*, stranger). The *augite*, supposed to have pre-existed in the volcanic minerals containing it, and not to have been formed by fire.

Am'phibole (from the Greek, *amphibolos*, equivocal). A name applied by some mineralogists to hornblende, because it may be mistaken for augite.

Peridote, or *Chrysolite* (from the Greek, *chrusos*, gold, and *lithos*, stone), from its colour. The topaz of the ancients.

These substances constitute the centre of thick currents, the inferior part of the mass formed in excavations or hollows; they are often divided into prismatic columns.

42. 4th. *Porous, or scoria'ceous lava.* A substance of the same nature as the preceding, but rarely having crystals embedded in it, and its structure is porous, or cellular. These lavas constitute the upper parts of thick layers, and envelope lava currents and streams which rest on the surface of the ground.

43. 5th. *Pouzzolani, volcanic tufa.* Masses of small scoria'ceous fragments, or *rapilli*, accumulated around volcans, or earthy substances, which contain them in greater or less quantity. *Pumice-tufas* are formed of fragments of pumice, and *tra'chytic conglomerates* of fragments of tra'chyte, united by crystalline or earthy cement.

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40. What is obsi'dian?	41. What is compact lava?
42. What is scoria'ceous lava?	43. What is volcanic tufa?

44. 6th. To these may be added scoriæ in tears, irregular stala'ctites scattered on the surface of volcanoes, and *volcanic bombs*, which are sometimes found at considerable distances.

45. Volcanoes furnish annually but a small quantity of materials to the solid crust of the globe, and the upheavals they cause produce very slight change in the elevation of countries where their action is manifest. Nevertheless, if we remember that a great number have been in action since the time of history, and observation shows that a great many more were previously in action, we are led to the conclusion that volcanic substances are important, and their presence must have occasioned great modifications on the surface of our planet.

LESSON VII.

INFLUENCE OF EXTERNAL AGENTS ON THE SURFACE OF THE EARTH. —*Effects of the Atmosphere—Degradation—Effects of Winds —Dunes—Effects of Lightning.*

EFFECTS OF WATER. — *Dissolving power — Softening power — Denudation—Erosion—Effects of weight of Water—Running Waters—Debacle of Lakes—Mud-torrents—Slope of Torrents and Rivers—Rolled Flints—Transportation by Ice and Glaciers—Action of Waves—Deposits formed by Water—Geysers — Structure of sedimentary Deposits — Ta'lus — Effects of Transport or Drift—Effects of oscillation in Waters—Nature of Deposits from Water — Coral Reefs — Polypa'ria — Peat-bogs.*

1. *Atmospheric Effects.* — Variations of temperature, the air, winds, dryness, and moisture, act very perceptibly on most mineral substances; there is not a rock on the surface of the earth which does not present an appearance, externally, totally differing from what is seen internally, when it is broken. This is everywhere seen in escarpments formed by making roads, in mountainous countries, where it is necessary to cut through rocks; the exterior is discoloured, and more or less extensively disaggregated, compared with the freshly-exposed interior. These effects are not solely produced by a great lapse of time; a few years are sufficient for them to be shown, not only on the surface, but to considerable depths: these effects are seen in ancient quarries of marble, or of

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44. What other solids are produced by volcanoes?

45. What influence do volcanoes exert on the elevation of countries?

1. How are the effects of the atmosphere on rocks manifested? How does frost act on rocks? Is a very long period of time necessary for the atmosphere to produce its effects on rocks?

certain granites, and in dressed stone. The effect is more rapid and perceptible, in proportion to the susceptibility of the substance to imbibe moisture, and to dry again; alternations which produce a very rapid disaggregation, when frequently repeated, as is generally the case in mountains. The substances which degrade most easily, are those of a granular structure, either earthy or crystalline; those of a foliated structure; or compact masses, fractured and split on the surface, such as are often seen in mountains. Frost, when it attacks water absorbed by a body, is also a powerful cause of destruction, because the expansion consequent upon it produces a multitude of cracks in all directions. As long as the cold continues, its parts are held together by ice as by a cement; but when a thaw comes, the whole falls in scales, grains, or dust.

Mountains cannot be visited without meeting evident traces of degradation of this kind. In limestone escarpments (*fig.* 204), we see parts of loose texture, more or less hollowed out, and the more solid banks remain. Hence the falling of the latter, which are successively detached in more or less voluminous blocks. In high mountains (*fig.* 205), often formed of inclined strata, which present their cuts or planes to the slope, we observe the most marked degradations; parts are constantly detached, particularly at times of most sensible atmospheric variations; at the instant of thaw, enormous *avalanches of stones* occur, and roll down the sides with astonishing rapidity, sweeping everything in their course; sometimes great blocks, and considerable portions of the mountain fall with tremendous noise. Hence the enormous debris which accumulate at the base, sometimes covering a great extent.

Fig. 204. *Fig.* 205.

Daily effects of degradation in mountains.

2. *Degradations attributable to these effects.*—The degradation which many rocks present is generally attributed to atmospheric influences, long continued. Almost all rocks, in fact, are more or less deeply changed, and are in a state of much less solid aggregation, much less homogeneous, on the surface, than they are internally. In almost all quarries, it is necessary to remove a great mass of matter, before obtaining blocks which are homogeneous, solid, free from cracks, and possessed of the bright colours which are ordinarily sought; this is especially the case with marble, and generally, also, with compact limestone. Certain granites are so deeply disintegrated, that the whole surface of the soil presents a

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2. What is meant by degradation of rocks? What are rocking stones?

mass of gravel in rounded hills, gullied by the rain in all directions. Frequently we find these granites on the surface of the soil, in great rounded blocks, piled up one on the other (*fig.* 206), in the strangest manner, sometimes in unstable equilibrium, and susceptible of oscillating from the slightest effort; these are termed *rocking stones*, in some localities.

Fig. 206.—*Degradation of granite as seen in different places.*

In mountains where the granite is easily decomposed, we often remark that the mass, more or less cut, is in a sort of horizontal stories, divided by vertical fissures, so as to present a kind of agglomeration of irregular paralle'llipipeds. It is supposed that, in consequence of atmospheric influences, these angular blocks are altered on their faces and angles; that the disaggregated parts are successively detached, producing rounded masses, piled on each other like cheeses, as we now see, sometimes, isolated on the surface of the soil.

3. *Action of winds—dunes.* Although winds act but very feebly on solid mineral masses, they exert an important influence on deposits of fine movable sands. We know that in the deserts of Africa and Arabia, the winds raise immense clouds of burning sands, conveying them from place to place, and suddenly producing vast hills, sometimes quite high, which a new gale again destroys. All sandy sea-coasts are exposed to similar effects; the least gale sets the sands in motion, and produces, on the previously uniform surface, a multitude of wrinkles or ridges, parallel to each other, separated by a greater or less interval, and each presenting a gentle slope towards the wind, and a more abrupt declivity on the opposite side, as represented (*fig.* 207); the next gust of wind sets all these ridges in motion, and each one is soon found to occupy the space which separated it from the preceding ridge. This phenomenon of *dunes*, or *downs*, is seen in miniature on the sea-beaches; and they sometimes invade immense tracts on adjacent planes. These hills, placed one behind the other, in a direction perpendicular to that of the prevailing winds, are constantly in motion, and constantly advance towards the interior of the land; the wind from

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3. What are dunes? How are they formed? What is meant by ta'lus? At what rate do dunes advance?

seaward drives the sand from the foot of the hillock (*fig.* 207, *a*), to its summit (*b*), whence it falls in the line *b*, *c*, forming at this point a falling *talus*, always more abrupt than the first or rising ta'lus. The result of this is a single hillock, *a b c*, taken separately (*fig.* 208), which grows behind, if new sands be furnished in front, or it is displaced, if the same sands are continually removed. Now, the wind acting on all these hillocks at the same time, the mass formed by them is found to have moved a certain distance inland, in a short time, while new heaps are formed in front, at the expense of the sands freshly washed up from the sea. It is calculated that *dunes* advance, in this way, twenty or thirty yards a year; so that it is evident there must have been a time when they were far from the places they have invaded. A great many localities are known, which have been submerged by these seas of sand.

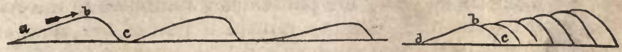

Fig. 207. *Fig.* 208.

Progress of dunes, or moving sands.

4. *Lightning* sometimes produces remarkable effects; in a great many places and on various rocks, traces of fusion by thunderbolts in high mountains have been observed. According to the observations of Friedler, when lightning penetrates sand, it often forms narrow, irregular canals to a great depth, the sides of which are consolidated by the fusion of quartz itself; and there are instances where considerable portions of rocks have been turned round, torn from their places and hurled to great distances by lightning.

5. *Effects of Water.*—Water plays a very important part in the changes which are taking place on the surface of the globe; sometimes by its dissolving power, but more frequently by its softening action, its weight, and especially by the motion that may be communicated to it, and by the transporting power resulting from its rapidity. The extent and importance of modifications from this agent ought to be understood.

6. *Dissolving power.*—Water exerts a chemical action on some substances which it dissolves, either directly or by means of the carbonic acid it may contain. It acts directly on some salts which it meets here and there, or on some deposits of sulphate of lime, which it corrodes in various ways. When more or less charged with carbonic acid it acts on calcareous rocks, either under ground or where they crop out on the surface; or in high mountains at the time snows are melting. In this case, the water generally possesses itself of the carbonic acid contained in the air, in greater

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4. What are the effects of lightning on rocks?
5 By what properties does water produce its effects on rocks?
6. What effects result from the dissolving power of water?

quantity than at other times, in consequence of its low temperature; and running over calcareous masses, it forms furrows which gradually deepen, and sometimes cause very considerable falls of rock. These slow effects of water are particularly remarked in the Alps and Pyrenees, where the snows remain a part of the year, and melt by degrees in the fine season.

7. *Softening power.*—Water, by penetrating argilla'ceous beds, sometimes softens them so much, that they cannot remain on the slopes they occupied, and fall from their own weight; this is the cause of many falls or slides in sedimentary formations. One of the most remarkable catastrophes of this kind happened in 1806 at Ruffiberg or Rossberg in Switzerland, after a very rainy season. The argillaceous matters which cemented the rolled flints forming the mountain becoming softened, a mass of more than 50,000,000 of cubic yards was suddenly detached, and precipitated into the valley, forming in it hills sixty yards high, and burying several villages under masses of mud and flints. We often see, on a small scale, thick beds of rock gently slide to the bottom of valleys, on softened argilla'ceous beds which supported them, and tranquilly displace plantations and even the inhabitants on them, without the proprietors perceiving it at the first moment.

8. Waters which filter through rocks to argilla'ceous layers which may arrest them, and on the plane of which they are directed to the surface, sometimes soften these substances also, carrying away parts successively, and especially sands that may rest on them, laying bare in this way underlying beds: this is termed *denudation*. There results from this, at the point where the water breaks forth from the declivity of hills, more or less extensive voids, which leave the solid superposed masses without support, which are then dislocated in different ways (*fig.* 209) and soon overthrown. This is frequently seen in certain escarpments, at the base of which are found argilo-arena'ceous layers which conduct the springs externally.

Fig. 209.

Fig. 210

Escarpments produced by the action of water.

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7. What are the effects of the softening power of water on rocks?
8. What is meant by denudation?

9. *Erosion.*—Something analogous happens when waters, which washing the foot of a mountain, meet there with substances that they can easily soften or disaggregate. These substances being destroyed, the upper parts of the soil are soon undermined, and more or less considerable falls occur. This takes place on sea-coasts, on the shores of lakes or rivers where more or less elevated escarpments are formed, and more and more degraded. The same thing happens sometimes at the foot of cascades which fall over rocky peaks (*fig.* 210), forming alternately calcareous and argilla'ceous deposits; the latter are disaggregated, and borne away little by little by the waters which exude on the parietes or jet forth after the fall, and other layers being undermined must fall sooner or later from their own weight. In this case the cascade cuts deep into the soil, and the same being successively repeated, necessarily forms a gorge or bed the whole length of the rivulet, which deepens more and more. It is in this way that the falls of Niagara, by which the waters of lake Erie are precipitated into those of lake Ontario, have sensibly receded since the discovery by Europeans, and probably have excavated the deep bed through which they afterwards escape.

"The waters, after cutting through strata of limestone, about fifty feet thick in the rapids, descend perpendicularly at the falls (of Niagara) over another mass of limestone about ninety feet thick, beneath which lie soft shales of equal thickness, continually undermined by the action of the spray, driven violently by gusts of wind against the base of the precipice. In consequence of this disintegration, portions of the incumbent rock are left unsupported, and tumble down from time to time, so that the cataract is made to recede southwards. The sudden descent of huge rocky fragments of the undermined limestone at the Horse-Shoe Fall, in 1828, and another at the American Fall, in 1818, are said to have shaken the adjacent country like an earthquake. According to the statement of our guide in 1841, Samuel Hooker, an indentation of about forty feet has been produced in the middle ledge of limestone at the lesser fall, since the year 1815, so that it has begun to assume the shape of a crescent, while within the same period the Horse-shoe Fall has been altered so as less to deserve its name. Goat-Island has lost several acres in area in the last four years (prior to 1841); and I have no doubt that this waste neither is, nor has been, a mere temporary accident, since I found that the same recession was in progress in various other waterfalls which I visited with Mr. Hall, in the state of New York. Some of these intersect the same rocks as the Niagara—for example the Genesee at Rochester; others are cutting their way through newer formations—Allan's creek, below Le Roy, or the Genesee at its upper falls at Portage. Mr. Bakewell calculated that, in the forty years preceding 1830, the Niagara had been going back at the rate of about a yard annually; but I conceive that one foot per year would be a much more probable conjecture, in which case 35,000 years would have been required for the retreat of the falls from the escarpment of Queenston to their present site, if we could assume that the retrograde movement had been uniform throughout. This, however, could not have been the case, as at every step in the process of excavation, the height of the precipice, the hardness of the materials at its

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9. What is meant by erosion? What are the effects of erosion?

base, and the quantity of fallen matter to be removed, must have varied. At some points it may have receded much faster than at present, at others much slower; and it would be scarcely possible to decide whether its average progress has been more or less rapid than now."—*Lyell's Travels in North America.*

10. *Effects of weight.*—Water acting by its own weight like other bodies, evidently often contributes to such land-falls as we mention, and also exerts a powerful action on the dykes and barriers which retain it. We see the unhappy effects of inundations, to which certain countries are subject from their vicinity to rivers, lakes, or seas, retained by natural or artificial dykes.

11. *Action of running waters.*—To the softening action and weight of waters is often added a new power, from the motion they acquire by running over steep descents. This force is sometimes prodigious. The effects are seen after storms which pass over moveable substances, in the deep ravines found to have been excavated. These effects are in proportion to the mass of water, and the rapidity of its motion on a particular point. When a hurricane or violent storm bursts on a mountain, the soil is often found, unless it consist of living rock, removed and gullied to great depths. The numerous fissures on the surface of rocks facilitate the action of waters, and a considerable mass of fragments is soon detached, which increase more and more the destructive power of the current. Then blocks of every size are loosened, torn from the mountain and transported to great distances, multiplying the effects ten or even a hundred fold, in proportion to their mass and rapidity of motion. Hence we have great ravines on slopes that were previously unbroken, and an immense accumulation of debris at the foot of the mountain, and especially where the soil or the swiftness of the stream abated. Torrents swollen by circumstances of this kind, or by the sudden melting of snows, also produce frightful ravages; they sweep everything in their way, even the living rock, which they soon attack forcibly by the fragments and blocks they swiftly urge along. Nothing is more terrible than this kind of water-course, and to form an exact idea of the effects one must see a gorge through which it has passed, sometimes rolling along rocks measuring ten or fifteen cubic yards.

12. *Debacle of Lakes.*—Lakes which sometimes form in valleys, by avalanches or falls of land, constituting a barrier which retains them, are most fearful in their *debacle* (sudden escape of their waters from breaking of their barrier), in consequence of an enormous mass of water rushing forth in a few seconds. Scarcely does a flow begin through a few rents, before the first opening rapidly enlarges, and in an instant the whole dyke is carried away. An

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10. Does the weight of water contribute to its effects?
11. What are the effects of running waters?
12. What is meant by debacle? What are the effects of debacle?

enormous volume of water is then precipitated with extreme violence, and nothing can withstand the combined effects of its mass and rapidity. All is overturned, and the most solid rocks, if they project, in the least, across the direction of the current, are instantly torn away, broken, and transported to great distances. The clearing is so complete, at the origin of the current, and in the narrow passages where the slope is rapid, that the exposed rock seems to have been cut by the hand of man.

13. *Mud-torrents*, from one cause or another, are also formed, which are not less terrible in their ravages. It sometimes happens, as in Ireland, that turf-beds placed on a slight declivity, after being swelled, more or less arched by retaining rain-water beneath them, cannot resist the first heavy shower, and are set in motion. They run then, in spite of the consistence of the mud, and the gentleness of the descent, with prodigious rapidity, and sweep everything they meet. Under other circumstances, the rain-waters soak in loose, argilla'ceous substances, accumulate in the midst of them, and, at a certain moment, the dykes of the reservoir give way, and a torrent of thick mud, filled with fragments of rock and even blocks, suspended in the viscid mass, is formed, and rushes with fearful rapidity, overturning everything, and cutting deep ravines.

14. *Slopes of torrents and rivers.* — The disastrous effects of torrents are in proportion to the descent on which they move; but it does not necessarily follow that their bed must have a very considerable inclination. The most rapid torrents, forming a continuous bed and carrying rocks a half-yard in diameter, have a descent of only one or two degrees, and many rivers flow very swiftly on a much less slope — a descent of from three to four minutes (sixty to a degree) is about the limit for navigable rivers.

15. *Rolled flints, or pebbles.* — In the ravages produced by water-currents, the debris torn from mountains are transported to a greater or less distance, accordingly as the inclination of the soil permits the current to maintain its force for more or less considerable distances; but in proportion as the slopes diminish, the swiftness decreases, and the larger blocks successively remain behind, at the bottom of the valley, and then those of smaller size, and successively the sand and mud, which are often carried enormous distances. In this rolling of different substances, the blocks and fragments sinking during their transportation, rubbing against each other and against the soil, gradually lose their prominences and angles, and in the end become completely rounded, forming what are termed *rolled flints*, which may be more or less voluminous.

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13. How are mud-torrents formed? What are their effects?

14. Upon what do the effects of torrents depend? What is the rate of the slope of beds of rivers that are navigable?

15. How are rolled flints and pebbles produced? What is gravel? What is sand?

All the lower part of torrents, where the soil is sufficiently flattened, or the enlargement of the valley permits the waters to expand, diminishing their depth, and consequently their rapidity, is generally found covered with these flints, which are sometimes accumulated in immense quantities, and through which, in its ordinary course, the stream meanders in different ways, in a bed it forms and often changes. Rivers and lakes into which torrents empty, and where they consequently lose their swiftness, are often loaded with these flints; and this is the cause of the constant elevation of the bed of the river Po (see page 15). *Gravel* and *sand*, which are merely small flints, the mud which results from their friction, and the earthy particles removed, are always transported far, either immediately into lakes, or seas, or rivers, which deposit them on their banks, and especially at their mouths, which they more or less obstruct.

16. Rolled flints, or pebbles, are also formed by the action of the waves on fallen rocks. In this way, on the coasts of France and England, the silex, or flints of the chalk, are rounded, by being rubbed against each other, and constitute considerable banks of pebbles or shingle. Something similar must have taken place at points now far inland, where we find blocks round and smooth, at a short distance from rocks from which they were evidently detached.

17. *Transportation by ice and glaciers.*—On the shores of northern seas, the ice envelopes blocks and masses of rock, which, at the breaking up, are floated away on ice-cakes in all directions, and deposited here and there, wherever they may ground, or fall to the bottom of the sea. In this way, in Canada, Greenland, and on the coasts of Nova Zembla, &c., very voluminous blocks are transported from one place to another, and often to very considerable distances from the point of departure. There is no doubt that many small debris, embedded in the ice, are transported in the same way, and form adventitious deposits of more or less extent.

18. Glaciers, that is, beds of ice occupying the high valleys of lofty mountain chains, are also very remarkable means of transportation. Various circumstances (their great weight chiefly) keep these deposits in constant, though very slow motion, from half an inch to an inch an hour, descending along the slopes on which they rest; now, the surface of these glaciers is found to be covered with fragments and blocks which have fallen from the surrounding mountains, and the whole is conveyed from the upper to the lower part; and blocks, often of enormous size, are carried

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16. Are rolled flints, or pebbles, produced by running water exclusively? What is shingle?

17. How are rocks transported by ice?

18. What are glaciers? At what rate do they move? What are moraines?

without friction to considerable distances from their place of origin. These debris, from several causes, always accumulate on the lateral parts of the glacier, against the side of the valley, and frequently in the middle also, from other valleys emptying laterally into it, from which result long, slender hills, designated under the term *moraines.* All these debris, having reached the inferior extremity of the glacier, tumble into the valley on its slope, and form at its foot other moraines often of considerable height. If, after having increased for a certain time in consequence of a series of cold summers, the glacier diminishes again by a succession of warm, prolonged summers, the moraines of different kinds, abandoned by the ice, are left on the soil; some form dykes, of more or less height, at the bottom and across the valley, and others long lines on the flanks of the valley, at a greater or less elevation.

19. It must be borne in mind that the slopes on which glaciers move are always much greater than those of rivers, and that they never descend at an angle of less than three degrees. This must also be the minimum slope of masses of debris resting on the sides of the valley, in consequence of the rapid melting of the glacier. Thus we have a means of distinguishing the remains of lateral moraines from deposits which may have been made by water-currents, the slopes of which are very much less.

20. *Striæ, channels, polishing of rocks.*—Among the effects produced by the motion of a glacier loaded with debris, and moving slowly over the exposed face of a rock, is a rubbing, wearing, and polishing of the surface which is passed over. The angles of the rocks passed over are rounded; deep undulating grooves, nearly parallel and longitudinal, are cut in the surface, and the polished surface of the rock passed over is scratched with fine striæ, even when it is of the hardest quartz. These effects are well known to be produced by modern glaciers.

21. *Action of the waves and of tides.*—Waves exert an enormous power, particularly where rocks are abrupt and directly exposed to the open sea. The shock is sometimes so great that the earth trembles beneath the feet; great blocks of stone are torn up and carried far inland, pushed up against the inclination of the shore, sometimes thrown up vertically on projecting points, where they afterwards roll about like small pebbles: heavy banks of sand and of shingle are often removed, and entire countries have been in a moment destroyed.

Chronology and tradition of maritime countries furnish numerous instances of successive changes, of instantaneous disasters which have occurred in a great many localities. Immense ones have taken place, and every day new ones occur on low, sandy coasts, bordering the sea, in many

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19. What is the least slope or angle at which glaciers move?

20. What effects are produced on rocks by the movement of glaciers loaded with debris?

21. What is the effect of the action of waves?

parts of the world: we have famous examples from the mouths of the Scheld to the canal of Jutland, where the Bies-Bosch, the Harlem sea, the Zuyder-Zee, the Dollart, have been produced in the extraordinary irruptions of the ocean; where numerous changes have taken place in the islands, from the Texel to the mouths of the Elbe, in the windings of Lymfiord, or on the coasts of the Cattegat and of the Baltic: immense cuts, bays, and deep gulfs are formed during tempests, and these are still daily forming by the ordinary action of the waves, which sometimes carry away banks of sand, and sometimes destroy the dykes they had already formed.

22. The action of waves is not confined to moveable soils, but takes place on the most solid rocks; and hence those daily modifications in the enormous precipices found on the coasts of France, England, and almost all parts of the world. The more abrupt the coast, the more it is exposed to denudation from the waves, because directly breaking them, the shock is felt in all its force. On flat coasts, on the contrary, the wave meeting with no obstacle, advances as long as its force lasts, and until its rapidity is sensibly lost; and it carries up in sand and pebbles much more than it destroys, even on the most moveable soils. The natural disposition of solid beds is sometimes opposed, and at others favourable to the action of waves; it is opposed when the beds, being uniform and homoge'neous, incline towards the sea; because the return of the wave along the slope or ta'lus diminishes the action of the succeeding wave, the remaining force of which is spent in merely ascending the plane: the waters are spattered only by the crevices and fissures that may exist in the rock. But the same is not the case when the soil presents an escarpment to the action of the waters (*figs.* 211, 212): the lower parts, continually attacked by reiterated shocks of waves, which nothing contributes to diminish, are degraded and excavated successively, and with a rapidity in proportion to the facility with which the substance is disaggregated; the upper beds being soon undermined, are not long in being precipitated into the sea. In this way considerable portions of coast have been overturned at different times, promontories have disap-

Fig. 211. *Fig.* 212.

Action of waves on abrupt rocks.

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22. Are all coasts equally subject to the action of waves. What circumstances diminish the effects of the action of waves?

peared, and others have been cut off and separated from the main land. These effects are more rapid in places where a deep sea swallows up the detached blocks, or in those where the force of the waves is sufficiently powerful to break up the debris, and wear them one against the other and successively remove them, so that the foot of the escarpment always remains bare.

23. When masses of debris falling from precipices are not immediately removed, a natural rampart is formed against the action of the waves, which break before reaching the foot of the escarpment (*fig.* 213); then it is only in a long time that the debris are worn, rounded, and carried away little by little, depending on the solidity of the rocks of which they are formed. These natural ramparts are imitated as much as possible by piling rocks before the ta'lus we wish to preserve on sea-coasts or river banks.

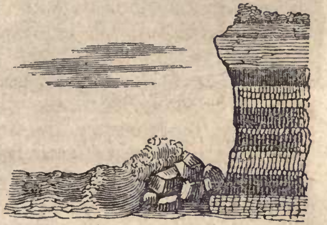

Fig.* 213.—*Accumulation of debris opposing the action of waves.

24. To the action of waves must be attributed certain excavations frequently found, on a level with the sea, in calcareous precipices, as well, perhaps, as the arches of greater or less height which traverse certain promontories. Nevertheless, this action does not immediately produce great results, except on matters easily disaggregated, such as chalk, clay, and arena'ceous substances, and it is infinitely slow on more compact and harder substances: in fact, there are points where no effect whatever has been produced within historic times. The erosive power of water does not explain all these facts, nor even the impetuous force of waves; the soils on which this power is exerted are cracked in all directions, either by previous action, or at the moment of earthquakes, accompanied by violent agitations of the sea, and it is then they yield to the combined forces to which they are exposed. By this means we can account for isolated rocks, for islands in the vicinity of continents, for those great gaps through which the sea finds passage, for those groups of split rocks which form shoals in the midst of the sea, and for all those severings so common and varied on the coasts of France and England, in numerous islands that extend towards the North Sea, and in a great many localities (*figs.* 214, 215).

25. *Deposits of detritus formed by waters.*—Although waters continually degrade certain parts of the globe, they create in a measure new deposits proportioned to those they remove. Tor-

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23. What circumstance protects coasts from the action of waves?
24. What effects are attributable to the action of waves?
25. How are deposits formed from water?

Fig. 214.

Fig. 215.

Examples of rocks eroded and shaped by waters.

rents, after having torn away blocks and fragments of rocks, reduced them to rolled flints or pebbles, and carried them to a greater or less distance, deposit them, in proportion as the swiftness of the waters diminishes, in the inferior parts of valleys they run through, or at their confluence with rivers, or in lakes. Hence the masses of debris, sometimes immense, the coarse parts of which are cemented by the mud, they deposit at the same time.

26. Great rivers, running through valleys of little inclination, generally leave behind the coarser parts they have received, and only bear forward those whose weight is in relation to their force; but as their slope diminishes more and more, becoming almost insensible towards the end of their course, they deposit the matters they carry, and in this way generally elevate their bed; and finally they even bar up their passage, and divide into several branches, each of which cuts its way through sands. Rivers have in this manner covered flat countries through which they pass with sand to a considerable depth and extent. In great freshets these sands are often taken up again, transported from one point to another, forming islands in the middle of the river, or *alluvions* on one of its banks, while the other is hollowed out. In rivers, lakes, or seas, these deposits become most remarkable. There, if the current is not rapid enough to carry the debris to a distance, in spite of the opposition of tranquil waters, or if the waves have not sufficient force to remove the sands and mud which have been deposited; they form *deltas* at the mouths of certain rivers (*see page* 16).

27. The sea itself, which in so many places has made breaches in the main land, in others, heaves up and accumulates enormous quantities of *pebbles*, formed by the trituration of rocks fallen from precipices, or masses of sand and mud produced by the waves, or

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26. What are the effects of deposits from rivers?
27. What are the effects of deposits from the sea?

brought down by rivers. In this way banks and beaches, of greater or less extent, are formed on coasts, the finer parts of which, carried inland by the wind, form *dunes* (see page 125). There are many places where accumulations of this kind are daily formed, and many points of coast have been invaded by deposits from the sea from remotest times: sometimes, by a single irruption, entire kingdoms have been covered by sand, and fertile countries changed to arid plains, either in extraordinary tides, or in tempests, or by the sudden displacement of waters consequent on earthquakes. Low countries, exposed to these *alluvions*, daily grow at the expense of the waters, and, at certain points, this growth has been estimated at several yards a year. Bays and ports have been filled up in this way; buildings and towns, formerly situated on the seashore, are now far from it; lakes have been transformed into marshes, marshes into solid land, and islands joined to the main by sands deposited around them. The sea, in some instances, contributes to the growth of deltas.

28. Torrents and rivers transport not only mineral debris, but also organic remains, immense masses of plants, detached from ravines, or by falls. Here and there great masses of materials are formed, especially in rivers which are bordered by immense forests. Great deposits of debris of this kind are formed in the Mississippi and its tributaries; they there form immense rafts of trunks of trees, interlaced, which are stopped here and there by the sands, and finally are buried under the enormous alluvions daily deposited. The mass of plants that the river carries is so considerable, that it has been estimated at several thousands of cubic yards per hour.

29. Currents of the sea also often transport immense masses of various vegetables, marine plants, and organic debris of every kind, and from all climates, which are here and there deposited in the bays these currents meet in their course. This is especially the case as regards the great Atlantic current, the Gulf Stream, the strongest and most considerable of all, which extends along the coast of North America to the icy regions, where the polar currents accumulate these debris with those of other parts of the world.

We cannot doubt, on reflecting on the quantity of debris borne by the waters, that lakes which receive rivers are filled up, little by little, by the matters daily brought into them; this is evident, in some places, where marshes and considerable alluvions are thus formed. The same must be true of the bottom of the sea, where all waters finally come; it is easy to conceive there must be daily formed considerable deposits of all the substances which are carried there, as well as of those washed away by the waves, and of all the remains of animals which perish in this vast abyss.

30. *Deposits of substances held in solution.*—Waters degrade

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28. Are all the materials, transported by waters, of a mineral origin? How are the rafts in the Mississippi formed?

29. What effects are due to currents of the sea?

and carry away different substances; some they also dissolve, and afterwards deposit them, by evaporation, in form of solid sediments, which are sometimes more or less crystalline. To the infiltration of these waters, for example, is due all kinds of stala′ctites (from the Greek *stalassô*, I drop), which form in various subterraneous cavities, and especially large in caverns found in calcareous countries. Certain waters are rich in dissolved materials, and sufficiently abundant to give rise to extensive deposits on the surface of the earth. Those particularly, which, by carbonic acid, hold a great quantity of carbonate of lime in solution, and which, from abundant or numerous springs, give origin to rivulets and even lakes, at the bottom of which is daily formed what is called *travertin* or *calcareous tu′fa.* These waters are met almost everywhere, in calcareous regions. Scattered over a flat country, or on the slope of a valley, these waters incrust the plants growing there, and, from these agglomerated and superposed incrustations are formed considerable rocks, the mass of which is consolidated by waters which percolate the interstices they meet, and render the whole solid and uniform. When these waters flow over slopes free from vegetation, they deposit thin and successive layers, following the undulations, the whole forming compact masses which daily grow in thickness. In lakes into which waters of this kind flow, horizontal beds of solid calcareous matter are formed, which are often filled with fluviatile, and even terrestrial shells, daily brought into it.

31. Sands washed up by waves, either in fresh-water lakes or seas, are daily consolidated by waters more or less charged with carbonate of lime. Examples of this kind are seen in the sands of lake Superior, in those of the gulf of Messina, at several points on the coasts of England, of the West-India islands, chiefly at Guadaloupe, New Holland, &c. These arena′ceous substances often become sufficiently solid for building purposes.

32. *Sili′cious deposits.*—A great many mineral waters, particularly those which are warm or hot, contain, besides carbonate of lime, a certain quantity of *silex* (from the Greek *chalis*, a pebble); on this account many calcareous tu′fas are more or less silicious. But there are springs in which the silex is sufficiently abundant to form considerable deposits of hydrated sili′cious deposits, sometimes nearly pure, and sometimes mingled with other substances. The tu′fas of the *geyser* in Iceland are deposited for nearly a quarter of a league round the spring, three-quarters of a yard thick. One of these *geysers* (a word which according to some means spouting, and furious, according to others) spouts up every half

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30. How do waters form deposits from matter held in solution? What are stala′ctites?

31. By what means are sands consolidated?

32. How are sili′cious deposits formed? What is a geyser?

hour a column of boiling water, eighteen feet in diameter and one hundred and fifty feet high. Analogous springs of hot water exist in the Rocky mountains, and in India, as well as in Saint Michael's (Azores), where the sili'cious deposits are found in thin beds, alternating with argilla'ceous substances which the same waters bring from the interior of the earth. Organic remains, particularly vegetable, are found in all, some of which have passed into the sili'cious state, while others have disappeared, leaving only their impressions behind.

33. *Structure of sedimentary deposits.—Effects of land-falls.*—If we examine deposits of de'tritus, formed at the foot of mountains by the daily destruction of its rocks, it will be seen their slopes are very variable, the greatest not exceeding an angle of forty-five degrees, and the least being seldom less than twenty degrees; the variations between these limits are found to be in relation to the size, the form of the fragments, and circumstances of the fall, rather than to the nature of the substances themselves. Hence it is, if, at different successive fallings, there are variations in the form of the fragments and in the circumstances of the fall, there will be an accumulation of deposits, the slopes of which will be successively less, and which, in ravines excavated by water, will have nearly the arrrangement represented, *a*, *b*, *c*, *d*, *e*, (*fig.* 216), where each additional deposit is thicker at its base than at the upper part. It is evident the same thing may take place in stagnant waters; whence it follows that from the fall of a river into a lake with steep banks, a very considerable ta'lus may be formed, and from different accessions or growths, which bring materials of different form and size, deposits similar to those just mentioned may be produced.

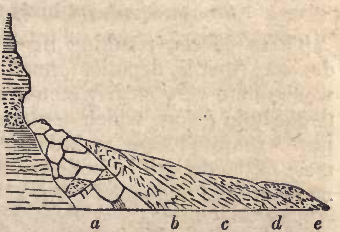

Fig. 216.—*Talus from falling.*

34. *Effects of transport.*—If in some places, even under water, beds may be deposited at an inclination of from twenty to forty-five degrees, it must not be inferred that the same is true of extensive deposits, where running waters, if unimpeded, may force the debris in every direction. Here the inclination of the ta'lus is much less; they never attain even the minimum angle of slopes formed of fallen matter, and never reach even ten or twelve degrees, only in exceptional cases of very rapid torrents, or rather of true cascades, at the place where they fall into a transverse valley, and where there is as much matter tumbled down as transported. The beds of the most rapid rivers are much less inclined, and the successive

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33. What is the structure of deposits from land-falls?
34. Is the angle or slope of a ta'lus always the same?

deposits are for the most part nearly horizontal. Gravel and sand which the waves wash upon coasts, are also deposited at very small angles, and slopes of ten degrees are exceptions, even in localities exposed to the strongest billows; most frequently they are much less, and nearly horizontal.

35. It frequently happens, during the drift or transportation of matters by currents, and by freshets in rivers, when the bottom is disturbed, that effects analogous to those of sea-winds on dunes are produced. Ridges are formed across the current; various matters, pushed over these initial hillocks, accumulate behind them, forming a ta'lus of successive fallings, which impart the structure represented in *fig.* 217. If the river change its course, the undulated surface of the first deposit is soon levelled, and quiet deposits are formed above (*fig.* 218), from which the preceding may be distinguished by the particular *structure* attributable to the circumstances of its formation.

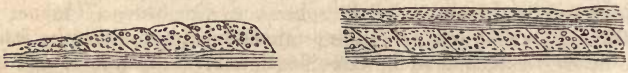

Fig. 217. *Fig.* 218.

Structure produced by the transportation of materials.

These effects, resulting from a mixture of rapid and tranquil deposits (that is, deposits formed from rapid currents and tranquil waters), are very clearly seen in alluvions on river banks, and particularly in deltas, which terminate their course when the waters have excavated some ravine near by. We then perceive that the mass of the deposit is formed of horizontal layers, having a surface more or less undulated (*fig.* 219), which are distinguished from each other by the size of the component parts, by the colour, by the structure produced by rapid accumulation, either by pushing forward the matters in the direction of the ordinary current, as in the deposits *a* and *b*, or in a different direction, as in the deposit *c*, which indicate counter-currents formed at one time or another. Often there are particular masses, *d*, formed here and there, which ordinarily consist of coarser gravel, or of different organic debris.

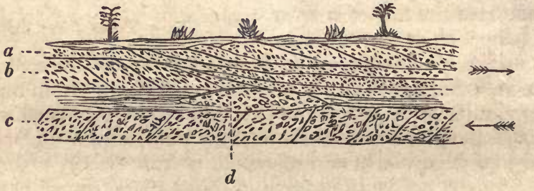

Fig. 219.—*Structure of alluvions in rivers.*

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35. What effects result from transportation or drift?

36. *Effects of oscillatory motion.*—Great masses of water, subject, like the sea, to undulatory motion, present another order of facts; not only are suspended substances deposited there in horizontal beds, as a more weighty fluid would do, but the slightest agitation does not permit any material particle to be solidly fixed on planes of the least inclination, but tends, on the contrary, to destroy all inequalities of the bottom. It is impossible to ascertain positively these effects at the bottom of the sea; but the immense number of soundings, taken in all parts of the ocean by navigators, show that all moving bottoms have very slight inclination; that slopes, at an angle of half a degree, are rare, and that all above this are exceptions: hence it follows, that in great masses of water, beds formed by successive deposits must be entirely horizontal. This fact is most clearly exhibited in certain lakes, which have been entirely or in part dried up, where alternations of beds, of every kind, are seen to be perfectly horizontal; lakes Superior and Huron furnish examples of this kind.

37. This disposition of various matters deposited from water, bed by bed, at the bottom of rivers, lakes, marshes, is termed *stratification;* the deposits themselves are said to be *stratified.* This circumstance eminently distinguishes deposits formed by water, from those produced by igneous fusion, which are most frequently *massive*, or irregularly divided.

38. *Nature of deposits—organic remains.*—Beds of alluvium are formed of rolled flints, gravel, and sand, as well as of various kinds of mud, analogous to matter called clay or argil. They are more or less consolidated, as much by their own weight, as by waters charged with carbonate of lime, or various matters which may penetrate them. In lakes, we see calca'reous and argilla'ceous marls, which have the property of hardening in the air, as has been observed in certain half-dried lakes in Scotland, in modern building-stone found in Hungary, and in lakes Superior and Huron. Similar formations doubtlessly occur in the sea, as waters are sufficiently calci'ferous to consolidate the sands thrown on its coasts; and the nature of upheaved deposits, in many places, leave no uncertainty in this respect.

These deposits are frequently filled with remains of all the organized creatures now living on the surface of the globe. In river alluvium we find remains of fluviatile shells that still live in the same localities, or land shells, such as various snails, brought thither by rivulets; there are branches and trunks of trees, masses of plants, more or less changed, sometimes partly bitumenized, bones of terrestrial or aquatic animals, rarely human bones, but frequently the remains of art, such as fragments of brick and pottery, &c.

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36. What is the position of strata formed under the influence of undulatory motion of water?

37. What is meant by stratification?

38. Of what do beds of alluvium consist?

Alluvions formed by the sea are very similar; they contain marine debris of every kind, sometimes alone and sometimes mingled with fluviatile and terrestrial debris, brought into it by rivers. Debris of human industry, anchors, boats, &c., are frequent, and even man's remains exist; not only in cemeteries of villages that have been overwhelmed by sands, but also among the debris cast up by the sea, as at Guadaloupe, where human bones are found in a sand consolidated by a calca'reous tu'fa, and mingled with debris of human art. In deltas formed partly of fresh water and partly by the sea, we find alternate layers, the one filled with marine debris, and the others by those of fresh water; but, under other circumstances, all these remains are found indiscriminately mingled.

Argilla'ceous, marly, or calca'reous deposits, in lakes, contain the remains of fluviatile and terrestrial mollusks, similar to those now existing in the same regions. Remains of fishes and mammals are also occasionally found. There is no doubt deposits formed in the sea also contain remains of the numerous animals that daily perish. We learn from soundings that the bottom of the sea, in many places, is covered by shells, broken or entire, fragments of madrepore, echinidæ, &c., sometimes mingled with sand, sometimes by themselves, constituting considerable banks in progress of formation and consolidation.

39. *Coral reefs.*—Formations of stony polypa'ria, agglomerated with each other, often of great extent, are thus named; in intertropical regions they constitute a great number of islands, on a level with the sea, or submarine banks, the mass of which rises more and more. It is scarcely twenty years since it was supposed that the little animals which form these deposits, by a calcareous exudation, had the faculty of living at great depths in the ocean; it was thought they began their dwelling, and gradually augmented the mass, until it formed immense mountains, the summits of which constituted the reefs, and that they gave origin to most of the large islands formed in those regions. These microscopic creatures, it was said, tended thus to fill up the ocean, and were preparing prodigious changes on the surface of the globe. But all this exaggeration has disappeared, the observations of MM. Quoi and Gaimard having shown, that the species which contribute most to the formation of reefs, such as *caryophy'lliæ* (*fig.* 220), *meandri'næ* (*fig.* 221), and particularly the *as'treæ* (*fig.* 222), which sometimes cover immense spaces, and various *madrepores* (*fig.* 223), cannot exist except at moderate depths, and ten or twelve yards below the surface no trace of them is to be found. It is, then, on pre-existing rocks, already elevated under water, often very steep on the sides, as soundings show, that these animals begin to build; and from this they afterwards accumulate their solid product to the level of the sea, where their last generations perish. They cannot, then, fill up the ocean; but the incrustations they form are not the less important, since they are sometimes ten or twelve yards thick, extending over immense spaces, and these are found in a great many places in all seas comprehended

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39. In what parts of the world do we find coral reefs? How are they formed? At what depths do polypa'ria live?

Fig. 220.—Caryophy'llia fastigiata.

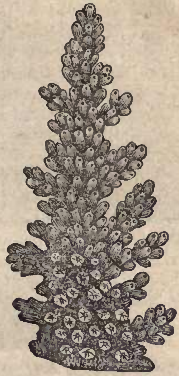

Fig. 223.—Madrepo'ra murica'ta.

Fig. 221.—Meandri'na labyri'nthica.

Fig. 222.—Astrea viridis.

between the tropics. They crown most submarine mountains, and cover thousands of square leagues, distributed among thousands of islands and reefs.

40. These sa'xigenous polypa'ria, attached to every kind of rock, surround most large islands with their products, forming around them a kind of rampart, separated frequently by deep water. In other instances they form islets, detached or grouped in different ways, and they are, when there are breakers, the more dangerous, because they are not seen before being cast upon them, and because the depth of water is so great as not to afford anchorage. It is these deposits which render navigation so difficult in certain parts of the South Sea, and cause so many deplorable losses by shipwreck. Some of the forms assumed by these deposits at the surface of the sea are particularly remarkable, and are not yet entirely explained; sometimes these reefs are completely annular

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40. What is the form of coral islands?

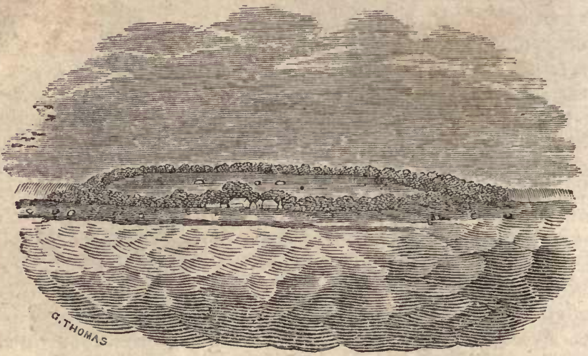

Fig. 224.—Coral island in the Pacific Ocean.

(*fig.* 224), with a lake in the centre, enclosed on all sides; sometimes they form broken circles, having one or more openings through which the centre may be reached; again, they are in groups of islands, arranged in a circle, and frequently there are several in a series. In these internal seas the water is often very deep—but sometimes very shallow, and an immense number of polypa'ria are developed, which sooner or later fill up the space. It appears evident that these circular reefs are the edges of different upheaved craters, upon which the polyps have established themselves; this is inferred from the volcanic nature of most islands in the Pacific, and from the manner in which submarine eruptions sometimes take place. Nevertheless, this explanation is not received as satisfactory in respect to many reefs of the kind, and particularly those which constitute the Maldives and Lakadives, groups in the Indian Ocean. The great number of circular groups found in certain localities, and the immense expanse which we must suppose craters of elevation to have in other places, are facts urged in objection to the explanation.

Around coral reefs, as well as in the lakes they enclose, soft and white mud of a calcareous nature, analogous to chalk, has been observed, which has sometimes been referred to the disintegration of madrepores, and sometimes to dejections of worms which pierce the polypa'ria, or to those of fishes which feed on them. In many places in the South Seas this mud seems to constitute considerable deposits.

41. When a reef has reached the level of the water, the sea often covers it with debris of every kind, on which vegetation is afterwards developed. Most low islands in the Pacific have been produced in this way, all of which rest on masses of polypa'ria. A great many other islands have sprung up on their coasts in the same way; and there are many which will sooner or later grow

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41. How are coral islands formed?

up in the same manner, for now, at low tide, we may walk over reefs extending half a league from the shore. But one very important circumstance is, that in many places we find precisely similar deposits, composed of the same species of madrepores, in the interior of land at an elevation of from 200 to 300 yards; this is seen at Timor, where the deposits are ten or twelve yards thick; at New Holland, Van Diemen's Land, at the Marian Islands, Sandwich Islands, &c., where they rest on argilla'ceous schist, sandstone, limestone, volcanic products, &c.; in the Isle of France a similar bank, four yards thick, is found placed between two currents of lava. The existence of these deposits in such situations evidently indicates that all these islands have been upheaved from the bosom of the waters, and often at several different periods, for we often find banks of coral at different levels.

42. *Peat, or Turf Bog.*—There are daily formed, in different excavations of the surface, in valleys of gentle slope, in low and marshy situations, deposits of vegetable matter, the decomposition of which furnishes a combustible called *turf* or *peat*, and the mass bears the name of *peat-bog*. These deposits are formed only under particular circumstances: they are seen only in places where stagnant waters constantly exist, and only in shallow depths; the presence of light is necessary to secure vegetation, to which peat chiefly owes its origin.

The production of peat, to which all aquatic plants contribute, is principally owing, however, to those which are always submerged, and which multiply rapidly; their debris form the principal paste that envelopes all the others, and probably contributes to their decomposition. A number of terrestrial plants also, brought to these bogs by brooks, contribute to the formation. Frequently large trees are found buried in the mass, particularly in the lower parts, where they accumulate on sands and clays which form the bottom. Often they are seen broken and fallen near the root, which is found attached to the bottom of the bog. In some instances these debris are very numerous, and seem to indicate that entire forests must have been buried on the spot where they grew, before the formation of peat. The plants found in these situations all belong to existing species; they are resinous trees, oaks, birch, &c. Remains of mammals are often found in *peat-bogs*, such as the bones of oxen, the horns of deer, tusks of wild-boars, &c.

43. Peat-bogs rest on every variety of soil, sometimes even on crystalline rocks; most generally, however, they overlie deposits of sand or clay, and sometimes the rolled flints of the country. There are places where accumulated debris of plants form but a single mass, of greater or less thickness, more compact and blacker at the lower part than in subsequently formed parts of it; there are other places where the different beds are separated by sedimentary deposits of alluvium. These are formed of sands, clays, calca'reous or argilla'ceous marls, often containing fresh-water shells in great quantity. Sometimes the surface of the deposit remains

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42. What are peat-bogs? Of what do they consist?
43. On what do peat-bogs rest?

covered by water, and at others it is covered by a luxuriant vegetation.

44. Peat-bogs are numerous in different parts of the world; they occupy basins or depressions in the soil at different elevations, even in the Alps. One-tenth of the whole surface of Ireland is said to be covered by peat-bog. In the Great Dismal Swamp of Virginia and North Carolina, there is a deposit of peat from ten to fifteen feet in thickness.

LESSON VIII.

EXPLANATION OF VARIOUS PHENOMENA.—*Consequences of Central Heat — First effect of cooling — Warm Springs — Deposits referable to Sediment—Fresh-water Deposits—Fossils of Marine Deposits—Fossils of Carbona'ceous Deposits.*

EFFECTS ATTRIBUTABLE TO UPHEAVAL AND SUBSIDENCE. — *Shell Deposits and raised Beaches—Submarine Forests—Tracks of Quadrupeds and Birds—Dislocation of Strata—Faults—Crate'riform arrangement of Strata—Valleys of Elevation—Upheaval without Dislocation—Distortion of Strata—Origin of Valleys — Valleys from Dislocation, from Subsidence, from Folding or Plaiting, from Erosion or Denudation—Origin of Caverns.*

Having established the fact of a central heat capable of keeping everything in a state of fusion, at a short distance beneath the surface we inhabit; having shown the actual effects of earthquakes and of volcanic action; having pointed out those which waters produce, both by denudation, or degradation, and the formation of new deposits, it is natural to attempt, by reference to these effects, the explanation of all geological phenomena which have occurred on the surface of the globe from the first moment of its existence. The causes now in action are the same as those which have acted through all time; but doubtlessly they were more energetic at certain epochs than present observation shows.

1. CONSEQUENCES OF CENTRAL HEAT.—The complete fluidity of the globe gave rise to its ellipsoïdal form: the heat so long preserved, and still existing beneath the cooled pellicle or crust, has produced, and is now producing a great number of phenomena. The temperature of the surface is nearly stationary, and has not varied since the period of records, and will not probably change. But before reaching this state, which probably required thousands

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44. Where are peat-bogs found?

1. What influence is central heat supposed to exercise over the form of the globe? Had the central heat any influence on climate? How do you account for the fossils of tropical plants and animals being found in northern regions?

of years, the surface of the earth must have passed through every degree of heat, from the state of fusion in which the centre still is to its present degree of cold; consequently, there was a time when the temperature of the earth was such as to do away with differences of climate, or an atmosphere of vapour, which, by overcoming radiation, diminished the rigour of winter. Then vegetation, and life generally, could be as equally maintained in all latitudes as in a hot-house. From this it follows, that plants and animals now found only between the tropics could then live anywhere, even under the poles, which were not then encumbered in ice. It is therefore not astonishing that we should find the remains of these various creatures buried nearly on the spot where they lived, in countries which are now the coldest in the world, and in which it would be impossible for them to live at the present time.

There is in England, on the island of Portland, and at several places on the continent, intercalated in other deposits, a bed of black matter, called *dirt-bed*, and small argilla'ceous beds, in which, among a great many vegetable remains, bedded and scattered, are various plants in their place of growth (*fig.* 225), the roots of which extend into the fissures of the calcareous soil beneath. Therefore, there must have been a vegetable soil, on which all the plants now buried in the earth then grew. But all the species found in this bed belong to genera, such as cycas and zamia, which now live only in the tropics, and the remains of animals also belonged to the same zone; consequently the mean temperature at the time of this formation was very different from what it is now in England.

Fig. 225.—*Portland dirt-bed.*

Most of the coal deposits of Europe lead to a similar conclusion. Entire trees with their roots, many of them still erect, are found, as in the mine of Treuil, near St. Etienne (*fig.* 226), in the mines of Anzin (North) in England, in Scotland, &c., which seem to indicate, as in peat-bogs, plants that grew very near the places where they are now found. It is evident from the perfect preservation of the most delicate parts of plants, the manner in which the leaves are extended on schists, that these remains could not have been carried far. All the remains of plants found in these deposits belong to the equisita'ceæ, lofty ferns, to the lycopodea'ceæ, &c., and cannot be compared with those now existing in the tropics; consequently, the climate of Europe must have been then very different from what it is at present.

We find, in the latitudes of Europe, certain beds containing the remains of intertropical plants, but we also find above them considerable deposits in which are dicotyle'donous plants of the present time. The formation of the last deposits, then, must have taken place long after the first; and it is probable that between the epochs, a period of time elapsed, sufficient for cooling the surface of our planet.

Madrepores of reefs, which now do not exist beyond the tropics, then evidently extended to the polar circle. In fact, the limestones of different periods contain a great number, and frequently show that reefs existed comparable to those of our days. Facts show that the limits of these banks of zo'ophytes have retrograded, from the period of the deposit of the oldest

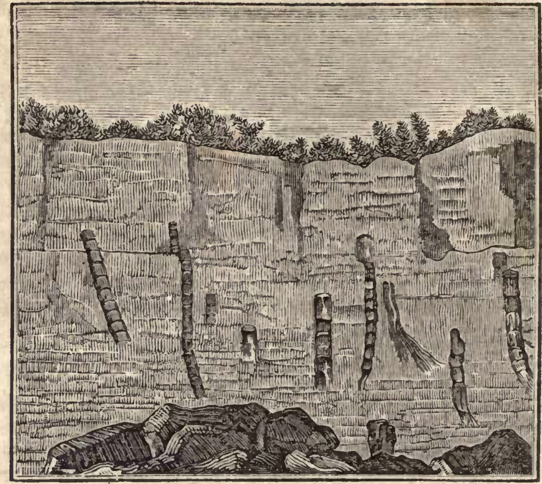

Fig. 226.—Vertical stems in the mine of Treuil, St. Etienne.

limestones to that of the chalk, after which they suddenly retired to their present limits; in other words, the climate of Europe has grown successively colder.

First effect of cooling.—The idea of complete fusion, and of cooling, which the observation of the phenomena forcibly leads us to admit, also leads us to conceive what must have taken place on the first consolidation of the globe's surface. The first solid pellicle formed underwent, from cooling, more or less contraction, and on this account must have broken in all directions, from the action of the melted matter it covered, swimming in pieces on its surface, and uniting anew more or less irregularly, to be again broken. But assuming greater consistence, and pressing more and more on the liquid part, this must have gushed up through the rents, then more rare, and formed above the crust projecting ridges, of more or less extent, which increased in height in proportion as the resistance of the crust became greater, and caused stronger and stronger reaction. Hence the first rugosities, the first ridges formed on the surface of the globe, which possibly afforded the first hold for the action of water, the precipitation of which took place, without doubt, long before the temperature of the terrestrial crust had descended to 212° of Fahrenheit's thermometer, in consequence of the pressure exerted by the vapour then diffused in the air. From that moment waves produced debris, and arena'ceous matters, and sediments began to form. Probably the water, at a high temperature, charged with the principles disengaged from the solidified masses, like lava of the present time, attacked the stony matters, disintegrated and dissolved them, and subsequently formed chemical deposits, or consolidated the debris. In fact, we find deposits formed of fragments, of rolled flints and of sands, in the most ancient layers yet examined, and before meeting with organic remains.

All the solid layers formed beneath the first pellicle, like it, being subjected to the law of contraction from cooling, must have been filled with cracks in all directions; therefore the whole terrestrial crust, thus formed, could not have been as solid as might be at first imagined: it could not resist, so successfully as might be thought, the internal actions, which, meeting no obstacle in the sedimentary deposits subsequently formed, must have dislocated them in all ways. In fact, there is no deposit on the surface of the globe, either sedimentary or crystalline, which is not found to be cracked in all directions; even on the upper surface, most rocks are broken in small fragments, to a considerable depth.

While the crust of the earth was gradually cooling, things must have passed nearly as we have stated; but, after the temperature had become stationary, as it is now, it could not have been the same: the superficial pellicle does not contract, because it does not grow sensibly cooler. Nevertheless, the interior mass is still cooling more and more, although with extreme slowness*, and consequently diminishing in volume; now, the fluid part tending to drag with it that which covers it, and which becomes successively too large, this must contract on itself, and ridge the surface by dislocations through its whole thickness. This may take place tranquilly, for some time; but, at certain moments, the effect cannot fail to take place quickly, and hence the sudden catastrophes experienced on the earth's surface.

All observations, in accordance with geometrical considerations, show that these ridges and these dislocations are formed according to the great circle of the sphere, and extend over the half of its circumference.

2. *Warm springs.*—The different degrees of temperature of warm springs are referable to the central heat, which is communicated through fissures of greater or less profundity. The waters come to the surface with the temperature of the point whence they started, and, it is known, that at the depth of about 3280 yards, they boil. Now it may be readily conceived how, during earthquakes, new hot springs may appear in a country, and how those that existed there may be lost; in the first instance, all that is required is a fissure, to establish a communication between the surface and a proper depth; and, for the second, that the existing communication should be interrupted.

We may easily conceive, also, that before the earth had reached its present degree of cooling, hot springs must have been infinitely more numerous than they are at present. When, instead of one-thirtieth of a degree, centigrade per yard, the temperature increased one-third of a degree, that is, ten times more rapidly than at present, and when water boiled at a depth of 325 yards, it is clear, there must have been a great many springs at a temperature of 212° Fahrenheit, or of boiling water, and that *fumarolles*, now rare, were then common. Consequently, the condition of the atmosphere was then very different from what it is now; thick fogs must have spread over the surface of the earth, in the absence of the sun, and hence radiation towards the celestial space, at present an important cause of refrigeration, must then have been nothing. Winter was consequently less rigorous; and this explains, too, how so many plants and animals, which cannot now exist in northern climates, could then live in them as between the tropics, and precisely as southern plants now live on northern coasts and islands which are constantly shrouded in thick fogs. The whole earth, tempered by these

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* According to Fourier, a decrease of internal heat of not more than one degree in thirty yards, would require 30,000 years.

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2. How is the temperature of hot springs accounted for? At what depth do spring waters boil?

abundant vapours, could then support the same organic creatures; here we have the reason why mineral beds, of a determined age, differ less in the organic remains they contain, wherever found, than existing creatures of different zones.

DEPOSITS REFERABLE TO SEDIMENT.

3. Rolled flints, sand, and mud, are formed by the action of running water and of waves; and, being transported by these waters, they accumulate in lakes, in seas, at the mouths of rivers, and on coasts. Whenever we find these kinds of matter accumulated in more or less considerable deposits in the interior of countries, we have a right to conclude that there existed somewhere, far or near, high mountains, from which these matters were detached; water-courses, which carried them; undulating waters, which heaped them up on their shores, and often lakes and seas, that received them. By the greater or less abundance and size of the rolled flints, we can judge of the mass and force of the waters that transported them; and their nature, and various course or track, ought to lead to the point of their origin, if circumstances have not destroyed the traces left by currents in their course.

As in the present day we see deposits of shells formed in lakes and seas, we infer that the numerous beds of the same kind we find at all heights, even on the summits of the loftiest mountains, were necessarily formed under water; the nature of the organic remains enables us to determine whether they were deposited under fresh or salt water, on coasts or in depths of the sea; their mixture, their alternation, indicate mouths of rivers, alternations of salt and fresh water, &c.

4. *Deposits from fresh water.*—These deposits are easily recognised from the organic remains they contain being comparable to different genera, sometimes even to different species of animals now living in our lakes and rivers. These are especially remains, impressions, or moulds of shells, like those of the genus *limne'a* (*fig.* 227), *planor'bis* (*fig.* 228), *paludi'na* (*fig.* 229), *mela'nia* (*fig.* 230), and of land shells of the genus *helix.* These are all

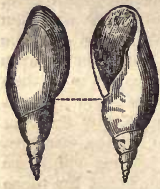
Fig. 227.—*Limne'a longisca'ta.*


Fig. 228.—*Plano'rbis euom'phalus.*


Fig. 229.—*Paludi'na lenta.*


Fig. 230.—*Mela'nia inquina'ta.*

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3. How are rolled flints formed? What does the presence of a deposit of rolled flints in a country indicate? What is inferred from their size and quantity?

univalve, unilocular shells. The bivalve shells of fresh-water deposits, more rare than the preceding, are like *mussels—u'nio* (*fig.* 231), *anodo'nta* (*fig.* 232), *cy'clas* (*fig.* 233), and *cyre'na* (*fig.* 234). The entire absence of every species of polypa'ria (*figs.* 235, 236, 237—239), and echini'deæ (*figs.* 238—240, 241), is an important characteristic of fresh-water deposits, which are very common in different parts of the world.


Fig. 231 — *U'nio littora'lis.*


Fig. 232.—*Anodo'nta cordieri.*

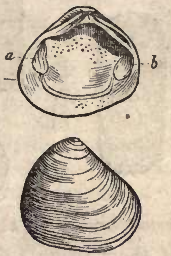

Fig. 233.—*Cy'clas obo'vata.*


Fig. 234.—*Cyre'na trigo'nula.*

5. *Marine deposits.*—These are distinguished by the analogy of the organic remains they contain (*figs.* 235 to 250) to the debris

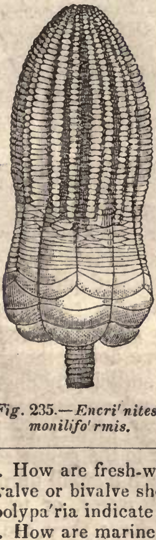
Fig. 235.—*Encri'nites monilifo'rmis.*

Fig. 236.—*A'piocri'nites rotu'ndus.*


Fig. 237.—*Cy'athocri'nites planus.*

4. How are fresh-water deposits recognised? Which are most numerous, univalve or bivalve shells, in fresh-water deposits? What does the absence of polypa'ria indicate?

5. How are marine deposits distinguished? What fossils are characteristic of marine deposits?

of different animals now living in the seas. Polypa'ria, more or less analogous to those which form coral reefs (*figs*. 220 to 223—p. 141), are highly characteristic; *encri'nites* (*figs*. 235 to 237), or the remains of their joints (*fig*. 239)—the *echini'deæ* (*figs*. 238 to 241). Not one of these organic bodies is found in fresh water

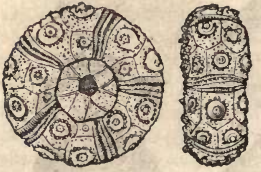

Fig. 238.—*Cida'ris corona'ta.*

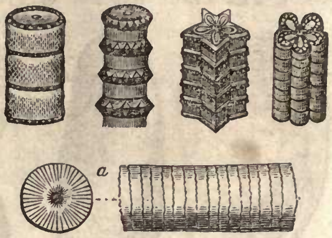

Fig. 239.—*Different joints of Encri'nites.*

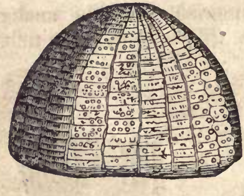

Fig. 240.—*Ananchytes ovatus from the Parisian chalk*).

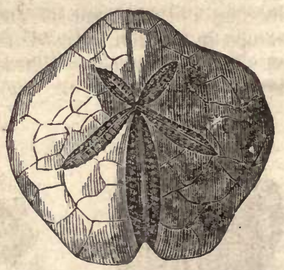

Fig. 241.—*Spata'ngus ambula'crum* (*from the chalk of the Pyrenees*).

Fig. 242.—*Turbo costa'rius.*

Among the marine univalves there are some which are more or less analogous to those of fresh water, mentioned (p. 148), although they are thicker, and more generally covered with tubercles (*fig*. 242). But, setting aside those on which at first sight there might be some doubt, there are many others which are sufficiently characteristic: these are shells whose aperture is terminated by a canal of greater or less length, and belong either to the genus *ceri'thium* (*fig*. 243), of which a small number of species lives in fresh water, or to the genera *mu'rex* (*fig*. 244), *volu'ta* (*fig*. 245), &c.; they are all marine, and abound in calcareous deposits.

Fig. 243.—*Ceri'thium muta'bilė.*

Fig. 244.—*Mu'rex alveola'tus.*

Fig. 245.—*Volu'ta athle'ta.*

Marine bivalve shells generally differ very much from those found in fresh water; some resemble oysters, and others are almost entirely like them; a great many are furnished with ribs, or striæ, or rugosities (*figs.* 246, 247), and possess, in a word, many characteristics entirely different from those found in the genera we have just mentioned.

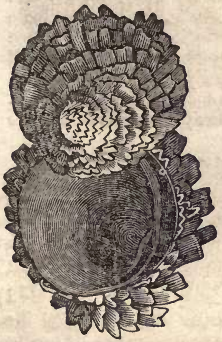

Fig 246.—*Chama folia'cea.*

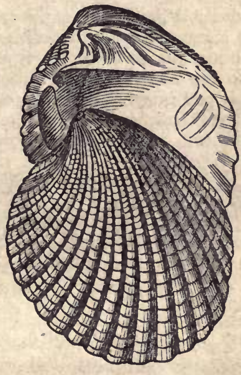

Fig. 247.—*Ve'nerica'rdia imbrica'ta.*

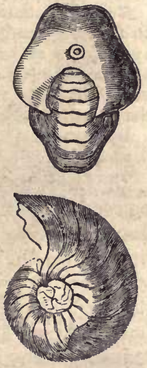

Fig. 248.—*Nau'tilus trunca'tus* (*from the Lias*).

Chambered shells are found only in seas, such as the *nautilus* (*fig.* 248), more or less like numerous species of *ammoni'tes* (*fig.* 249), no analogue of which is now living, but with which certain terrestrial strata are filled.

These deposits are generally formed very slowly, by the accumulation of shells left by dead mollusks as fast as they perish, and not by sudden catastrophes, which would have heaped them up alive in greater or less numbers.

Fig. 249.—Ammoni'tes cate'na.

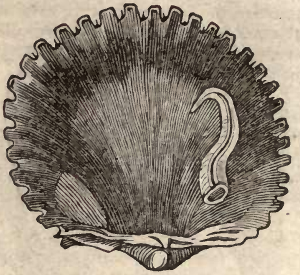

Fig. 250.—Se'rpula, on the inside of a Ca'rdium porulo'sum.

This is proved by the fact that frequently on the inside of shells we find parasitic animals, that attach themselves to bodies of all kinds (*fig.* 250), and which could not attach themselves here, in the interior of the shell, if the mollusk had not been previously destroyed. Often the very shell of the parasite is covered by others, showing that the first had long existed in the sea. The shells of bivalves are frequently found separated, showing the animal must have died before they were buried. And there are shells which are pierced by lithopha'gi, as well as the flints and fragments of limestone which accompany them, leading to the same conclusion. There are of course some exceptions, but these are commonly due to local circumstances.

Generally, these shelly deposits are on the spot where the animals lived. In fact, they contain a great number of uninjured shells, the most delicate appendages of which are in a state of perfect preservation; a circumstance not reconcilable with the idea of transportation by currents, which would have broken the whole and rounded the fragments. Even in decomposition, the finest parts have left their impressions on the substances enveloping them.

By means of the debris alluded to, we may always recognize marine deposits.

6. *Carbona'ceous deposits.*—It is undeniable, that the carbona'ceous deposits found in different strata of the earth, were produced there by the accumulation of the remains of plants; this is proved by the numerous and clearly characterized remains of stems and leaves met with, either in the combustible mass or in the earthy matter containing it. On this point all are of one opinion; but all do not agree as to the manner of accumulation of these remains. Some geologists suppose that all carbona'ceous deposits result from the sinking of great rafts of divers plants, transported by great rivers, by maritime currents, and sunk in different places; others think, on the contrary, that most of these deposits were formed, in place, in the same manner as peat-bogs, in depressions of the surface to which rivulets daily brought debris from the surrounding vegetation.

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6. From what are carbona'ceous deposits derived? How are carbona'ceous deposits formed?

Opposed to the idea of floating rafts is, the enormous thickness they must have attained, to have produced beds of coal such as are known, between two layers of arena'ceous matter. In fact, taking into consideration the specific weight of wood, the amount of carbon it contains relatively to that of carbona'ceous deposits, we find that the latter can only be twenty-two hundreds, or even seven hundreds (according to the kind of plants), of the primitive volume of the matters which gave origin to them. Besides, estimating the numerous voids left by the irregular interlacing of these debris in a raft, we know that coal, for example, which is formed of the lightest plants, as the equisita'ceæ, ferns, &c., cannot be, in the bed, more than thirty-five thousands of the thickness of the raft that formed it: that is, a coal-bed of from one or two to thirty yards thick, would require the rafts to have been twenty-eight or fifty-seven, to eight hundred and fifty-seven yards in thickness, which evidently exceeds the limits of probability, and in most seas would be impossible.

The idea of the formation being analogous to that of peat-bogs does not present this difficulty, and only requires time for the accumulation of the necessary organic materials. In the present state of things, this time would be very considerable; for, according to the calculation of M. de Beaumont, on the quantity of carbon annually produced by our forests, not much more than six-tenths of an inch in thickness of coal would be formed, in carbona'ceous deposits, in the period of a century. But everything leads to the belief, that at a mean temperature of 71° (Fahrenheit), when the atmosphere was filled with vapour, and vegetation, in the genera of plants that then grew in our country, was infinitely more vigorous than at present: we are also led to believe that at the epoch of these formations, when the earth had not yet cooled to its present temperature, a great deal of carbonic acid issued from its interior, and the appropriation of the carbon by plants was then more rapid. It is not only for the formation of coal that a long period of time is required; all sedimentary and calcareous deposits formed only of shells, which acquire much greater thickness than carbona'ceous deposits, have certainly required many centuries to reach this point.

The hypothesis which assimilates deposits of coal to peat-bogs, is fortified by the different characters they present; such are, not only the trees found erect with their roots, and the remarkable preservation of the leaves in schists, but the deposition in isolated basins, of greater or less extent, seems to indicate swamps and marshy places formed in depressions of the surface of the soil. These deposits are often surrounded on all sides by rocks of an anterior formation, which form the parietes of the cavity where they took place; frequently, we also find that a certain number of small basins, independent of each other, forming part of a more extensive basin of a species of lake filled with contemporaneous arena'ceous matters, on the surface of which there would be formed as many masses of combustible. There are some, too, that extend through the length of certain ancient valleys, and are contained in them. All these circumstances are observable in the deposits of the centre and south of France; but in the north of France, in Belgium, in England, and in Scotland, it is different. There, the beds of combustible seem to extend over great spaces; and the assemblage of facts, as well as the immediate superposition of marine limestone, found in all these countries, leads us to suppose that these deposits, now dislocated and separated by seas, have once formed part of the same whole. It was not in swamps or in closed lakes they were formed, but in a vast sea, the receptacle of all the debris of the vegetation of its coasts and islands, that they must have taken place, and in which undulatory motion stratified these materials as well as all other sedimentary deposits.

Certain deposits of lignite were evidently formed in the same manner as coal; but there are others which constitute irregular masses of wood thrown pell-mell, more or less bituminous and preserving their tissue, found accidentally buried in the midst of sedimentary deposits, and which probably had a similar origin to those transported by great rivers, which are deposited in lakes or conveyed to the middle of seas.

Remains of shells are rare in deposits of coal, properly so called. There is no trace of them in any of the deposits of the centre of France; and it is only in the great formation comprising the north of France, Belgium, and England, that some examples are met: marine shells are found in the environs of Liege and of Namur, in Derbyshire, &c. Fresh-water shells, similar to u'nio and anodo'nta, are found in the same place. In most deposits of lignite, in which the structure of the wood has generally disappeared, we find, on the contrary, a great number of fluviatile shells, which proves, that the formation of these deposits took place in fresh-water lakes.

EFFECTS ATTRIBUTABLE TO UPHEAVAL AND SUBSIDENCE.

7. At whatever height we may find fluviatile deposits on the surface of the globe, there is nothing to excite astonishment; for we readily conceive that lakes could have existed at all heights on continents, and that after their waters flowed away their deposits remained dry on the soil. But we find also marine deposits at all heights, in very extensive beds, and at first sight it is not so easy to account for them. It is evident that such deposits could have been formed only under waters of the sea; and, as they are now found thousands of yards above the present level of the ocean, we must admit one of two things; either that the water was elevated above these points for a sufficiently long time to form thick beds there, or that these deposits were raised up from the bottom of the sea to the height we now find them. Nothing in the phenomena of the present time warrants a belief, that the sea, which has not changed its level within the time of history, could have been so elevated, long enough to form considerable deposits. The universal deluge of the Holy Scriptures was a catastrophe of short duration, and therefore could not have produced the immense deposits referred to, which, everything leads us to believe, were formed slowly. Besides, this catastrophe is comparatively of modern date, and must be referred to the last modification of the surface; now, all the deposits of shells of which we speak were long anterior, and were independent of facts belonging to the history of the human race. Nothing informs us what became of the excess of water (a greater or less volume than now exists) above the present level, without having recourse to divine interference, which must have been frequent in ancient times, to cause these waters to appear or disappear a great many times, and even suspend the action of the laws of equilibrium. In fact, very often deposits of shells, seen here and there at a great height, are not found on corresponding summits, and are represented on the contrary with all their characters, thousands of yards lower down; hence we must suppose the

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7. How is the presence of marine shells in deposits, at great heights above the present level of the sea, accounted for?

waters were considerably elevated on the first of these points, and remained low on the other, which is absurd, or we must admit that the same animals could live in one place, near the surface of the water, and in another, at immense depths, which is contrary to all observation. Therefore, the only reasonable supposition left is, that of upheaval; an idea supported at least on positive events which have taken place in our own times, and which are, doubtlessly, not the only ones which have been manifest on the surface of the globe. If an upheaving force could suddenly elevate 200 leagues of the coast of Chile (page 99), spreading as far as the islands of Juan Fernandez; if the same effect were slowly produced in all the gulf of Bothnia, in Sweden, and in Finland, over a surface of not less extent, we may comprehend how vast countries might have been elevated anywhere. The enormous liquified mass forming the interior of the globe, oscillating from side to side beneath its thin crust, could emboss it in every direction, and nothing more would be required to raise continents out of the sea, and vary the slight relief in all manners. And let not such effects excite alarm because they appear gigantic; we judge them to be so because we compare them with our feeble powers, for they are nothing compared to the globe itself. What are the 25,660 feet in the height of Himalaya, the highest mountain in the world, and the 24,580 feet depth, the deepest soundings in the midst of the sea, compared with the 19,685,500 feet, measured by the mean radius of the earth? And notwithstanding such eminences or depths, the sum of which is less than .5000 of an inch to the yard, are rarities on our planet, whose inequalities are not even comparable to the unperceivable irregularities which are formed in our manufactories on moulded glass or metals, which nevertheless pass unnoticed. If to these reflections we add our knowledge of the immense force often exerted, from the interior towards the exterior, none of these phenomena will astonish us.

8. *Shell deposits, and upheaved* or *raised beaches.*—Parts of soil upheaved above the level of the sea, are characterized, on the surface of exposed rocks, by the presence of various shells, that live, ordinarily, attached on a level with the water, such as barnacles, mussels, &c.; or by that of some small deposits of shells, identical with those daily formed at the bottom of neighbouring seas. Now, on examining the hills near the coast of Chile, there has been found on the plateaux (which succeed each other in terraces, the sides of which are parallel to the present shores), shells similar to those, that have been left dry in our day, and which are still attached to rocks, as well as shelly deposits, which contain the same organic remains as those now forming in the Pacific Ocean. Is it not most probable that these deposits are indications of successive upheavals, similar to those which have recently taken place?

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8. How are raised beaches accounted for?

This inference is sustained by observations made on the coast of Peru, near Lima, in the island of San Lorenzo, where, thirty yards above the level of the sea, deposits have been found which contain woven osier, portions of cotton thread, &c., clearly showing that the deposits in question were formed since the existence of man in those countries; as the level of seas has not changed since history began, it is only by upheaval they could be brought to light.

That the coast of Sweden has been uplifted slowly, has been established by the most exact observations. In digging a canal near Stockholm, in the midst of beds of sand, clay, and marl, filled with shells similar to those that now live in the Baltic, there were found the remains of very ancient vessels; all this country, which must have been, at some period, under water, and in which some ships were wrecked, has been upheaved since the presence of man; the level of the ocean being invariable. It is therefore evident that the shelly deposit of Uddewalla, in which organic remains of the Baltic are found, seventy yards above the level of the sea, and in which M. Brongniart found balani attached to rocks, as they are on the present coast, is a fact of elevation. Similar deposits and evidence of elevation are met in other parts of the world. The upheaval and subsidence of the temple of Serapis has been already mentioned (page 19).

In thus admitting that very extensive deposits, formed of shells that are now living in the sea, have been evidently upheaved to greater or less heights, is it not therefore exceedingly probable that the same is true of all the rest? Why should this not be true in regard to the neighbourhood of London and Paris; to that of the plains of Gascony, Austria, Hungary, Poland, &c.? All the shells found in those places are not similar to those in the present seas; but there exists a considerable quantity of them, and moreover, their preservation is so perfect, in many places, that they seem to have been recently buried. If we admit the fact of elevation, for these deposits, can we refuse it to the chalk that everywhere envelopes them, forming not only the Jura, but a great part of the calcareous mountains of France; or to any shell-deposits, the organic debris of which bear witness to their marine origin?

9. *Subsidence of various deposits.*—Upheaval has been shown; subsidence is not less demonstrable. At many points, on the coasts of France and England, may be seen, at low tide, very extensive deposits of plants, similar to those now living in those countries, and which appear to have grown on the spot where they are found, for the roots are seen attached to the soil. These deposits rest on earthy matter, covered with leaves, heaped upon each other, or sunk in a peat-like substance. In these places have been found birch-trees, chestnuts, oaks, and fir-trees, sometimes scarcely altered, species of deer, similar to those met in peat-bogs; the whole covered by argillaceous deposits, which contain fresh-water shells. These *submarine forests*, as they are called, could have grown only on a soil more or less elevated above the sea; and as they are now found beneath it, and are not uncovered, except in unusually low tides, the earth must have sunk, after the period of vegetation. The *dirt-bed* of Portland (*fig.* 225, p. 145) shows the

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9. What are submarine forests? How is the subsidence of deposits proved?

existence of a vegetable earth or mould, of a soil nearly dry, resting on marine deposits. This bed has been covered by a very thick deposit of lacus'trine limestone, and the whole passes under the green sand which precedes the chalk, and which is of marine formation. It is clear, therefore, that there was in those places a certain upheaval of the inferior marine limestone, on which terrestrial plants grew; that subsequently a lake, or a deep estuary, was formed, in which beds of limestone, sand, and clay, were deposited, filled with fluviatile shells, the entire mass being sometimes from 200 to 500 yards in thickness. A subsequent upheaval must have lifted the whole to its present level.

Around the Paris basin, the deposit of marine limestone, worked for building stone, must have been at first uplifted, at various points, above the sea, to be covered by a fresh-water lake in which lacustrine deposits were formed, and among them the plaster of Paris; subsequently, it must have been sunk beneath the sea, to be covered by a marine formation, and again uplifted, to be covered by a second fresh-water formation.

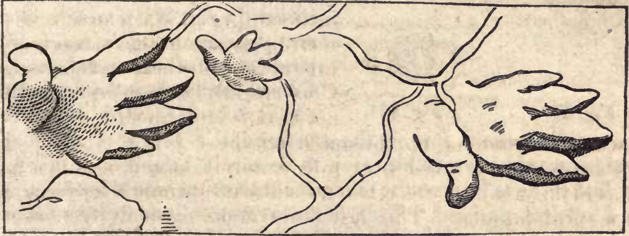

Fig. 251.—Impressions of feet of quadrupeds.

Hundreds of facts of this kind might be cited; but we will only notice the *impressions of feet and tracks of certain quadrupeds* (*fig.* 251) found at Hessberg, near Hildburghausen, in Saxony, on the faces of certain beds of sandstone, and the *impressions of the feet of various birds*, found in the valley of the Connecticut, in the United States, in the same deposits (*fig.* 252). These impressions show that the soil was in a degree soft, although partly dry, which is proved by the ridges it presents, and that it was out of water; the sedimentary bed on which these animals walked, is now covered by another, which is moulded on these tracks, and afterwards by considerable deposits of the same matter which could be formed only under water; it follows, therefore, that the soil, first uplifted enough to enable terrestrial animals to walk on it, was subsequently sunk to receive all those sedimentary deposits, and afterwards was again upheaved to its present position.

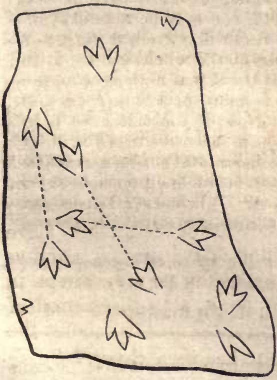

Fig. 252.—Bird tracks.

CHANGE OF POSITION AND DISLOCATION OF STRATA ATTRIBUTABLE TO UPHEAVAL.

10. It has been already stated that sand and shells are deposited, under water, in horizontal beds. Indeed, we frequently find them in this position on the surface, even over extensive spaces, and we then find flattened pebbles, valves of oysters, and other shells, lying flat, and turriculated shells lying on one side; and everything confirming the idea of a slow formation, by the weight of these substances. But it sometimes happens that we see deposits, more or less inclined in certain parts of their extent, raised up almost to a vertical position, and sometimes entirely overturned; they still preserve, however, all the characters which show they were at first horizontal, for the debris of shells and pebbles they contain are still found arranged parallelly to the planes of the beds. Besides, there are deposits which contain ge'odes of agate, in which are found stala'ctites with the axis more or less inclined (*fig.* 253), which is directly opposite to the manner of production of these substances. Consequently, these deposits could not have been formed in the position we find them, for, on the one hand, the debris of shells and pebbles would have rolled over to be surely balanced, or fallen to the foot of the ta'lus; on the other, the stalac'tites would have formed in a vertical position. This last observation, particularly, shows that the beds were at first horizontal (*fig.* 254), and that their position has been changed subsequently to their formation; this is one of the great geological phenomena we seek to explain.

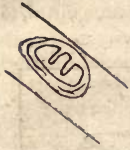

Fig. 253.

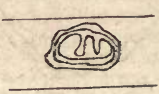

Fig. 254.

The effects of earthquakes, and those of volcanic phenomena, will serve as points of comparison in our inquiry. On one hand, the crevices produced in the soil at the time, to a greater or less depth, can only be the effect of upheaval; for the separation of parts does not result here from drying, nor from cooling, which would produce a retreating of the whole mass. It is remarked, in the neighbourhood of cracks, that the soil is no longer on the same plane as the rest of the country; that it is more or less arched, and often one part is more elevated than another. Now, if the soil have been uplifted, it must follow that the internal beds have been disturbed in their position; consequently, when in a formation of horizontal strata, a crack is made in a straight line (*fig.* 255), the beds must be inclined on both sides through their length, like the two slopes of a roof. When several divergent cracks are formed (*fig.* 256), the beds ought to incline symmetrically around the axis of elevation.

Now, if we find all inclined beds in one or the other of these positions, we have a right to conclude they have been uplifted by the same causes.

11. *Faults.*—When a crack is made, it often happens that one

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10. What proves that the position of strata has been changed by upheaval?

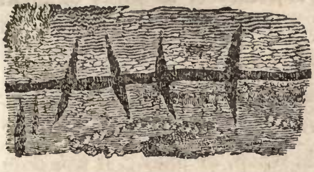

Fig. 255.

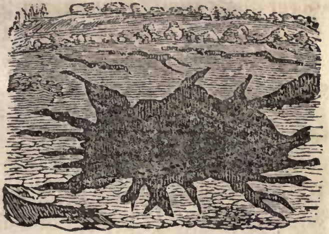

Fig. 256.

of the parts of the soil is more elevated than the other, no matter whether the crack remains open or not. These effects are often observed, and it is presumed they are all produced by the same cause, namely, upheaval. The beds are then inclined in opposite directions (*fig*. 257), and one of the parts is more elevated than that which is adjacent; the junction is sometimes distinguished by subterraneous work, either subsequently filled with gravel, or a slight fissure, or at least by a surface of separation, the planes of which are smooth, and sometimes polished or striated vertically, showing a close crack and a rubbing of one part on the other. This arrangement has been called *fault* (from the German *fall*, an accident, *fall*, or sinking), because one part is lower than the other; faults are observed in every kind of soil, and present crests or ridges extending over great spaces, nearly in a straight line, sometimes broken here and there, but the different parts preserve the same direction.

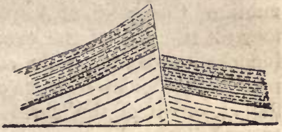

Fig. 257.—*Fault.*

12. Besides showing themselves on the surface, faults are also perceived under ground, by the disturbance they have caused in beds or veins worked for the benefit of the arts. It is thus, for example, in coal measures, the same bed of coal *a*, *b*, *c* (*fig*. 258), is found so much deranged in its position, that the miner, after having worked on a part of its direction, from *d* to *c*, for instance, finds it suddenly end, and would at once abandon all his labours, had not experience taught him that, by following the fault, he will find the deposit either above or below the point where it abruptly terminated. Sometimes there results from these disturbances serious mistakes for speculators;

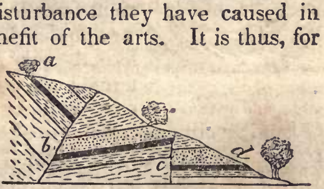

Fig. 258.—*Bed dislocated by faults.*

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11. What is meant by a fault? How are faults produced?
12. Do faults always show themselves on the surface?

observing various outcrops on the surface of the ground, *a, b, c, d* (*fig.* 259), they have inferred the existence of as many different beds, and consequently great wealth, when, in reality, it was only one and the same bed dislocated and raised up to different levels by successive faults.

Fig. 259.—*Dislocation, causing a single bed to appear as several.*

13. *Crate'riform disposition.*—The known formation of *Monte-Nuovo*, in explaining to us the uplifting of the beds seen in its crate'riform cavity, leads us to attribute also to upheavals, the epochs of which are unknown, the structure of several other hillocks of the same country, such as those of the solfata'ra of Puzzuoli, of Camboldi, of Astroni, &c., where the strata are all raised towards the axis of the excavation found in the centre. In these hillocks, the bottom of the cavity, particularly at Astroni (*fig.* 260), presents the point of a tra'chytic dome, which doubtlessly caused the elevation of the surrounding beds of pumice tu'fa. These crater hillocks at once explain all those of the Champs-Phlegreens, which are full at the top, but all the strata of which are raised around the axis (*fig.* 261); probably there would be found at their base some point of a cone which had not been uplifted with sufficient force to crack the summit. When strata are inclined in opposite directions (*fig.* 261), like the two sides of a roof, they form what is termed an *anteclinal axis;* but when they dip oppositely, it is termed a *synclinal axis* (*fig.* 262).

Fig. 260.—*Crate'riform disposition, with a tra'chytic hillock in the centre.*

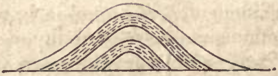

Fig. 261.—*Hillock with strata raised towards the summit.*

Fig. 262.

Similar circumstances are observed in many places, on a greater scale. At Cantal and Monte-Dore, basa'ltic and tra'chytic beds, which could only have been deposited on a horizontal plane, are found raised up around one or more centres, leaving towards their point of convergence a crate'riform basin of more or less extent, or rising around a more or less projecting tra'chytic dome (*fig.* 263), like the Peak of Teneriffe, above the escarpments surrounding it.

Fig. 263.—*Beds elevated around a tra'chytic dome.*

13. What is meant by an anteclinal axis? What is a synclinal axis?

Granitic masses are found under similar circumstances, in the midst of which rise hillocks of basa'lt or scoriæ, which doubtlessly followed the first explosion, as at Monte-Nuovo and the island of St. George.

14. Calcareous countries are not more exempt from these accidents than others; only the crate'riform cavities, in place of being nearly circular, are more frequently elliptical, sometimes very much elongated, as seen in the Jura mountains. In general, the length is produced, like cracks, extending to a great distance, and forming along its direction elongated hillocks, in a line with each other, offering here and there more projecting summits. These summits are most frequently rent, and present what are termed *closed valleys*, and *valleys of elevation* (*fig.* 264), which are in fact craters of elevation.

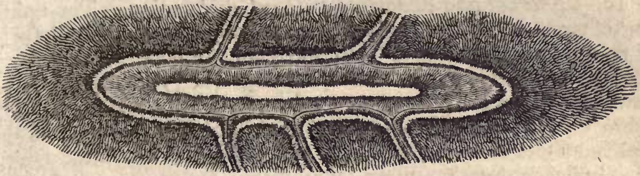

Fig. 264.—*Plan of a crater of elevation in calcareous countries.*

15. Ruptures of calcareous mountains do not always present the crate'riform uniformity just indicated, but vary much, in this respect. One side of the rupture sometimes remains low, while the other is elevated, as represented (*fig.* 265). Sometimes the superior beds seem to have retired horizontally, and the inferior strata are arched up between the fractured extremities, as seen (*fig.* 266).

Fig. 265. *Fig.* 266.

Craters of elevation in calcareous formations.

Often, among the upheaved beds, some are found which are easily disintegrated, and their projection soon tumbles, inducing the fall of solid strata; from this we have ridges of rock parallel to each other, separated by little valleys, in which the rain-water flows, and they become covered by vegetation; in this case the general ridge of the mountain is as represented (*fig.* 267). Sometimes the summit only presents a mass of calcareous blocks piled one on the other, but arranged in line, as if the work of a mason. Again,

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14. What are valleys of elevation? What is the peculiarity of crate'riform cavities in calcareous countries?

15. Are the crate'riform cavities, in calcareous countries, always uniform in configuration?

when two parallel upheavals take place (*fig.* 268), it sometimes happens that one portion (*a*) of the formation is cut off, and then forms the culminating point of the whole mass, giving the appearance of a repetition of certain strata in the same deposit. The central part of the uplifted mass is formed of matters sometimes analogous to those that essentially constitute the formation, and sometimes totally different.


Fig. 267.

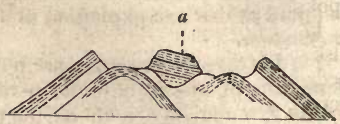

Fig. 268.

Various dispositions of craters of elevation in calcareous formations.

16. *Upheaval and distortion without dislocation.*—The uplifting of strata is often accompanied by ruptures, but frequently there is no apparent dislocation. We have already noticed the isolated mounts or hillocks on the Champs-Phlegreens (*fig.* 261), and the same is also seen, for greater or less lengths, which then have more or less projecting sides, or *anteclinal lines*, formed by the uplifted strata on either side, like the dip of a roof; these effects are similar to those produced by crevices; but acting on strata of a certain degree of flexibility, like the matters placed in the centres of the preceding figures. The Jura mountains present a number of instances of this; we often see there different parallel ridges of this kind, clearly marked on the simplest maps, which leave between them valleys of greater or less breadth, on the two slopes of which the beds are uplifted. The result is great undulations in the strata, remarked especially in escarpments, produced by different ruptures, which cut the ridges in a great many places. These

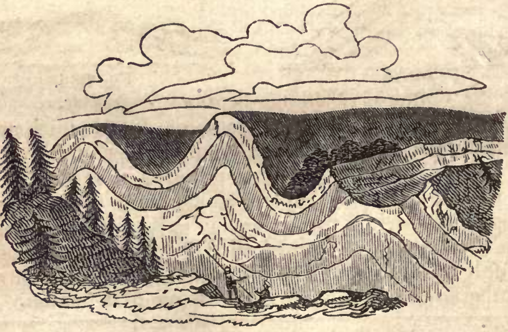
Fig. 269.—*Distortions of the Jura. Valleys from plaiting.*

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16. Is upheaval always attended by rupture of strata? What are anteclinal lines? How are undulations in strata produced?

undulations on a grand scale, represented *fig.* 269, are not interrupted except by crate'riform ruptures of summits, previously spoken of.

17. *Plaiting or folding of schistose strata.*—Distortions are also observed under other circumstances, in which it seems that beds of a degree of flexibility, or in a pasty condition, have been compressed by two opposing forces, rather than uplifted. Certain facts observed in matter of the structure of schist, naturally lead to this idea. It often happens that the laminæ of these deposits, instead of continuing on the same plane, horizontal or inclined, are all found very much contorted without ceasing to be parallel, or folded on themselves into a more or less acute zig-zag (*fig.* 270). The supposition as to the mode in which this plaiting has been effected, has been verified by experiments made by Sir James Hall.

Fig. 270.—*Contortion of schists.*

Fig. 271.—*Contortion of coal.*

Entirely similar circumstances occur in coal measures; all the strata of these deposits, both argilla'ceous and combustible, are found plaited, and often at acute angles (*fig.* 271): this is especially remarkable in the coal measures near Mons, in Belgium.

Now, how did these compressions take place? In a degree, an explanation is required for each locality; but we know that in a deposit of inclined strata, the mass of which is pushed from below upwards, the superior part presses with all its weight on the inferior, and the beds of the latter, being placed between two opposing forces, may fold on themselves, if they are sufficiently flexible. On the other hand, as matters in a state of fusion are often injected with great force into sedimentary deposits, it is conceived that from this results the lateral compression which produces the same effects.

18. *Origin of Valleys.*—If mountains are only the result of dislocations which have taken place on the surface of the globe, by the force of internal agents, there would be no difficulty in accounting for valleys. The first idea of the origin of valleys was based on excavation by the erosive action of water; but then mountains having been previously formed, it is clear that water would always follow the natural slope of the soil, and only excavate in that direc-

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17. How is the folding in schistose strata accounted for?

18. How are valleys produced? What is meant by valleys of dislocation?

tion; when arrested by any obstacle, or in a basin, it would of preference cut through deposits of sand and gravel. We see the contrary of this natural action: valleys do not generally follow the real slope of the soil; it is not by the lowest part of basins that waters are generally turned, nor through moveable formations that they make a passage. Rivers, in place of having excavated their beds, as was thought, are simply directed by the canals they found already made. Now it is not difficult to go back to the origin of these canals; they are evidently the result of upheavals, which have embossed or ridged the soil, until then horizontal. It is clear the inflexible beds must have been broken, and consequently a number of cracks were formed, as in the transverse section (*fig.* 272). The cracks became valleys, placed in different relations to each other according to circumstances of upheaval: parallel if the action, taking place in a certain direction, extended a sufficient length; divergent, if the action occurred at one point, as in certain massive mountains; often perpendicular to the direction of uplifted chains, as the secondary cracks manifested during earthquakes (*fig.* 255), which occurs especially when the internal action forces crystalline matter through the principal crack. It may be easily conceived that crevices would remain more open in solid matters than in arenaceous deposits, the falling of which would tend to fill the vacancy; and this is the reason why rivers seem to shun moveable formations, which they could easily excavate if they had not found a bed ready prepared in another direction.

Fig. 272.—*Production of valleys by dislocation.*

19. It must not be concluded, however, that water has no agency in the configuration of valleys. On the contrary, we must believe that when a country has been suddenly rent, causing the accumulated waters to flow all at once, that torrents of frightful power were produced, tearing away and removing all parts fractured by upheaval, and they thus modified the passages offered to them. It is probable, also, that certain valleys, which pass through a moveable formation, little disposed to fracture, have been produced exclusively by water. Valleys referable to this origin are very different in character from the first: they follow the natural line of slope; they change their course on meeting masses which offer resistance, and turn round them to remain constantly in the moveable deposits. Such are the valleys which cut through the great deposits of rolled flints found at the foot of the oriental Alps.

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19. How are valleys of erosion produced?

Fig. 273.—Valley of erosion in a moveable formation.

Many great rivers have themselves cut their beds in the ancient alluvium (*fig.* 273), very different from that now forming; the Seine, at Paris, excavated its bed in a deposit of rolled flints very unlike the gravel it now deposits.

20. *Valleys from disruption*, are those which have been produced by cracks of every size, sometimes colossal, during the upheavals that have brought the land to its present configuration of surface. They generally present abrupt escarpments, in which are seen the section of the fractured strata, the projecting angles on one side often corresponding with the retreating angles of the other. The circles which frequently terminate them above, or those that divide them in their length, are so many craters of elevation, most of which are clearly characterized either by the uplifted strata or the barrancos they present.

21. *Valleys of subsidence* are also spoken of, but it does not appear there are any arising purely from this cause. Subsidence is frequently correlative to upheaval; and valleys as well as craters of elevation may exhibit the effects of both, which must have taken place especially in the circles found along their line, and at their superior extremity.

22. *Valleys from folding or plaiting* are produced by two neighbouring upheavals, causing the elevation of strata, and leaving a space between, the slopes of which being formed by their planes; this is seen in the high parts of the Jura (*fig.* 269.) Many rivers flow in valleys resulting from two opposite uptiltings of the soil.

23. *Valleys of erosion or denudation* are produced in loose formations like ravines, made by rain-storms, the waters of which carry off the materials constituting the soil.

24. *The origin of caverns* is one of the phenomena attributed to the action of water; but, although we find on a level with the sea some caverns of slight depth, which may have arisen from the repeated action of waves, it is difficult to believe that great caves, which are sometimes many leagues in extent, have been produced solely by the action of the waters running through them. The action of water on compact limestone, in which caves are principally found, is so slight, that it has been supposed the open spaces now found, were at one time filled by masses of salt, which the waters had subsequently dissolved and carried away.

It is presumed, however, that the first origin of caverns is due to cracks, produced in the interior of the soil, which have been afterwards modified by

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20. What are valleys of disruption?
21. What are valleys of subsidence?
22. How are valleys from folding produced?
23. How are valleys of denudation formed in loose strata?
24. How is the origin of caverns accounted for?

different causes. We know, in fact, that during earthquakes, rivers as well as lakes suddenly disappear under ground, sometimes temporarily and sometimes continuously; it is conceived that the water flows through internal cracks, similar to those produced on the surface, which form canals for its passage. The phenomenon is sometimes coincident with the appearance of some abundant spring in a more or less distant place; but it often happens also that the water nowhere re-appears, and we must conclude that it runs directly into the sea. All these circumstances explain the disappearance of certain rivers, which are swallowed by the earth after a superficial course of more or less extent, as well as the sudden appearance of springs gushing from the side of a rock. They point to the existence of subterraneous canals, and lead us to think that, dried up by a more or less considerable upheaval, these canals may have formed the now empty caverns found at all heights, as well as those, the bottom of which are still occupied by a stream of water fed from lakes or rivers on the surface.

Still, if the real origin of most of these subterraneous cavities be not doubtful, it must be admitted that subsequently important changes took place in the general form and condition of their parietes; the rounded form, wear and polish of surfaces, grooves, different excoriations, and in all positions, even on the upper part of the vault, an erosive action of which water alone is incapable. It has been thought this liquid might have been charged with carbonic acid gas, which is frequently disengaged from the earth through fissures formed in it, particularly at the time of earthquakes, and that the subsequent effects were owing to its dissolving power.

LESSON IX.

EXPLANATION OF VARIOUS PHENOMENA CONTINUED.—*Deposits attributable to Volcanic Action—Lava—Basa'lt—Action of Basa'lt on Adjacent Rocks—Dolomisation—Giant's Causeway—Tra'chytic Formation—Trap Rocks—Porphyry—Granitic Rocks—Injection of Granite—Metalli'ferous Veins—Metamo'rphism—Effects of Erosion.*

1. *Volcanic cones and lava currents.*—When we find conical hills isolated, or arranged several together on a line, and covered with scoriæ, sometimes having crate'riform cavities at the summit, surrounded by rapilli, we may be certain they are volcanic cones, however ignorant we may be of the epoch of their activity. If on mountain sides, whatever may be their nature, we see long, straight masses, terminated below in a club, hollow in the middle, and thinning out above in a pellicle of dislocated scoriæ (*fig.* 274), their origin cannot be doubtful, although every other trace of volcanic action may have disappeared. These long, straight masses are lava currents. If we find these matters in pebbles, in more or less extensive tables, compact below, porous, cellular, or scoriaceous above, with a nearly uniform

Fig. 274.

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1. By what features are extinct volcanoes recognised?

surface, we may conclude they were accumulated on a horizontal soil, or that in a more or less liquid state they flowed into a depression. They are evidently deposits which have issued from the bosom of the earth in a state of fusion. It is by observations of this kind we are enabled to recognise extinct volcanoes, in relation to which the history of the most remote times is entirely mute.

2. Some of these currents resemble what is called basa'lt, that is, black rocks with a compact base of la'bradorite, containing black pyroxene, and almost always magnetic oxide of iron. Very frequently there is found in it more or less voluminous nodules of peridote, and sometimes crystals of feldspar, which give it a porphyritic structure. These currents ordinarily form thick deposits, frequently divided into prismatic columns, sometimes in large irregular pieces, all indicative of slow cooling. "The palisades" on the North River are examples of basa'ltic columns.

3. *Basa'ltic deposits of different kinds.*—If basa'lt is found in well-ascertained currents, traceable to craters, entirely similar matter is found in very different positions. There is a great deal of it that forms extensive tables of considerable thickness, constituting vast plateaux; or heaped-up fragments on different mountains, at the same level, the heaps corresponding, and seem to belong one to the other like parts of the same whole, showing a vast dislocated table. Basa'lt also forms isolated masses, hillocks in the midst of planes, sometimes very distant from every other formation of the same kind. It is found in seams, sometimes enclosed in the soil that conceals it, sometimes rising here and there like a wall, or presenting various hillocks on the same line of direction.

All these dispositions of basa'ltic deposits, as well as currents or streams, are sometimes found together in the same country. In some countries, on the contrary, there is no trace whatever of volcanic cones or of currents. In all cases, however, the rock possesses the general characters of basa'lt, and seems to rest indifferently on every kind of formation, even on vegetable earth.

4. *Tabular basa'lt* brings to mind the great tables of Iceland, especially those of the eruption of 1783; they possess all the characters of lava that has been arrested on horizontal planes, or filled depressions. The lower part is compact, crystalline, and most frequently divided into vertical prismatic columns (*fig.* 275); and the upper part is porous, cellular, sco'riform, irregularly di-

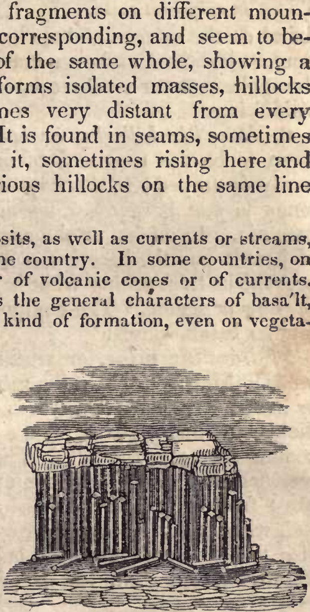

Fig. 275.—*Relation of prismatic to porous basa'lt.*

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2. What is basa'lt? What does it contain? What is its form?
3. Where is basa'lt found, and under what circumstances?

vided, and terminating on a plain horizontal surface. When the mass is composed of several stories, the separations are sometimes formed by thin beds of rapilli, and most generally they are distinguished by alternations of compact and porous matter, which characterizes each particular effusion.

5. These characters leave no doubt as to the igneous origin of these deposits; but there are still others. When we can penetrate beneath basa'ltic tables, as in cases where they rest on moveable formations, we almost always find the inferior part of the mass presents a multitude of appendages (*fig.* 276), which penetrate into the soil, indicating a liquid matter that has been moulded in rents or crevices. The earth on which the mass rests is often found calcined through a greater or less thickness, and the debris of plants it contains are carbonised. On the other hand, there is often found on the surface of basa'ltic tables points of scorification, particular elevations, and even crate'riform depressions, towards which the melted matter seems to have retired at a certain moment before solidifying.

Fig.* 276.—*Appendages of basa'lt in subjacent rocks.

6. *Basa'ltic hillocks, or bosses*, are of different kinds; some seem to be the remnants of an extensive table which had been partly destroyed; in this case the principal mass of the bosse belongs to one or another species of soil, and the summit only is basa'ltic. In others, on the contrary, the whole hillock is formed of basa'lt, and the base is lost in masses of sand and debris, which prevent us from seeing what is beneath; some others are attached to veins or seams. The composition of these hillocks, like that of tabular basalt, varies.

7. *Basa'ltic veins, or seams.* Basa'lt is frequently found in veins. Most frequently the mass of the seam or vein is compact, or irregularly cracked, but it is often divided into prisms, perpendicular to the parietes of the crevice, which then become the cooling surfaces (*fig.* 277). The matters in these seams are rarely scorified, but some instances are met in Vivarais and Auvergne. Most frequently basa'ltic veins are prolonged to the surface of the soil, where they present their out-crop; but it frequently happens, also, they terminate above in pointed masses (*fig.* 278), sometimes bifurcated, which are lost in the rocks through which they pass.

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4. What are the characters of tabular basa'lt?
5. What is the origin of basa'lt?
6. What are the characters of bosses of basa'lt?
7. What are the characters of basa'ltic veins?

Fig. 277.—*View of prismatic basa'lt.*

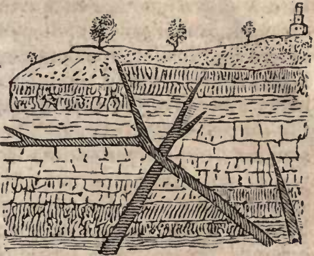

Fig. 278.—*Basa'ltic seams of Villeneuve-de-Berg.*

This circumstance positively indicates that the basa'lt was not introduced from above, and that it could only have been injected from the interior towards the exterior of the earth. Sometimes the vein glides betwixt two strata, which it follows to a greater or less extent; or, in ramifying, it launches a part of its mass into the interval, and ends by terminating there in a corner, whence it spreads into all the little fissures of the rock.

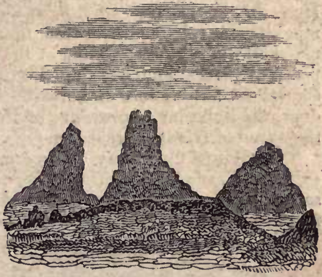

Fig. 279.—*Hillocks on the course of a vein.*

8. Along the course of basa'ltic veins, the out-crops of which are seen on the surface of the soil, various isolated hillocks are frequently observed (*fig.* 279), several together at various distances apart, which appear to be nothing more than partial ejections, like the cones formed along the same crack in modern volcanic eruptions. Most often they are almost entirely composed of scoriæ, but some are found which consist of pure basa'lt. Sometimes, instead of hillocks, there are effusions of tables of more or less thickness (*fig.* 280), which are also found along the course of a vein. All these circumstances tend to explain the formation of isolated hillocks, as well as the series of hillocks in line, found in a great many localities where the internal vein has found here and there an outlet.

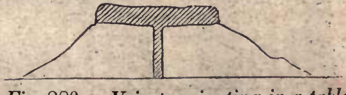

Fig. 280.—*Vein terminating in a table.*

9. *Action of basa'lt on adjacent rocks.*—The calcination of clays, and the carbonisation of vegetable debris lying beneath basa'lt, have been mentioned; granite traversed by veins of it is very much altered, portions of rocks which have been enveloped in

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8. How are isolated hillocks of basa'lt accounted for?

basa'lt are often melted on the surface, quartz and feldspar are cracked, sometimes enveloped or penetrated by vitreous matter. Marls, earthy limestones in contact with basa'lt, or pierced by its veins, and especially fragments of matter drawn into the basa'ltic mass, are converted into compact limestone, sometimes approaching the saccharoïd state. These limestones also become magnesian, and are converted into true dolomites, distinguished from the rest of the enveloping mass by their slow effervescence. Dolomisa'tion seems to be due to the presence of igneous products. When basa'ltic veins pass through carbona'ceous deposits, the clays are calcined, the coal is deprived of its bitu'men, and assumes a baccillar (berry-like) structure.

Basa'ltic deposits, in tables, hillocks, or veins, are more abundant on the surface of the globe than all the lavas in ascertained currents, which is, doubtlessly, owing to their mode of ejection. Basa'lts are found in France, on the borders of the Rhine, in Saxony, Bohemia, &c. Iceland contains a great quantity, and the same rocks predominate in the West Indies, at St. Helena, &c., and in almost all the islands of the South Seas.

Basa'ltic formations are noticed wherever they occur, in consequence of the tendency of the principal rocks to divide into long prisms, the varied arrangements of which have often excited the admiration of the curious. Here all the prisms converge at the summit of a hillock; there they form magnificent colonnades of the most picturesque appearance; in another place all the columns, broken at the same level, present a pavement composed of pieces regularly joined, extending over a greater or less space, and sometimes formed into an amphitheatre, one above the other. The grandeur, the imposing appearance of these pavements, have obtained for them the name of ***Giants' Causeway.***

The Giants' Causeway in Ireland is famous; but a similar structure exists in France. Sometimes there are excavations in the middle of basa'ltic masses, or trappean rocks, which resemble them most, some of them forming very remarkable grottoes. The most celebrated is Fingal's cave, in the island of Staffa, which is formed in the midst of trap, divided into prismatic columns with the utmost regularity, and into which the sea continually beats. Others exist in the basa'lt, properly so called; there is a famous one on the banks of the Rhine, between Treves and Coblentz, near Bertrich-Baden (*fig.* 281), the columns of which are composed of rounded pieces, which has caused them to be compared to piles of cheeses, whence the name of cheese-grotto, common in the country.

Fig. 281.—*Cheese-grotto, at Bertrich-Baden.*

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9. What influence does basa'lt exert over adjacent rocks? What is meant by dolomisation? Give some instances of basa'ltic formation.

10. The *Tra'chytic formation* is very extensive. It presents itself not only in conical hillocks, running in narrow bands, but also in piled-up tables on the surface; tra'chyte constitutes great mountains, most frequently united in very extended groups, which form very high masses, ordinarily the highest in the country, covered with asperities; their sides are broken into valleys and deep ravines, with steep escarpments, and with all the circumstances of lofty chains. The tra'chytic formation is in strong contrast with the igneous rocks we have heretofore studied, although close inspection would show them to bear various relations with deposits of basa'lt or lava.

11. The rocks which constitute the tra'chytic formation are extremely varied. Most of these substances, as their name indicates, are rough to the touch, because they are most generally finely porous, sometimes cavernous, scoria'ceous, pumice-like; but there are some that are perfectly compact, and present the porphyri'tic structure, frequently with tints of grey, red, brown, or black, on which are white crystals of albi'te and of rya'colite. There are some, more or less earthy, ordinarily of clear tints, called *domi'te*, because the Puy de Dome is composed of it. The base of all these rocks, which is inattackable by acids, is albi'tic or ryacoli'tic, formed of a multitude of microscopic crystals mingled together, the whole constituting a mass which is more or less compact. The disseminated substances are albi'te, in crystals of greater or less size, rya'colite, black mica, amphibole hornblende, but rarely py'roxene augi'te. Quartz in crystals, and chalcedony in small nodules are also found in it sometimes, and especially in a certain very cavernous species, hitherto found only in Hungary, the cement of which also contains many small striated balls of sphe'rolite (from the Greek *spheira*, a sphere, and *lithos*, a stone).

12. The name *pho'nolite* (from the Greek *phône*, a sound, and *lithos*, a stone) has been given to rocks more or less analogous to tra'chyte, but differing from it in this, that their base is attackable by acids, leaving a residue of rya'colite. These rocks are most often compact, greyish or greenish, sometimes porphyroid, but in which disseminated substances are rare. They are frequently divided into plates or leaves of variable thickness, and in certain cases the whole mass is divided into prismatic columns, which are more frequently divergent and contorted than vertical. Pho'nolites have been sometimes confounded with certain porphyroïdal varieties of tra'chyte, which possess nearly the same appearance, but not the same solubility.

13. Some tra'chytic formations contain considerable deposits of

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10. Under what forms do we find the tra'chytic formation?

11. What are the characters of those rocks which constitute the tra'chytic formation? What is domite?

12. What is phonolite? What are its characters?

13. Do all tra'chytic formations contain obsidian?

obsidian and of pe'rlite, with all their gradations to pumice. Their abundance and character vary according to locality; they preponderate in some countries, while in others scarce a trace of them is to be seen.

14. *Di'orite, trap rocks, amyg'daloïd, &c.*—There is nothing more analogous to basa'lt than certain black rocks, some of which, according to the numerous gradations they present in deposits in which the elements are distinct, must be mixtures of albi'te and of amphibole, and others are of an unknown, or at least doubtful nature. The first are designated in France under the name of *di'orite*, and in Germany they are known as *grunstein.* The others have long borne the appellation of *trap* (from the Swedish, *trappa*, a stair), the nature of which it is still impossible to determine definitely. These rocks bear some relation, as much by their position in certain localities as by their mineralogical character, to certain substances called *amyg'daloïds*, in consequence of the nodules of various matters they contain, which are known in England as *toadstone*, and *whinstone*, the nature of which is often not better known.

15. For a long time these rocks were supposed to be of aqueous origin; but it is now ascertained that they are from igneous causes.

16. At first, in spite of the absence of scoria'ceous matters, these rocks, and especially those named *trap*, present all the features of basa'ltic deposits; they are found in isolated hillocks, or in tables of greater or less extent; their mass is often divided into prismatic columns, which possess precisely the same appearance as basa'ltic colonnades, giants' causeways, and all the forms of basa'lt. On the other hand, these substances are frequently found in veins; and it is remarked that these veins or seams terminate above in a pointed mass (*a, fig.* 282), or in their course send off small ramifications (*b*) into the rocks through which they pass—small masses (*c*), sometimes isolated, sometimes communicating with the principal mass by a thin seam. The enclosing rocks are sometimes occasionally perforated by small ramifications, and even to the finest fissures. These circumstances evidently show these are not cracks filled from above, and can be regarded only as injections from the interior, thrown with sufficient force to penetrate the smallest fissures, to detach and carry away fragments of rock sometimes found in their substance, as at *d*.

Fig. 282.—*Veins of trap—Iceland.*

17. All these circumstances are exactly the same as those seen

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14. What is di'orite? What is trap?
15. What is the origin of di'orite and trap?
16. What are the characters of trap? In what form is trap met with?

in basa'lt. It is the same with beds, in appearance regular, seen between sedimentary layers; observation shows they are only ramifications of veins. This is clearly seen at Trotternish, in the isle of Sky (*fig.* 283), where a great seam of trap communicates with a bed of similar matter, which is itself divided further on into three branches. Hence it is evident the intercalation of tra'ppean rocks in arena'ceous beds is the result of an injection, which followed the separation of the beds of the sedimentary deposit to a greater or less distance, as in the case of the basa'lts of Villeneuve-de-Berg (*fig.* 278).

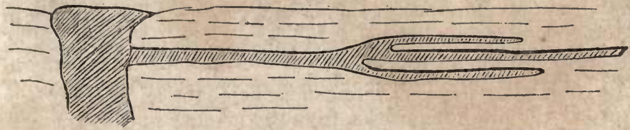

Fig. 283.—*Injection of trap into sedimentary rocks. Isle of Sky.*

18. *Ser'pentine and Diallage; different porphyries.*—Magnesian rocks, called ser'pentine, often accompany trap and di'orite; they very frequently form seams or veins of themselves. Ser'pentines and eu'photides are often injected in all manners into calcareous deposits belonging to the jura'ssic period. Sometimes they form veins, sometimes thick strata; they often present breccias of every species which constitute the marbles called *verd anti'que, verd d'Egypte*, &c. The limestones mingled with these rocks are all in the saccharoïd state, and furnish the most beautiful statuary marble and the most brilliant breccias; yet, if we examine them carefully, we find they belong entirely to the compact, and more or less earthy limestones, the surrounding deposits of which they are evidently a continuation. The schistose clays and sandstone, which alternate with the last, are found converted in the others into jaspers of different varieties.

The appearance of pyroxenic rocks, *mela'phyries* (porphyries, the constituents of which are united by a black cement), and other porphyries which belong to them, is productive of circumstances of the same kind; M. de Buch long since pointed them out in the Tyrol, and subsequently in upper Lombardy. They are also found all along the Alps, and are represented in the same direction in Provence in the midst of the mountains of Esterel: all is upturned in the neighbourhood of these rocks, which, in "coming to day," have upheaved around them calcareous deposits of different formations, dislocating and placing them in the most abnormal positions. Wherever they are in contact with these porphyries, and to a considerable distance beyond, limestones are transformed into dolomite, and in such a manner that the same deposits are of simple limestone in some parts, and of dolomite injected into those which are near to rocks of crystallization. What is most remarkable is, that the few organic remains met in

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17. How does trap resemble basa'lt?
18. What is serpentine? What is verd antique?

these modified limestones, even the shells of mollusks or madrepores, are found changed into magnesia; this clearly proves that an action subsequent to the formation of the deposit has produced dolomisa'tion, for no shell or madrepore exists which naturally contains magnesia, either in the living or fossil state, where the deposit has undergone no modification.

Feldspathic porphyries are often so characterized that there can be no doubt of their igneous origin. Not only are they found in veins in the midst of rocks, but they act like trachytes, in passing through split rocks, the fragments of which they glue together to form conglomerates; they often unite themselves in the most intimate manner to arena'ceous deposits which harden in their vicinity.

19. *Granitic rocks.*—There can be no doubt as to the igneous nature of the preceding rocks, from the manner in which they are injected into all kinds of deposits, and from the modifications they produce in the substances they pass through or upheave. The same is true of all granitic rocks, that is of granite properly so called, of syenites, which resemble them more or less in appearance, and pass into them in all manners, of certain gneiss rocks, which belong immediately to one or the other, &c. In short, it is inferred from a great mass of observations, collected first in England by Dr. Macculloch, afterwards verified by other geologists, that the granites, which are massive rocks, and therefore distinct from aqueous deposits, which are ordinarily stratified, act, on their appearance, exactly like the traps, diorites, and porphyries.

20. In the valley of Glen-Tilt, in Scotland, granite is found injected into calcareous deposits, which alternate with argilla'ceous schists (*fig*. 284), into which it sometimes forces separate masses (*a*); fragments of limestone (*b*) are also found enveloped in the granite itself. In other places vertical veins traverse the rock (*fig*. 285), sometimes entirely, sometimes terminating in pointed

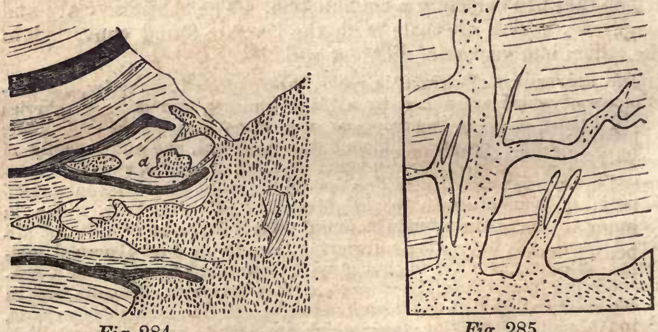

Fig. 284. *Fig*. 285.

Injection of granite into different rocks.

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19. What is the origin of granitic rocks? What rocks are included under the name of granitic rocks?

20. What circumstances prove the igneous origin of granitic rocks?

masses, like the diorites and basa'lts, which also shows that the matter came from below upwards, and that it was driven with great force. These facts do not present themselves in a particular locality only, but are observed in all parts of the world.

The state of pasty fusion in which the granites were, is indicated by the manner in which these rocks are enveloped in certain sedimentary deposits, or effused on the different soils they pass through. In the coal-measures of La Pleau, to the south-west of Ussel, a portion of the formation has been enveloped by porphyroid granites, which are found above and below. The coal is there hard, as on all the plateau, and the deposit is very irregular. In a great many localities, we find granite superposed on all sedimentary deposits from schists, and the most ancient rocks, to those of the jura'ssic period. There are different places in the Alps, where one may touch at the same time, superposed rocks of crystallization and the subjacent sedimentary deposit.

The action of granitic rocks on those through which they pass is the same as that of the preceding rocks; compact, o'olitic, and earthy limestones are converted into saccharoïd limestones, from which organic remains have most frequently disappeared; they assume bright colours of every kind, green, red, black, &c., and, in contact with mica, are filled with garnets and various other crystalline substances. They are often converted into dolomites, which are nowhere more abundant than in formations of granite—and sometimes into gypsum, as proved by the out-croppings of this substance in certain parts of the Alps. Clays, and various arena'ceous substances are transformed into jasper, and finally assume the characters of mica'ceous or talcose schist, and gneiss. Simple sandstones of sedimentary formations, on the approach of granite, are converted into beds of granular quartz. It sometimes happens that modified schistose sandstones still preserve their arena'ceous structure, although they may have become very solid; even the mica-schists to which they pass contain here and there thin strata of sandy quartz, interposed between laminæ of mica, which seems to announce the remains of ancient modified sandstone.

Granitic rocks, referred to different ages, are very abundant on the surface of the globe; being found sometimes in very lofty mountain chains, and sometimes forming rounded hills disintegrated on the surface, and covering considerable extents of country.

21. *Metalli'ferous lodes, veins, masses.*—The dolomisa'tion and the sulphatisa'tion of limestones, the presence of various substances in adjacent rocks, are not the only facts referable to the passage of igneous rocks from the bosom of the earth. It also happens that, on the contact of the new with the ancient rock, the deposits are filled with different metallic minerals, either disseminated or injected into fissures, and between beds, or accumulated in small masses, sometimes united by slender threads. This has been remarked by M. Dufrenoy in regard to iron ores in the Pyrenees, which are found either in limestone, or placed between sedimentary deposits and the granite which upheaved the solid mass.

It is evident, lodes or seams of ores are related to igneous action. As to those which are deposited in veins, it is to be remarked, we have never had occasion to follow them to a sufficient depth to ascertain whether they ter-

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21. How are metalli'ferous veins produced?

minate abruptly, and consequently whether they fill cracks opened from the surface towards the interior; but they are known to terminate in pointed masses upwards, as at Joachimstal in Bohemia, and in many other places, in small veins which have been worked. This circumstance leads us to think that metalli′ferous veins have been produced by an injection from the interior towards the surface, in the same way as the stony veins we have mentioned. Besides, veins of this sort are strongly united to the others: thus, at Pontgibaud, the same veins are sometimes granitic and sometimes metalli′ferous; in many other places metalli′ferous veins accompany porphyritic veins, and even veins of basa′lt, as in Bohemia, and the two substances mutually penetrate each other, sometimes one and sometimes the other being above. On the other hand, we very frequently find in the same localities stony and metalli′ferous veins running parallel to each other, sometimes crossing in different ways, one throwing the other aside, and thus mutually producing more or less marked faults. Sometimes the stony displace the metalli′ferous veins; sometimes, on the contrary, the latter turn aside the others: in everything they act exactly alike, and it is impossible not to refer them to the same origin. It is also remarked that veins generally follow great lines of dislocation of the crust of the earth.

We find in metalli′ferous veins the influence of those which pass through or accompany them, and which deposit, to a certain extent, substances not previously observed. The influence of the rock passed through is seen in metalli′ferous veins, as well as in those of trap; and it has been long known to miners, that a poor vein in a determined bed at once becomes rich by passing into another, and the contrary: hence, the sudden success and unforeseen reverses in mining operations.

Fig. 286.—*Metalli′ferous mass.*

22. Metalli′ferous masses being in general but accumulations of small veins running in all directions (*fig.* 286), or an abundant dissemination in the midst of a stony substance of the kind attributed to the action of fire, it is clear these deposits are produced in the same way as those just mentioned. These masses, the principal of which present us with ores of tin, copper py′rite′s, and magnetic iron, are chiefly composed of granites, porphyries, various magnesian rocks, in which the ores are found. The metalli′ferous mass of Zinwald, in Bohemia, is a particular granite enclosed in a porphyry; that of Altemberg, in Saxony, is a porphyritic mass enclosed in gneiss. The celebrated mass of magnetic iron of Taberg, in Sweden, is a mass of diorite enclosed in gneiss; that of Cogne, in Piedmont, is a mass of serpentine driven into the calci′ferous mica′ceous schist.

23. Metalli′ferous lodes in regular beds, are merely veins which have followed the stratification, as we observed in traps (*fig.* 283), or deposits which were formed in contact with sedimentary beds and the fused matters that upheaved them. But we must not confound the masses and veins, just mentioned, with certain deposits of o′olitic iron ores found in sedimentary formations. Among the

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22. Of what do metalli′ferous masses usually consist?
23. What is meant by the term lode?

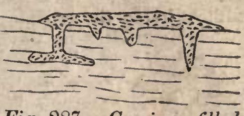

Fig. 287.—*Crevices filled from the exterior.*

latter, some form beds of more or less extent in the midst of calcareous formations, others fill wide apertures of little depth, from above, which sometimes communicate with caverns (*fig* 287); but these facts are of a different order from those just described.

24. *Metamorphism.*—From all the facts we have cited (which might be vastly augmented in number by reference to details in many localities), we must conclude that crystalline rocks, which are all formed of si′licates, extensively varied and mixed with each other, have been produced by the action of fire; that at different epochs they have dislocated, uplifted, or overturned the sedimentary deposits, modifying the mass in all manners—and it is to these great phenomena that are due all the seeming disorder observed on the surface of the globe, as well as all the successive changes, the traces of which may be perceived at every step.

When we see earthy or compact limestones become crystalline on the approach of these different kinds of rocks—to fill with various substances they do not contain at certain distances—to be charged with magnesia in cracking in all parts, and to disintegrate with more or less facility; when schistose clays and arena′ceous substances are converted into different jaspers, and become charged with mica and am′phibole, and assume the characters of gneiss, of mica′ceous or talcose schist; finally, when sandstones are transformed into beds of solid quartz, can we be surprised that most modern geologists have adopted the idea of complete changes effected in a great number of sedimentary deposits, and that they resort to this *metamorphism*, long since perceived by Hutton, Playfair, and Dr. Maculloch, to explain a multitude of facts, observed especially in deposits anciently designated under the names of primitive and transition formations? The facts appear so extraordinary, that we may be led to suppose a little exaggeration: but we must reject evidence to deny that there are saccharoïd limestones, dolomites, mica-schists, gneiss, granular quartz, &c., which are the result of a change produced in earthy or compact limestones, clays, sands, &c. of sedimentary formation: is it then so ridiculous to suppose that such has been their origin in all cases?

These ideas, now more striking, because they are expressed by a proper word, are nevertheless not absolutely new; all works on geology are actually full of them, and the facts are not less remarkable from being expressed in other terms. There is no description of a country, going back to the time of Saussure, whose works are still remarkable for their fidelity of details, in which are not seen numerous passages of different arena′ceous deposits to rocks of crystallization, of schistose grauwackes to talcose schists, to mica′ceous schists, and from these to gneiss, or the passage of sandstone to different kinds of granite and porphyries on which they rest, &c. Is not the fact of the modifications, now described under the term of *metamorphism*, here clearly indicated—to which time has added only more details and greater precision?

It is certain that in departing from schistose grauwackes, for example, and going towards some mountain or islet of crystallization, we find these

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24. What is meant by metamorphism? Of what do crystalline rocks consist?

substances themselves become more crystalline in character, and sometimes, without losing the organic remains they contain, become filled with new minerals; in Brittany these schists are filled with andalu'site, sometimes staurotides, near all granitic deposits. Elsewhere, as in Vosges, in the mountains of Var, we see them pass to mica-schist; and the latter to gneiss, which, itself, insensibly becomes granite. Now, as if the intimate union observed were not sufficient, these mica-shists, then the gneiss itself, contain carburetted schist, or even graphite, veins of anthracite, which remind us of the deposits which are found further in the schists of grauwackes, and sufficiently marked to determine the pursuit of coal.

It is, then, evident that all the rocks we have cited, no matter how they may differ, are only modifications, mere metamorphoses of one or all; and, as it is in approaching granitic rocks, evidently produced by igneous action, that these metamorphoses become more and more marked, it is clear that it is to the influence of the latter that they are due. The same influence is manifest on the sandstones of different ages, at various points where they are in immediate contact with granite: the modifications are such that the special name, *arkose*, has been applied to them. They then pass through all shades to granite, and become filled with different substances that they do not contain elsewhere.

Near porphyritic ejections, schists frequently present modifications of another kind. Here the most earthy, and the most evidently sedimentary parts, pass by degrees to compact substances, more and more feldspathic, preserving more or less of their schistose character, and finally end by containing crystals of feldspar; elsewhere these same matters pass to solid clays, containing veins of limestone, then nodules of the same substance, which assume all the characters of amygdaloids, losing, only little by little, their schistose structure.

The same phenomena are remarked between diverse sandstones and porphyries that intersect them. The arena'ceous matter gradually hardens, becomes more compact, and finally unites with the porphyry in such a manner that it is not easy to determine where one begins or the other ends.

All these facts pertain really, with the exception of some details, to ancient geology; and it is only the manner of explaining them that has changed. Everything conspiring to demonstrate that crystalline substances have been produced by the action of fire, and forced through sedimentary deposits, we now understand that the latter have been modified, or metamorphosed in different ways by their influence, in a degree corresponding to their proximity: the effects entirely cease only at greater or less distances.

It is conceived that one part of these metamorphoses of sedimentary formations arises from the simple action of heat without new fusion, but sufficient to modify the texture of masses, and even to unite elements in other proportions, as happens when transparent glass is submitted to a temperature insufficient to melt it, in which, nevertheless, a new crystallization takes place. But this idea is not sufficient of itself; we must conceive another action, which we are not yet able to explain or account for, in virtue of which particular substances have been borne, or developed, in the midst of rocks found in the neighbourhood of divers upturnings, of which the globe is the theatre. We readily conceive of the introduction of sulphuric acid, which is frequently formed in volcanoes; but we do not understand that of magnesia and different species of si'licates, and, as respects them, all is still purely hypothetical. We may compare these facts to *cementa'tion*, by means of which iron is converted into steel; a phenomenon which is manifested not only in contact with carbona'ceous matter, but extends far into the ferru'ginous mass, and even takes place at a distance, according to the experiments of M. Laurent, who has shown that carbona'ceous matter may penetrate iron even through porcelain tubes. We also know, from experiment, and many effects observed in manufactories, that the peroxide of iron, the oxides of chrome, &c., are vola'tilized, and penetrate the substance of bodies that envelope them. The experiments of M. Gaudin, with a blow-pipe on a de'tonating mixture, show that silex, magnesia, and lime, are also volatile oxides; the first after fusion, the others before being melted. These facts evidently lead to an explanation of all the phenomena of metamorphism, and the intrusion of foreign substances into sedimentary deposits, either in veins or in a state of dissemination.

EFFECTS ATTRIBUTABLE TO EROSION.

We have seen that waters act by the carbonic acid they contain; by their weight; by their dissolving power; by their transporting power; by their shock, as in waves of the sea, and thus denude continents. We have also pointed out, that in arena'ceous formations, valleys are produced by erosion, precisely as ravines are formed in sandy soils, by the action of rain-water. Hence we may infer that, in every revolution that movements of the soil must have necessarily determined, the waters, thrown forcibly sometimes on one side and sometimes on the other, must, as in our time during earthquakes, have ravaged, divided, and modified pre-existing deposits in various ways. Many circumstances may be explained by erosion of waters, and the *denudations* it occasions.

25. At first, when we see more or less numerous hillocks of sedimentary matter in a country (*fig.* 288), whose summits are nearly on the same level, and whose strata correspond with each other, we are naturally led to consider them as evidence of great removals effected by the waters, at certain epochs, the relative dates of which remain to be ascertained. In this way we explain, according to appearance, all the sections which the sandstones present on the eastern slope of Vosges; that remarkable assemblage of peaks of every form seen at Aldersbach, in Bohemia; the numerous hills that cover Ross-shire, in Scotland; the gypseous hills in the neighbourhood of Paris, all composed of the same beds placed at the same height; and the division of the basa'ltic tables that crown the hills, in certain localities, as well as the rupture of certain lava-floods that had barricaded valleys, &c., &c.

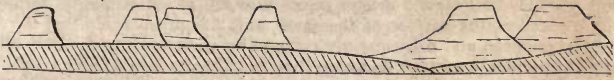

Fig. 288.—*Hills produced by denudation.*

Valleys which intersect moveable formations are evidently produced in the same way; and there is no doubt that most of those existing in solid formations, have been modified by erosion of water after the rupture which gave origin to them. In this way we may explain the smoothing of all their parietes, in a great many localities, and the widening of their upper parts. The great lakes sometimes found at the extremity of valleys, as on the two slopes of the Alps, in Switzerland and Piedmont, may be attributed to the afflux of waters which rushed through them, at the period of some great catastrophe, and emptied with violence on the plain in which they terminated.

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25. What forms of surface are attributable to erosion and denudation?

Many other facts are explained by the power of erosion and transport by water. When, by studying faults in the interior of mines, we clearly see that the beds no longer correspond, and that a part of the formation must have been uplifted (*fig.* 289); then, if the soil, *a*, *b*, *c*, is level on the surface, we naturally ask what has become of the beds *d* and *f*, which ought to have formed a hillock between *b* and *c*. It is clear these beds must have been removed, which we may conceive was only by a posterior action of waters, which carried away the debris, and perhaps spread them over the surface. In the same way, when we see a vein form a projection, a dyke on the surface of the soil (*fig.* 203, page 119), we conceive that it could not have formed in this manner, and that the uncovered part must have been once encased just as that is which is now covered; the surrounding formation has been uplifted then afterwards, at least along the whole actual height of the projection. Something similar necessarily took place at points where veins crop out on the surface, or are covered by moveable soil (*fig.* 290); it is not probable that melted matter injected in the crack would be immediately arrested at the surface of the earth, and it is presumable that the soil has been removed and subsequently covered by various clearings. We are thus led to understand how so many basa'ltic masses now offer no trace of scoria'ceous matter, neither in themselves nor in their vicinity. These imperfectly aggregated debris have been subsequently carried away by the action of water, and perhaps it is the same with the scoria'ceous matter which must have accompanied the appearance of trap.

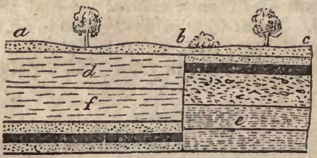

Fig. 289.

Fig. 290.

The prodigious power exerted by waves, and the effects they have produced in our times, lead us to think, also, that all the rocks formed around islands and reefs at a short distance from coasts, or the often fanciful groups in the midst of the sea, are also the remnants of some great division caused by water, as much in removable matters, easily disintegrated, as in masses broken by earthquakes and different movements of the soil, and certain parts of which have been afterwards removed, either by repeated shocks of waves or sudden debacles. In this way we may explain the numerous accidents in rocks which bound coasts, or are isolated in the midst of the ocean, as in the sinkings of the chalk of Etretat (*fig.* 291), and the sections of porphyritic or granitic rocks in the Shetland islands (*fig.* 292). It is conceived that straits, more or less extended, may have been formed by the two combined actions of currents of water and rupture which the soil might have undergone, by upheaval or subsidence, at determined epochs.

From these observations, we see that many effects may be attributed to the action of water which cannot be in any other way explained. We may see denudations in the midst of mountains and valleys, recognise the ancient sinkings which bordered seas at different ages, and hence appreciate their limits, as well as all other circumstances connected with them. Reference to the immediate action of water should be always carefully restricted to the moveable or loose matters found on the surface of the globe; for when solid matters are in question, which water attacks too slowly, we are led to

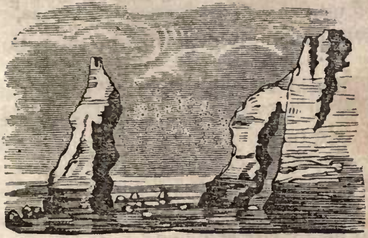

Fig. 291.

Fig. 292.

Examples of rocks cut and fashioned by water.

think that currents and waves cannot act effectively until the soil has been previously prepared by the fissures or deteriorations caused in rocks by movements of the earth.

We must not confound with divisions produced by water certain accidents which may result from shrinking produced by metamorphism. This probably takes place in dolomites, which follow compact limestone in a great many places, as in the Tyrol and in Cevennes. Masses of these matters are frequently split and slashed in all directions on the surface, particularly on the summits of mountains or on plateaux, very nearly in the same way that calcareous deposits are cut by water. Now, the change from a simple to a double carbonate, specifically heavier, requires contraction in masses submitted to dolomisa'tion; therefore, the latter must be split and cracked in all directions, and the denudations they present are consequences of these effects.

LESSON X.

Classification of Formations—Different kinds of Stratification—Dip—Strike—Conformable Stratification—Unconformable Stratification—False Stratification—The form and habits of an Animal deducible from a single bone—Relative ages of the principal catastrophes of the Globe—Systems of Upheaval—Classification of—State of Europe at different epochs of formation—Deluge—Geogeny.

Classification of Formations.

1. As already mentioned, the several formations are divided into two classes, namely:

1st. *Massive, or igneous formations*, which are produced by the

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1. How are the several formations divided? What are the divisions?

action of fire, and are not stratified. The terms *primitive* and *transition* have been applied to these formations, but, as they are inexact, they are going out of use.

2d. *Sedimentary formations*, which are deposited by the action of water, and are stratified.

2. MASSIVE, OR IGNEOUS FORMATIONS escaped from the earth in a state of fusion, and became solid by cooling, but without being stratified. They are divided into two classes: 1st, those crystalline rocks which are not traceable to the crater of any volcano now recognisable, such as granite, trachyte, &c.; 2d, massive rocks of a slightly crystalline structure, traceable to volcanoes, such as modern and ancient lavas, and basa'ltic formations.

3. SEDIMENTARY FORMATIONS are arranged according to their relative antiquity: they are divided into groups, composed of those which appear to have been formed either at the same epoch or during a geological period, during which the general condition of the earth appears to have undergone no important change. These formations are commonly divided into five groups, namely:

4. First. *Primary stratified rocks*, in which neither organic remains, nor fragments of the most ancient rocks are found; this group includes gneiss, mica-schist, quartz, transition limestone, and argilla'ceous schist.

5. Second. The *transition formations*, which rest on the primary stratified rocks, and contain fossils of plants or animals, but which appear to have been deposited prior to the creation of the most perfect beings of either kingdom, and only contain the remains of aquatic animals, which are all very different from those of our times, such as tri'lobites (*fig.* 4, page 28). This group includes fossili'ferous schists, transition limestones, &c.

6. Third. The *secondary formations* were deposited at periods less remote than the transition, and consequently rest on beds of the latter, or on primary rocks; but they go back to a time when the state of the globe was very different from its present condition; very few mammals then existed; ammonites are among the most characteristic fossils of the secondary formation:

The secondary formations are subdivided into,

1st. The *carboni'ferous*, which includes old red sandstone, mountain limestone, and coal:

2d. The *sali'ferous*, embracing new red sandstone muschelkalk, and variegated marls, forming the tria'ssic system:

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2. What are the divisions of the igneous formations?

3. How are sedimentary formations arranged? How are they divided?

4. How are primary stratified rocks characterized? What rocks are included in this group?

5. On what do the transition formations rest? How are they characterized?

6. On what do the secondary formations rest? What are the most characteristic fossils of the secondary formations? How are they subdivided? What are the divisions?

3d. The *jura'ssic*, embracing the lia'ssic, the o'olite, and wealden groups:

4th. The *creta'ceous*, embracing the lower greensand, gault, upper greensand, chalk marl, chalk without, and chalk with flints.

7. Fourth. The *tertiary formations*, which, being more recent, covered all the preceding formations; they date from a period when animals and plants belonging to all the great classes existed, but still anterior to the creation of man:

The tertiaries are subdivided into three groups;

1st. The older tertiary or eocene, which embraces the London clay, bagshot sand, and Paris Basin.

2d. The middle tertiary, or miocene, which embraces the Coralline crag, Red crag, the Molasse of Switzerland, &c.

3d. The newer tertiary, or Pliocene, which embraces Norwich crag, the sub-Apennine beds, the Brown coal of Germany, &c., as well as the superficial deposits, called *Pleistocene*, consisting of diluvium and alluvium.

8. Fifth. The *modern formations*, which are contemporaneous with the existence of man on the earth, and are still being formed.

The subdivisions embrace:

1st. Peat-bogs, formed by the accumulation of the debris of certain plants.

2d. Coral formations, from the multiplication of polypa'ria as seen in the coral islands of the Pacific.

3d. Concretionary formations, formed by calcareous and other matters, found in solution in the waters of certain springs, &c.; as travertin, stala'ctites, stala'gmites, &c.

4th. Formations from transport or drift; as fluviatile, terrestrial, or marine alluvions, dunes, &c.

5th. *Humus*, or vegetable earth, formed directly by the disintegration of other formations, and their mixture with the products of decomposition of plants and animals, spread in a layer of more or less thickness, on almost every point of the surface of the earth.

9. All these deposits are superposed one on the other, in a constant order; and if it were possible to make a sufficient section in a part of the globe where they all exist together, we should find a succession of twenty-seven stories, or layers, distinguishable by their different characters. But each of the great deposits is divided and subdivided into various layers, more or less distinct, composed most frequently of arena'ceous substances, clay and limestone, of different degrees of consistence, and in beds of varying thickness. The assemblage of their alternate beds often forms successive layers, several hundred yards thick.

10. It is evident, that if such sections existed in the crust of the earth, we could see all the beds, and easily distinguish their rela-

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7. From what period do the tertiary formations date? What are the divisions of the tertiaries?

8. From what period do the modern formations date? What formations are embraced in the divisions of the modern formations? How is humus formed?

9. What is the arrangement of the several deposits composing the crust of the earth?

10. Why is it difficult to distinguish the relative ages of deposits?

tive ages by their number in the order of succession; the deepest being the most ancient, and that forming the surface being the most modern. It would then be sufficient, in sections of different depths which would be found elsewhere, to count from above downwards, to know always where we were, and even the variations that a determinate bed might undergo in different places would offer no difficulty to observation. But such is not the case; the numerous escarpments we meet, always present us with but a very small portion of the series, sometimes in one part of its thickness, and sometimes in another; we never see the entire series; and it is only by combining the observations made in different places, that we have been able to establish what we now know, at the same time we discovered the particular circumstances of formation of each deposit.

In consequence of the divisions of the whole, it is conceived, it might become very difficult to distinguish them, and that in presence of an escarpment one might frequently be unable, at first sight, to decide on the point in the series to which it ought to be referred. Indeed, different beds of the same nature which succeed each other in the series, are often very analogous, the limestones of one story more or less resembling those of another; and the same is true of different deposits of sandstone and clay. It also happens that the same deposit varies at different points: here it is a compact, and there, an earthy limestone; in another place the same limestone is found mixed with sands, and, further on, it is nearly pure sand, &c. The injection of crystalline matter adds to the embarrassment, by the modifications it causes in the texture, and even in the nature of everything in its vicinity. It is also conceived, that the fewer the beds superposed in the same place, the greater the difficulties, and they are at a maximum when we meet an isolated deposit, without knowing on what it rests, and not being able to perceive anything it covers: this occurs in a great many countries. It often happens, too, that one or more beds are entirely wanting in one locality, and then the deposits which should naturally separate them, being immediately superposed, exposes the observer to attribute to the succeeding beds an age very different from that which really belongs to them.

11. To obviate this difficulty, we have observations on the continuity of beds, some of which we can follow from points where they present certain characters, to others where they offer different characters; from points where they are entirely isolated, to others where we can see on what they rest, and what covers them, &c.

We have also observations on *stratification* and *inclination* of different beds towards one point or the other, which enable us to infer that such a species of deposit passes below or above another, found isolated or at a distance. Fragments and rolled flints may evidently indicate the priority of deposits which contain them, to those from which they came, and thus furnish a good means of distinction, when they are sufficiently characterized. And the nature of organic remains has now become a very decided aid in distinguishing different formations.

12. *Different kinds of stratification.* There are two kinds of

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11. How are we enabled to judge of the relative ages of deposits?

12. How many kinds of stratification are described? What is observed in inclined stratification?

stratification: one horizontal (which is the natural stratification), according to which all transported matters are deposited under water; the other more or less inclined, resulting from upheavals which have taken place at different epochs. In the latter we distinguish the *degree of inclination*, or *dip*, which may be vertical, and *the point of the horizon towards which the beds dip*. The last part of the observation determines the direction of the crests of the strata, or, as we say, the *strike* or *direction of the strata*, which is always at right angles to the *dip* or *direction of the inclination*, and which also indicates the direction of the movement by which the effect was produced. But the first observation of horizontal, or inclined strata, is not always sufficient; it is frequently necessary to distinguish the relative stratification of different deposits, which is reduced to the *concordance* or the *discordance* which may exist between them.

13. The *dip of strata* is the point of the compass towards which they slope, while the angle they form with the plane of the horizon is called the *angle of dip*. The term *dip* refers to the inclination of a stratum, and the term *strike* is used to express its direction. Thus, strata may dip to the north at an angle of forty-five degrees; in this case, the *strike*, or *line of bearing*, must necessarily be east and west, because the *strike* is always at right angles with the *dip*. "Dip and strike may be aptly illustrated by a row of houses running east and west, the long ridge of the roof representing the *strike* of the stratum of slates, which *dip* on one side to the north, and on the other to the south." The angle formed by the roof with the plane of the horizon would be the *angle of dip*.

14. *Conformable stratification.* When all the strata of a formation are parallel to each other, that is, when there is a concordance between them, whatever may be their general position, horizontal or inclined, convex or concave, they are said to be conformable (*figs.* 293 to 296).

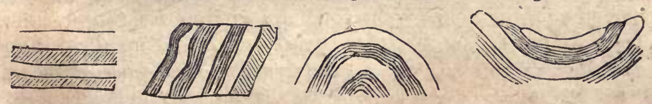

Fig. 293. *Fig.* 294. *Fig.* 295. *Fig.* 296.

Different kinds of conformable stratification.

15. *Unconformable stratification.* When the strata of a formation are not parallel to each other, when there is a discordance between them, as where horizontal strata come in contact with

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13. What is meant by the dip of strata? What is the angle of dip? What is meant by the term strike?

14. What is meant by conformable stratification?

15. What is meant by unconformable stratification? Is it always of the same character?

inclined beds (*fig.* 297), or where the relative inclination of beds is different, as at *a* and *b* (*fig.* 298), they are said to be unconformable. Where a superior deposit, whether stratified or not, rests on a section of the beds of an inferior deposit (*fig.* 299), there is a peculiar kind of unconformable stratification, sometimes called *transgressive stratification.* There is another kind of unconformable stratification, where the beds are parallel; this occurs where a horizontal deposit, after having been furrowed in different ways by water, is again entirely covered by a deposit of the same nature which fills up all the excavations (*fig.* 300). In this case the strata are unconformable where they join end to end with beds on the slope of ancient valleys.

Fig. 297.

Fig. 298.

Fig. 299.

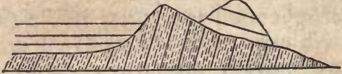
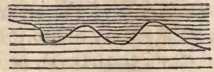


Fig. 300.



Examples of unconformable stratification.

16. To ascertain the relations in the stratification of two deposits, it is necessary to pay great attention to the particular structure of the beds, which in certain cases may lead us into error. For example, seeing that the divisions of the bed *a*, (*fig.* 301), dip towards the left of the figure, we must not conclude that the stratification is unconformable with the bed *b*; this appearance results altogether from the structure which the bed *a* owes to its rapid formation under particular circumstances. (See page 138.)

Fig. 301.

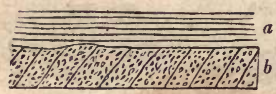
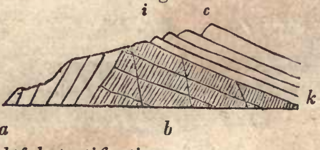


Fig. 302.



Examples of doubtful stratification.

17. Schistose substances often present many difficulties, in this respect, because their divisions run in every direction, and sometimes the least apparent is the real stratification. For instance, we might suppose the deposit *a*, (*fig.* 302), rested conformably on the deposit *b*, and that the mass *c* is an unconformable stratification, from regarding the finest divisions of the schist as indicative of the stra-

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16. What is meant by doubtful stratification?
17. What is false stratification?

tification. But we might also consider the deposit *a* as unconformable, and the deposit *c* as conformable, from regarding the parallel joints, *i* to *k*, as those of stratification; and it is also possible to view both *a* and *c* as unconformable relatively to *b*, by considering the other joints as those of the strata. It may be often difficult to decide; nevertheless, in general, the schistose division is frequently a structure which has perhaps a certain crystallization of mica'ceous matter; and it is this character, therefore, among others, that we must ordinarily select. Now, the joints of dislocation, for one or the other division must have been thus produced, are splits united and well marked, often a little open, which are ordinarily prolonged into several consecutive deposits, while the joints of stratification are more undulated and more adherent. The most irregular undulations of true strata are often traversed throughout by the schistose structure (*fig.* 303), without alteration. This circumstance evidently shows that this structure is an effect posterior to the contortion of beds, and may be attributed to a metamorphism more modern than their derangement. The extraordinary divisions just mentioned, are sometimes termed *false stratification.*

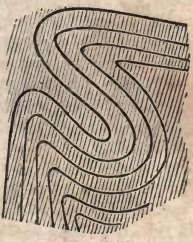

Fig. 303.

18. Organic remains, which are very numerous in most sedimentary deposits, also furnish a means of recognising strata. There are some which are peculiar to certain deposits, and are not found elsewhere, and which are therefore distinguished as *geognostic horizons.* Thus, the Silurian or Devonian formations are clearly recognised by the presence of the remains of a certain family of crusta'ceans, named trilobites (*fig.* 4, p. 28). The *Gry'phea arcua'ta* (*fig.* 71, p. 55), is found in the lias, and only in it: the *ex'ogy'ra vir'gula* (*fig.* 109, p. 65), belongs to the upper part of the jura'ssic formation; *baculi'tes* (*fig.* 130), and *turrili'tes* (*fig.* 131, p. 72), begin and end in the creta'ceous period.

19. Although the remains of mollusks and small animals are found entire, and therefore easily recognised, those of large mammals, &c., often exist only in fragments; and, without the necessary knowledge, the family, genus, or species, could not be discovered. But those well acquainted with comparative anatomy, and the laws which govern in the organization of animals, can deduce the form, and even the habits of an animal, often from a single bone.

"Every organized being may be considered as an entire and perfect sys-

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18. How do organic remains assist us in distinguishing the relative age of strata?

19. How is it that a portion of the fossil remains of an animal enable us to recognise its class?

tem, of which all the different parts mutually correspond, and concur in the same definitive action by a reciprocal re-action. No one part can undergo a change without a corresponding change taking place in all the others; and, consequently, each part taken separately, indicates and gives the key to a knowledge of all the rest.

"Thus, if the stomach of an animal is so organized as only to digest fresh animal food, its jaws must also be so contrived as to devour such prey; its claws, to seize and tear it; its teeth, to cut and divide it; the whole structure of its locomotive organs, to pursue and obtain it; its organs of sense, to perceive it from afar; and nature must have even placed in its brain the necessary instinct to enable it to conceal itself, and to bring its victim within its toils. Such will be the general conditions of a carni′vorous animal; they must inevitably be brought together in every species intended to be carni′vorous, for its race could not subsist without them; but under these general conditions there exist also special ones, relating to the size, the habits, and the haunts of the prey, on which the animal is to exist; and from each one of these special conditions there result certain modifications, in detail, of the form required by the general conditions; so that not merely the class, but the order, the genus, and even the species, will be found expressed by, and deducible from, the structure of each part.

"In order, for example, that the jaws may be enabled to seize the prey, there must be a certain shaped prominence for its articulation; a certain relation between the position of the resistance and that of the power, with respect to that of the fulcrum; a certain magnitude of the muscle that works the jaw, requiring corresponding dimensions of the pit in which that muscle is received, and of the convexity of the arch of bone beneath which it passes, while this arch must also possess a certain amount of strength, to enable it to bear the strain of another muscle.

"That the animal may be enabled to carry off its prey, a certain degree of strength is necessary in the muscles which support the head; whence results a peculiar structure in the vertebræ to which these muscles are attached, and in the back of the skull where they are inserted.

"That the teeth may be adapted to tear flesh, they must be sharp; and they must be more or less so, exactly according as they are likely to have more or less flesh to tear, while their bases must be strong in proportion to the quantity of bone, and the magnitude of the bones they have to break. Every one of these circumstances will have its effect on the development of all the parts which assist in moving the jaw.

"That the claws may be able to seize the prey, there must be a certain amount of flexibility in the toes, and of strength in the nails; and this requires a peculiar form of the bones, and a corresponding distribution of the muscles and tendons; the fore-arm must possess a certain facility in turning; whence also result certain forms of the bones of which it is made up; and these bones of the fore-arm, articulating to the humerus, cannot undergo change without corresponding changes taking place in this latter bone. The bones of the shoulder also require to have a certain degree of strength, when the anterior extremities are to be used in seizing prey; in this way again other special forms become involved. The proper and free play of all these parts requires certain proportions in all the muscles concerned in the motions of the fore-leg, and the impression of the muscles so proportioned will determine still more definitely the structure of the bones.

"It is easy to perceive that similar conclusions might be drawn as to the structure of the posterior extremities, which contribute to the rapidity of the general movement of the body; or of the vertebræ, which influence the facility of those movements; and also as to the structure of the bones of the face, in their relation to the degree of development of the external senses. In a word, the structure of a tooth involves that of the socket in the shoulder-bone, and of the nails, just as—to use a mathematical, but very apt illustration—the equation to a curve involves all the properties of the curve; and as the curve may be drawn when we know the root of the equation, so in comparative anatomy, by making each property separately the base of investigations, one may deduce all the other properties. Thus the shoulder bone, the articulation of the jaw, the thigh-bone, or any other bone, taken separately, gives the structure of the tooth, or, conversely, from the tooth, a knowledge of these peculiarities may be derived; so that, taking any one bone, he who is familiar with the laws of the animal economy, may reproduce the whole animal."—*Ansted.*

RELATIVE AGES OF THE PRINCIPAL CATASTROPHES OF THE GLOBE.

From observations, it would seem that the dry land must have appeared in successive portions, to cause on the surface all the variations of nature, form, humidity, and dryness, the combination of which should procure for man all the happiness designed for him by the Creator. The study of the successive appearances of land is now one of the most beautiful points of view in which geology can be presented; we are indebted to M. Elie de Beaumont for pointing out the course to follow, to establish the chronological order of the principal catastrophes which happened in Europe, and around which all facts of the same nature may be grouped.

As soon as we perceive some part of inclined sedimentary beds, we may decide that they have been displaced from their ordinary position by upheaval. The period of this accident remains at first undetermined; but if, at the base of more or less elevated projections which these beds produce, we find other sediments deposited in horizontal strata, resting against the preceding (*fig.* 304), it becomes evident that the upheaval of the first took place after the formation of the second, which are still found as they were when deposited from water. We now have a term of comparison, and, if we succeed in recognising the relative age of the horizontal deposit, we also have an epoch of the catastrophe, relatively determined, which produced the uptilting of the other. These differences of stratification are everywhere seen on the sides of mountains, and we then see that the several sedimentary deposits, *a*, *b*, *c*, are not all in the same position. In certain places the stratum *a*, for example, is uptilted, and the stratum *b* is horizontal; in another, *a* and *b* are both uptilted, and *c* is horizontal; in a third, *a*, *b*, and *c*, are uptilted together, and another stratum, *d*, rests upon them. We must infer, from these observations, that a first upheaval took place after the formation of *a*, and before that of *b*; a second took place between the strata *b* and *c*, a third between *c* and *d*, &c., and so on, chronologically, as far as they have been observed.

Fig. 304.

Systems of upheaval. If the inclined position of sedimentary strata reveals to us the existence of upheavals, the strike or direction of these beds, which is nothing but the line produced by their swelling upwards or the crest or ridge resulting from their rupture, shows us the course followed by the phenomenon. Hence it follows we may take one fact for the other, as the basis of observation, and that the different directions (strikes) of mountain chains, are also indications of the different kinds of upheaval. In fact, it has been long and perfectly established, on one hand, that the inclination of strata is intimately connected with the direction of chains, excepting the perturbations which result from crossings; on the other hand, we now know that the phenomenon of uptilting of a determinate number of beds extends as far as the chain itself. It has also been ascertained, at least for Europe, that parallel chains correspond, in general, in the epoch of upheaval; that is, in these chains, strata of the same age are found everywhere uptilted, and that the succeeding ones are horizontal. It follows from this circumstance that an upheaval does not take place purely on a mathematical line, but on a band of formations more or less wide, on which it is manifested by several parallel ridges. The same line does not continue always from one end to the other, but we find here and there high and low parts, and those which are concealed by subsequent deposits; therefore, it is the common line of all the elevated ridges which must be taken for the general direction or strike—(The word strike is formed from the German *streichen*, to stretch, to extend).

20. The assemblage of directions on the same line, and parallel directions, form what is called a *system of upheaval*, which is synonymous with the expressions, *system of fractures*, *system of uptilted beds*, and even *system of mountains*, although in a more restricted sense than in geography. To designate the different systems, the names of places in which each system is particularly developed have been borrowed; we say, *system of the Pyrenees*, *system of the Western Alps*, &c.

The great catastrophes which have successively occurred on the surface of the globe appear to have always taken place suddenly. At greater or less distances from places where the stratification is unconformable, we often find the same deposits in conformable stratification, and even joined to each other by a gradual passage; hence, it follows that deposition has not been suspended, but the movement of the soil has been local over a more or less considerable space of the terrestrial surface, and the interval during which it took place must have been extremely short. This is clearly seen, for example, at the period of the system of the Rhine, in which the vosgean sandstone is found upheaved, without the bunter sandstein having participated in the action; and, nevertheless, at a short distance the two arena'ceous deposits, where their stratification is conformable, are so joined to each other, that it cannot be determined where one begins or the other ends. The same is the case with the creta'ceous formations; if their different deposits are dislocated in a certain direction, they are conformable for great extents, and they then pass from one to the other in such a manner that they were for a long time confounded as a single formation.

Submerged and uncovered formations.—Sedimentary beds found resting horizontally on the sides of mountains, show that the sea beat against escarpments by deposits upheaved in an anterior epoch; hence the expression of the sea of this or that formation, as the *creta'ceous sea*, the *jura'ssic sea*, &c., which indicate the waters beneath which each of these sedimentary deposits was formed. When a deposit is wanting in a certain extent of formation, we should infer the formation was then above the sea of the epoch, and formed there a more or less elevated island or continent; thus, at the time when the Parisian limestone was formed, a great part of France, and indeed of Europe, must have been dry, as we scarcely see traces of these deposits anywhere except in the neighbourhood of Paris or Bordeaux. But it also happens that the deposits which we must regard as having been dry at a certain time, were afterwards covered by marine sediment, more modern than the preceding; and hence we must conclude that, although uncovered prior to the anterior formation, they must have afterwards sunk to receive new deposits: such sinkings make certain catastrophes particularly remarkable.

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20. What is meant by "system of upheaval"? What is meant by creta'ceous sea? How are the several systems of upheaval classed?

The several systems of upheaval have been classed according to their direction, and the epochs in which they occurred. The following table exhibits the supposed epochs of the European upheavals.

1st, Upheaval, or system of Hundsruck, between the cambrian and silurian formations.
2d, " or system of Ballons, between the silurian and coal formations.
3d, " or system of the North of England, between the coal and penine formations.
4th, " or system of Hainault, between the penine and vosgean formations.
5th, " or system of the Rhine, between the vosgean and trias formations.
6th, " or system of Thuringerwald, between the trias and jura'ssic formations.
7th, " or system of Côte-d'Or, between the jura'ssic and greensand formations.
8th, " or system of Mont-Viso, between the two creta'ceous formations.
9th, " or system of the Pyrenees, between the upper chalk and Parisian limestone "
10th, " or system of Corsica, between the Parisian limestone and molasse formations.
11th, " or system of the Western Alps, bet. the molasse and subapennine formations.
12th, " or system of the principal Alps, bet. the subapennine and diluvium.
13th, " or system of Tenare, between the diluvium and perhaps some modern alluvions.

Since in Europe the different great chains of the same direction, which are found on the same line or on parallel lines, belong to the same epoch of upheaval, there is room to suppose, as nothing indicates limits to the phenomena which gave rise to them, that the same effects were continued far beyond the countries whose geological structure is known; hence it follows, that wherever we find parallelism in the chains, we should be led to believe also that the formations were contemporaneous. It is at least interesting to examine, under this point of view, the principal chains we are acquainted with.

The direction of the Pyrenees extends from the Alleghanies, in North America, to the peninsula of India, through the Carpathian mountains, a part of Caucasus, the mountains of Persia, from Erivan to the Persian Gulf, and through the Ghauts, which determine the position of the coast of Malabar. To the south of this line of direction several parallel ridges are also represented: those which go from Cape Ortegal, in Asturias, to Cape Creux, in Catalonia; the small chain of Granada, which ends in Cape de Gatte; the mountains which bound the desert of Sahara on the north, cutting the direction of Atlas; finally, the Apennines, the Julian Alps, the mountains of Croatia, of Romelia, and those of the Morea.

The system of Ballons, so near to that of the Pyrenees, appears to be represented also in the Alleghanies: it is to be observed on the coast of Brittany, and will no doubt be found in several of the groups just mentioned, when careful study enables us to distinguish it from the neighbouring system.

The direction of the Western Alps is remarked from the empire of Morocco to Nova Zembla, passing through the eastern coast of Spain, the south of France, and a great part of the peninsula of Scandinavia. It is recognised in the Cordillera of Brazil, from Cape St. Roque to Montevideo. Parallel to this direction the same system is seen in the kingdom of Tunis, in Sicily, the point of Italy, and in Asia Minor. All the shore of the ancient continent, from North Cape, in Lapland, to Cape Blanco, in Africa, is parallel to the direction of this system.

The principal Alps form part of a system of direction of great extent. From the chains of Spain and those of Atlas, in the northern part of Africa, we find parallel chains which extend to the China sea. On this line of direction we find, starting from Sicily and Italy, the chains of Olympus, in Greece, the Balkan, Taurus, the central chain of Caucasus, crowned by Elbrouz, between the Black and Caspian seas, the long series of mountains which extend through Persia and Cabool, comprehending Paropamisus, Hindoukoh, &c.; finally, Himalaya, the highest mountain in the world.

STATE OF EUROPE AT DIFFERENT EPOCHS OF FORMATION.

From what has been stated, we are led to infer that the surface of the globe, so often disturbed, must have presented great variations in the relative extent of land and sea, and successively passed through many different shapes, to reach its present state. But, even in Europe, the only part of the world in relation to which positive information has been obtained, it is very difficult to say what may have been its condition in the most ancient epochs. The reason of this is, that having for a long time confounded, under the name of transition formation, deposits of very different epochs, we are not now able to distinguish, with sufficient clearness throughout, the limits of different formations comprised in it. Nor do we know, and this is a great obstacle to tracing the continents of the ancient world, what parts were successively sunk at each catastrophe, and the extent of which we can only know from induction. It was not until after the appearance of the jura'ssic formation, the limits of which are clearly marked, that we are able to distinguish, with precision, the shape and extent of lands in the midst of seas in which these deposits were formed.

By the term *epoch of this or that formation*, we understand the period of time during which the formation was produced beneath the sea, around the upheaved deposits of the preceding epoch. For example, the *jura'ssic epoch* indicates the time during which the deposits of the Jura were formed in the seas where the upheaved deposits of the trias and all that preceded were traced. The term, *sea of such an epoch*, as *jura'ssic sea*, *creta'ceous sea*, &c., is often used in the same sense.

Silurian and Devonian epoch. At the time when the Silurian and Devonian systems were formed in the midst of seas, it is evident there were different portions of land in Europe uncovered, which resulted as much from the upheaval of the Hundsruck as from previous catastrophes: we have seen those of considerable extent which entirely escaped these deposits, and which, in consequence, must have been raised above the waters in which they were formed. In France, there was at least one island, of the Cambrian formation, near the gulf of St. Malo, on a part of Brittany and of Normandy; the great granitic plateau, which comprises Limousin, Auvergne, &c., where the upheaval of the Hundsruck was manifest by the direction of certain uptilted beds of gneiss, and by the anfractuosities in which the coal formation was subsequently deposited, must have been, at that time, above water, and, perhaps joined, at the south, to the ancient group which preceded the Pyrenees. The mountains of Maures also existed, and, perhaps, a part of the formations comprised between Toulon and Inspruck, in a south-west and north-east direction. Some parts of the centre of Vosges, and of the Black Forest, Eiffel, the Hundsruck, where the first upheaval is clearly indicated, and Ardennes, were necessarily above water, as well as the county of Nassau, the Hartz, all the centre of Germany, including Saxony, Bohemia, and Moravia. The same is true of Scandinavia, and a part of the British islands.

From this moment lands were covered with vegetation, in arborescent ferns, equisita'ceæ, &c., sufficiently abundant to form the masses of anthracite found in the Devonian formation. The seas were then inhabited by trilobites, orthoce'ratites, orthis, productus, different kinds of terebra'tula and several species of polypa'ria, of the same genus as those found in madreporic reefs, which, as well as the tree-ferns, indicate a climate analogous to that of the present tropics. All these circumstances show that heat was not, in that epoch, distributed over the surface of the globe as it now is. Without doubt, the increase of temperature, from the surface to the interior, was more rapid; all springs were warm; and, according to M. Elie de Beaumont, the fogs, which were the result, hindering radiation, in the absence of the sun, everywhere tempered the rigour of winter, and thereby augmented the mean temperature of the seasons.

Coal epoch. The upheaval of the Ballons, in bringing "to day" the Silurian and Devonian deposits, no doubt, increased the extent of lands, and more or less changed their configuration. Vegetation must have been prodigiously developed, at that time, and over vast surfaces; which is proved by the enormous mass of coal formed, and the manner in which the deposits are piled up. On one hand, the carboni'ferous limestone, and the different marine beds found in the midst of the sandstone of the coal formation itself, seem to indicate at first a deep sea, and perhaps afterwards an immense maritime marsh, which extended from Ardennes and the Hartz to the ancient mountains of the British islands. On the other hand, the numerous coal basins known to exist in the surface of France and central Germany, clearly show there were extensive lands on which marshes were found, here and there, in which were formed, just as peat-bogs are in our times, all the coal deposits we have discovered.

The ancient and uncovered formations, which constitute Brittany and the central plateau of France, clearly indicate high land, on which are found the lakes of Bayeux, Quimper, Laval, and Vouvant, placed perhaps in the anfractuosities caused by upheaval of the ballons; then those of Burgundy, Limousin, Auvergne, Forez, &c., situated on a direction parallel to the elevation of the Hundsruck. This land, the limits of which cannot be fixed, extended at least to a peninsula towards Strasburg.

To the east of this land, and perhaps united to it, there is another, which was evidently uncovered, because there is nothing of the penine formation deposited on it. The latter probably extended over the space now occupied by Inspruck, Milan, Briançon, Genes, Nice, Toulon, and to the island of Corsica. Towards Toulon are the marshes in which was formed the coal now found in that part of France.

Lands also evidently existed over the space occupied by Bohemia and Saxony, with several coal lakes on their surface; the coal deposits of Moravia and Galicia seem to show their extension towards those countries. There was one island, at least, between Cologne and Francfort, presenting in its southern part the great coal basin of the country of Treves, and uniting, at the north, with the ancient formation of the Hartz. Dry land also existed in the peninsula of Scandinavia, where nothing has been deposited since the Silurian formations; but it seems to have been sterile, and without swamps, for it affords no trace of coal.

We are entirely ignorant of what existed where the great cities now stand; but the absence of carboniferous limestone, out of Belgium and England, may lead us to think that a great portion of western Europe was then uncovered, and perhaps presented coal lakes which subsequent catastrophes have sunk beneath the seas.

A part of the land just mentioned has always remained uncovered to the present time, or has been even upheaved more and more by various subsequent catastrophes, as Brittany and the central plateau of France. At certain points, in fact, coal deposits have been pushed upwards to a great height, as the plateau of Santa Fé de Bogotá, and in the Cordillera of Huarochiri, where some are found from 2700 to 4600 yards above the sea. In other places, on the contrary, it is evident the formations have sunk, to be covered by more modern deposits, through which the coal is sought in the depth, as at Anzin, under the chalk, in Vosges, under the red sandstone, in Cevennes, under the jura'ssic limestone, &c., and, in general, on the borders of new formations exposed by subsequent catastrophes. Without doubt, there is some deeply-buried, and for ever lost to us, either under different sediments, or under water, as at Whitehaven, in England, where the mine extends more than a quarter of a league from the shore, and a hundred yards beneath the bottom of the sea.

The vegetation of this epoch, favoured, no doubt, by the insular form of the land, as it now is in all islands, consisted of lycopodia'ceæ, equisita'ceæ, ferns, &c., of arborescent species, the analogues of which are no longer found except within the tropics, with co'nifers resembling the araucaria. The mass of coal was formed of their debris, with cellular cryptoga'mia, which then grew under water, as now, in peat-marshes, and under a still more favourable temperature for their development.

The seas of this epoch had lost their tri'lobites; but contained, in great abundance, spi'rifers, productus, orthoceras of particular species, different ce'phalopods, analogous to the nautilus and argonaut, and various other shells. The encri'nites were so extensively multiplied that their debris constitute, almost of themselves, certain varieties of Flemish and Belgian marble. Sauröid fishes, of great size, and of especially vigorous organization, then existed; and the family of sharks, still feeble, presented cestra'cions and hybodons (*figs.* 52, 53, p. 45).

The fresh waters which fed the coal marshes contained, as it appears, few conchi'ferous mollusks; the debris, which are rarely found, resemble anodonta and unio. Fishes were numerous, in some localities; they belonged to the genera palioni'scus (*fig.* 56, p. 48), and ambly'pterus, living, without doubt, in the rivulets which meandered at the bottom of abrupt fractures of the ancient formation.

Penine epoch.—The disturbance caused by the upheaval of the north of England, appears to have exerted more influence on the surface, of the then uncovered lands, than on their extent and form. Only the bottom of the sea, where the coal-beds of England and Belgium were formed, was elevated in part to escape, like all France, to the penine formation. On the other hand, a small corner of the south-west of Vosges must have sunk under water, to receive the red sandstones which there cover the coal formation. Further, in Mansfield the presence of the penine formation, which is there developed on a great scale with its shell-limestones, demonstrate the submersion of the country beneath sea-water. It was also beneath the sea, in the county of York, that *magnesian limestone* was deposited, which there represents the whole formation of this epoch.

Very little is known of the terrestrial flora of that time, for we find little, save the algæ in the bitu'minous schists of Mansfield, and some sili'cified trunks of co'nifers in the sandstone. Deposits of coal suddenly ceased to form, and it seems from that time there were neither ponds nor rivulets on the lands; nevertheless, there were still divers fishes of the genus palioni'scus, which lived perhaps as well in salt as in fresh water. The land was for the first time inhabited by saurian reptiles resembling the iguana and monitor, the remains of which are found in the cuprous schists. The seas beneath which all these deposits were formed, contained the same genera, often the same species of mollusks and radiata as those in which the carboni'ferous deposits were formed.

Vosgean epoch.—The system of Hainault, in dislocating the coal formation and ridging the surface of the land, had little influence on its form. In the Vosges some of the points where the red sandstone was deposited were elevated, around Sáint-Dié, Schelestadt, Montbelliard, and escaped the succeeding formations; while all the rest of the chain, which had escaped the deposits of the red sandstone, and consequently found elevated at this epoch, must have been sunk now to receive the vosgean sandstone: the same has taken place in the Black Forest.

Such was the state of things in this modification, that animals could not have lived on this part of the earth, and that plants, if any then existed on the surrounding soil, could not have been carried under the waters except in very small numbers.

The *trias epoch.*—After the system of the Rhine, subsequent to which the vosgean sandstone was upheaved, Vosges and the Black Forest underwent a little change in shape; but other lands in Europe have undergone scarcely any modification. We observe only a secondary elevation of the central plateau of France by the porphyroid granites of Lozere, by the hills which edge the coal formation from Fins to Mauriac. Subsidences occurred, on the other hand, in Bourbonnais and Rouergue, as well as in lands between Toulon and Nice. Vegetation then underwent great modifications; the ferns and equisita'ceæ of great height had considerably diminished, and coni'fers, on the contrary, became more numerous: plants analogous to za'mia, and perhaps to cy'cas (*figs.* 305, 306), then formed an important part of the flora of Europe, being a prelude to the immense development they took in the succeeding epoch.

Fig. 305.—*Za'mia pungens.*

Fig. 306.—*Cy'cas revoluta.*

In this epoch new saurians appeared, and traces of birds, which had not appeared in preceding epochs, are recognised. It was at this period also that those creatures existed, whatever they were, whose tracks are found imprinted on bunter sandstein, freshly lifted above water. Mr. Owen, who considers them enormous batrachians, supposes them to have been of the form represented (*fig.* 307).

The *jura'ssic epoch.*—At the time of the elevation of Thuringerwald the tria'ssic formation, which had just been deposited beneath the sea, was upheaved at different points; some patches of bunter sandstein were added around the central plateau of France, between Moulins and La Châtre, between Brives and Tulle, in the environs of Rodez, of Saint-Affrique and of Lodeve.

Fig. 307.—*Labyrinthodon pachygnatus.* (Owen.)

The island of Var was increased from these sandstones and conchylian limestone; the Vosges and Black Forest were also considerably augmented, the one to the west, in Lorraine, the other to the east, extending into Germany, and uniting various islands which had been separate till then. The same was the case with different islets which already marked the place of the British islands, and were then united to a continuous land by tria'ssic deposits upheaved between them, and with them. But at the same time that the new lands were raised above water, there were great subsidences in those which previously existed. The land which extended from Cherbourg to Perpignan, was then divided towards Poictiers, forming a strait, now occupied by the jura'ssic deposits; it was variously divided on its borders, and almost cut again towards Rodez. That which extended from Nice towards Inspruck was entirely sunk, to receive the new deposit which covers it. If perchance there existed, at the period of the coal, some portions of land where Paris, London, &c., now are, everything leads to the belief that they then disappeared, for the jura'ssic formation appears to be prolonged everywhere beneath the soil which serves them as a base.

All the data on the state of western Europe, at the period of which we speak, are furnished by the presence and disposition of the jura'ssic deposits. Developed on a vast scale, and upheaved later from the bosom of the waters, they clearly show what was then the configuration of the lands around which they were formed under the sea.

The ocean of the jura'ssic epoch also had its peculiar characters. It was inhabited by saurians, eminently swimmers, the ich'thyosau'rus and plei'siosau'rus, whose paws, in form of paddles, remind us of those of the chelonians of the present day; these voracious animals, all aquatic, took the place of the sauroid fishes of the carboni'ferous group, which had now disappeared. At the same period lived those flying saurians, called pteroda'ctyls, which peopled the air and completed the series of singular creatures of an ancient creation, now entirely annihilated, the exterior forms of which Dr. Buckland has attempted to paint from the skeleton (*fig.* 308).

These seas had lost the productus, and spirifers had almost dis-

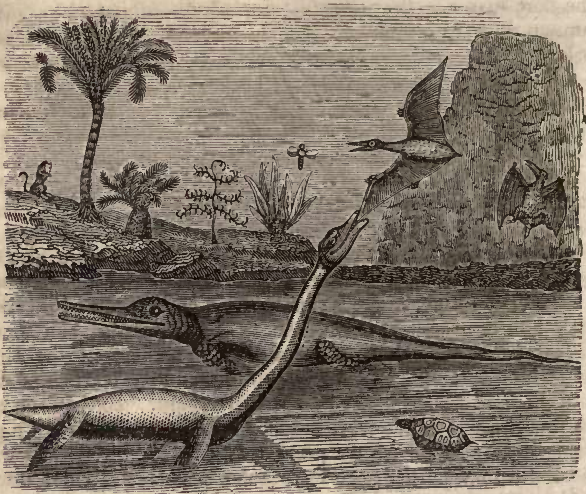

Fig. 308.—*Restoration of the saurians of the jura'ssic epoch.*

appeared. The numerous terebra'tulæ, which lived in this epoch, belonged to species entirely different from those seen in the preceding seas; but there was found a great number of mollusks with chambered shells, in general called ammonites, the race of which, as yet little developed, had begun to appear in the seas of the trias; there existed bele'mnites, the remains of which, until then unknown, are numerous from the lias to the chalk: and the *gry'phea arcua'ta* multiplied there for a moment, to disappear afterwards, when the lias was formed, and to give place to other species of the same genus.

As at present, coral reefs were formed in those seas, remains of which are found, showing a mean temperature, analogous to that of our intertropic seas.

On the land, fresh-water lakes without doubt supported palu'dinæ, and fresh-water streams carried he'lices, remains of which are now found in the Portland group.

There must have existed also, on land, several species of insects, which served to feed the pteroda'ctyls, the remains of which seem to show they were coleoptera and neuroptera, resembling the buprestes and libe'llulæ. Small marsupial mammals, analogous to opossums, were met there, a skeleton of which was found in the beds of Stonesfield. But these creatures seem to have been in small numbers, if we judge from the few remains that have been as yet found, and no one of the great animals which characterize the parisian epoch has been found with them.

The flora was not the same as that which furnished so many remains to the coal formation; the lycopodia'ceæ, and the gigantic ferns had disappeared; and it seems that many new species had been created after the penine and tria'ssic epochs. Then the cyca'deæ and co'nifers considerably exceeded all other families; and probably some palms were already in existence, the fruits of which are found in the lias. Also the carbona'ceous combustible, formed in this epoch, is very different from that of the great coal formation. They were at the same time much less abundant, which indicates a great difference in the extent of lands.

Creta'ceous epoch. After the system of upheaval of Côte-d'Or, which elevated a part of the jura'ssic deposits above the sea, the form and disposition of continents were considerably changed. The inferior limits of the chalk mark the shape of lands which then existed, and determine the extent of the seas of the epoch.

The three islands of the preceding epoch were now united, but without any change of shape. Brussels, which was inland, was now found on the coast; Arras, Dunkirk, Maëstricht, Wesel, Breslaw, and Vienna, were sunk under water. A lake was formed between Dresden, Brunna, and Prague; a strait was found in the place of Perpignan and Carcasonne; and, what existed previously to the Pyrenees, was in part submerged.

By compensation, the Vosges, washed by the sea in preceding ages, was then found in the middle of the continent which joined the central island of France. The space of sea which separated them was filled up. Langres, Nevers, Lyons, Toulouse, and Oxford, were on terra firma, and an isthmus was formed about Poictiers, to join the great island that existed to the west. A shore extended from the environs of Craco'via, to about Perpignan, by Ratisbonne, the position of which was not changed, and to Zurich and Lyons. An immense gulf was formed between Brussels and Oxford, extending to Poictiers.

Between Salzbourg and Avignon, a new island was formed, which marked the future site of the Alps: Briançon, Turin, Trente, and Inspruck, might have been already placed there; but Switzerland was then a channel which separated this island from terra firma. The island of Toulon was at the time limited, and some small islands marked the environs of Marseilles.

Little change, however, had taken place in living creatures. At the same time divers species of ferns and cyca'deæ vegetated on the soil; co'nifers, especially, became more and more abundant, and gave origin to masses of lignite found at the base of the chalky formations; but there were few terrestrial mammals, for no remains of them are found in the chalk, although they were met with in jura'ssic deposits. There existed, however, divers ceta'ceæ, such as lamantins and dolphins, some of which had already appeared in the jura'ssic seas. Reptiles were, among the animals capable of living on the earth, still the most elevated creatures of the creation. Aquatic and terrestrial species were very numerous; among them were the iguanodon, the megalosau'rus, and divers crocodiles. Fluviatile tortoises, fishes, and mollusks of fresh water, lived on the borders of lakes, or in their waters. The seas fed ba'culites and turrilites, of whose anterior existence there is no trace, and which, towards the end of the epoch, disappeared at the same time with all mollusks having peculiar chambered shells. Here and there true sharks existed, and have been continued to the present time, although their dimensions are considerably diminished.

Parisian epoch. The upheaval of Mount Viso, and later, that which gave birth to the Pyrenees, to the Apennines, and all the parallel chains we have cited, prodigiously changed the geographical constitution previously established. The last, especially, produced one of the greatest convulsions Europe has experienced: everything was shaken by it, and the greatest part of what was then under water, was elevated above it, to form an immense continent. This proves the little extension of the parisian sediments then formed, and which are found concentrated, one part in Belgium, Artois, Picardy, Isle of France, Normandy, and the opposite coasts of England; and the other, in the environs of Bordeaux: very few traces are found elsewhere. Hence it follows, that the seas of this formation did not penetrate far into this continent, although they covered the two capitals of the world; of the vast ocean of preceding ages there only remained a part of the gulf already limited, about Cambridge, Oxford, Exeter, Cherbourg, Angers and Poictiers, which was then narrowed in many places, and widened elsewhere at the expense of the ancient peninsula of Brussels; it probably communicated with some remains of the North Sea. In the middle were two islands of chalk, the Wealds, of England, and the country of Bray, in France. Another portion of the gulf also remained between Bordeaux and Dax.

The fauna of the land, at the parisian epoch, was very different from what it had been in preceding epochs. The gigantic saurians had disappeared, but there remained great fresh-water crocodiles, marine and lacu'strine chelonians, and the earth was inhabited by mammals. The last were then pach'yderms, analogous to tapirs, as the anoplothe'rium and paleothe'rium, which must have been nearly of the form represented (*fig.* 309); they lived at the same time with some carni'vora of the genus dog, &c. Belemnites, and all similarly chambered shells, had disappeared from the seas; the nautilus only remained, and it lived with the cere'thium giga'nteum (*fig.* 148, p. 80), and a multitude of species of mollusk, more or less resembling those of existing seas.

At this age of our planet, the flora of Europe was still modified; the cyca'deæ had disappeared, and the co'nifers, presenting still new species, to which were joined the dicoty'ledons, were found,

Fig. 309.—*Fauna of the epoch of the parisian formation.*

a Paleothe′rium magnum.
b Paleothe′rium minus.
c Anoplothe′rium commune.
d Crocodile.

with palms, to the centre of Europe. The last, which are not now found closer than Africa, at the nearest point, evidently indicates a mean temperature, higher than that we now enjoy, which must have been about 72°, the present mean temperature of lower Egypt. This circumstance may be attributed to the fact that the increase of internal heat was greater than at present, and that the fogs, by diminishing radiation, rendered the winters less rigorous.

Water-courses necessarily must have existed on the continent, and may account for deposits of lignite, and the remains of fresh-water mollusks, being found in place in the midst of marine deposits. We are especially led to suppose that one of these water-courses, emptying about Laon and carrying lacu′strine deposits from Soissonais, and another, somewhere between Exeter and Oxford, formed the deposits of the Isle of Wight, at the south-west of the Wealds. Around Paris, some parts of the sea must have been separated from the rest, at a certain time, and converted into a fresh-water lake in which the gypsum was formed.

Epoch of the molasse.—It was after the system of Corsica that the molasse was formed, and, in such a manner, that it is generally deposited where the Parisian limestone is entirely wanting. It follows that lands which were then elevated above the waters must have necessarily sunk, often to great depths, to receive this new formation, which is sometimes extremely thick; consequently, great modifications of the continent of the preceding epoch again took place. Partial subsidences must have occurred in many parts of Touraine, of Guienne, of Gascony, Languedoc, Provence, Dauphiny, and also in all Switzerland, &c.; lakes were formed, often extensive, sometimes isolated, and sometimes communicating with the sea; and it is this which indicates the contemporaneous deposits, some of which are fluviatile, and others marine. In opposition, more or less considerable upheavals took place at the same time in many parts of the northern gulf, in Belgium, in Picardy, in the isle of France, and all the coast of England. The marine limestone, laid bare, escaped in all this extent the succeeding deposits, and the sites of London and Paris were brought to light, although surrounded by water in which the molasse was deposited; it was the same in the gulf of Bordeaux, where all the northern part of the Parisian formation was upheaved, and escaped the deposit of the molasse, which is found in all the rest of the present basin which was from that time submerged.

This epoch was accompanied by a new change in the creatures which lived on the surface of the soil; and from that moment, besides some new species of paleothe'rium, *mastodons*, and the *dinothe'rium giga'nteum*, appeared in Europe (the last nearly of the form represented, *fig.* 310), as well as the rhinoceros, hippopo'tamus, monkeys, and many rodents, as castors, squirrels, &c. The flora was principally composed of coni'fers, with dicoty'ledons, which, however, had not attained, in all probability, the development they acquired in the succeeding epoch. There still existed palms, the remains of which are found in deposits of lignite, and particularly in those of Liblar, near Cologne, as well as in the plaster-works of Aix.

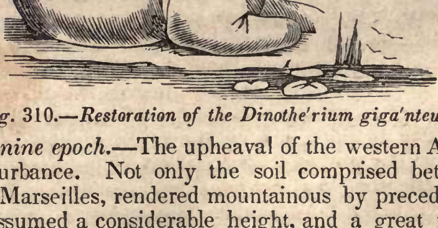

Fig. 310.—*Restoration of the Dinothe'rium giga'nteum.*

Subapennine epoch.—The upheaval of the western Alps caused a new disturbance. Not only the soil comprised between Constance and Marseilles, rendered mountainous by preceding events, suddenly assumed a considerable height, and a great part of the relief it now presents, but still the movement extended over all Europe. The greatest part of the Anglo-French gulf was filled by an elevation, which brought "to day" all that is referred to the molasse. It was the same in Guienne, in Languedoc, in Provence, in Piedmont and Switzerland ; and the form of the seas was once again changed. But, in time, great lakes were formed in the interior of the lands : one, from Dijon to near the Isere ; another, in the southern part of Alsace ; and a third, in Provence, from Sisteron to the borders of the Durance.

At that time all the carni′vora appeared of the genera *ursus, hyena, felis, canis, &c.*, which inhabited caverns ; their remains are not found in the Parisian formation ; their species disappeared, not only from the European continent, but from the face of the globe, in the next epoch. There also appeared several new rodents, horses, ruminants, and probably the gigantic edentate animal, with slow and heavy gait, the megathe′rium (*fig.* **178**, *p.* 92), whose head and whole aspect were similar to the sloths, although its size was that of the largest rhinoceros, and its body must have been covered by a bony cuirass like the armadillo.

Epoch of diluvium. At this time Europe took its present form, and its relief was definitely fixed. The upheaval of the principal Alps, in forming all the chains which extend to Austria, in elevating likewise some portions of the western Alps, also raised up the soil in a great part of Europe, and especially caused the division of the waters between the ocean and the Mediterranean. The effects produced show that enormous currents of water were established in all directions, which furrowed all the deposits then uncovered ; but the volume of waters furnished by lakes, previously formed in the interior of lands, whose barriers were no doubt broken in the new catastrophe of upheaval, was in relation to the vastness of the result produced ; it must have been prodigiously increased by some circumstances, attributable, perhaps, to the sudden melting of the snows, and glaciers then accumulated on the western Alps. The currents which were formed, in furrowing the surface of lands, carried their debris in all directions ; hence the alluvions of the valley of the Rhone, of Crau, of the plains of Lombardy, those of Bavaria, the valley of the Rhine, &c. ; hence the last configuration of the valleys, the denudations, and the dislocations, seen in so many different places. It is from the upheaval of this part of the Alps, that the separation of France and England appears to date, as well as that of Ireland, by ruptures effected between Brest and Cape Lizard, between Caernarvon and Dublin. It was then that the Mediterranean took its present limits, in consequence of the subsidence of formations which extended to the south of Marseilles, at the epoch of the parisian sea. The gulf of Bothnia was perhaps produced in this epoch, since the shell deposits found on some points of the coast are all referred to the sub-Apennine formations.

But change of configuration in the soil was not the only consequence of the appearance of the principal Alps ; this catastrophe, extending over a great part of the world, from the height of Spain to the centre of Asia, was marked by the sudden cooling of European countries to their present temperature. From that time palms ceased to grow in Europe, and dicotyle'donous plants were prodigiously increased. The rhinoceros, elephants, and panthers, which had just appeared in that part of the world, became entirely extinct there; and, if the cavern bear is represented in our present bear, its size is considerably diminished. The fauna of that part of the world was again completely changed, and replaced by that we now see. Besides, it was at this moment, probably, that man appeared on the earth: in fact, on one hand, there are no human remains in what has been too lightly named dilu'vium, for the skeletons of Guadaloupe are of the modern epoch, and cannot be reckoned; and, on the other, the animals which then began are precisely those with which man has always lived, since historic time.

Modern epoch. From the epoch of the principal Alps, no general geological disturbance has taken place in Europe; and some volcanic eruptions and upheavals, produced by earthquakes, are the only effects that have been manifest. Such, also, appears to have been the action of the 13th upheaval, which was revealed in the Morea, in Naples, Sicily, and in some parts of Provence, and which, perhaps, also determined the eruption of the modern volcanoes of Auvergne and Vivarais, through ancient fissures, the beautiful preservation of which attests their posteriority to the great denudations which followed the event of the principal Alps.

But if scarcely anything occurred in Europe after this great event, perhaps it was not the same in other parts of the world. We may suspect that a great part of the immense mountain range which extends through America, and traverses Asia from Kamtschatka to the Birman empire, is the result of a more recent catastrophe; this direction, at least, offers the most extended, the most decided, and, so to speak, the least effaced feature of the exterior configuration of the earth. It is there we see the greatest number of active volcanoes, and consequently the most extensive and best preserved communication between the interior and exterior of the globe, and perhaps, also, the greatest mass of volcanic products known.

Deluge. The successive appearance of great mountain chains has produced great disturbances in different parts of the globe. But it is evident that these catastrophes, at least those of great energy, and those which extended over large spaces, as the upheavals of the Alps, Pyrenees, &c., must have manifested their action over all the rest of the earth in secondary phenomena of more or less importance. If a simple earthquake is enough to produce a violent agitation of the sea, a sudden irruption of waters on continents, these terrible revolutions could not have failed to cause more or less impetuous movements in the ocean, and temporary derangement of level of more or less extent. Hence, without doubt, the extraordinary inundations, which, at each catastrophe, have ravaged the surface of existing lands, and produced, as in our day, various denudations, or superficial alluvions, of more or less extent.

Now, since, without counting all that escaped the investigations of science, we clearly see, in Europe, a series of successive movements of the soil, which have modified the whole continent, and many even a whole hemisphere, there is nothing absurd in admitting that what took place at so many different times, from the most ancient to the most modern epochs of formation, may have happened once, somewhere after the appearance of man on the earth. Consequently there is nothing contrary to reason in the belief of a great irruption of water over the lands, a general inundation, a deluge, in fact, which we find described not only in the Bible, but deeply impressed in the traditions of all people, and at an almost uniform date. Thus, in recognising in the recital of Moses, the extraordinary circumstances which bear witness to the supernatural intervention of the divine will, we see, on one hand, the material possibility of the fact transmitted to us, and, on the other, we find even the secret of the means brought into play; that is, the upheavals, the subsidences, the consequent oscillations of the water, which from that time became efficient causes of the great chastisement then inflicted on the human race. If, because the known results it has produced are feeble, we cannot too carefully seek the cause of this great phenomenon, in the last of the upheavals to this time classed, which dislocated the deposits in which traces of human industry have already been found: perhaps it may be discovered in that which caused the rise of the Andes in America, and the volcanic chain of central Asia, which, with a colossal development, also present striking characters of relative novelty.

As to the future of our planet, everything leads to a belief that the state of tranquillity we now enjoy is but temporary, like all the intervals of crises during which the different sedimentary deposits were formed. In fact, in the series of perturbations which, through all time, have formed part of the mechanism of nature, we perceive no law authorising us to conceive a termination to the succession of these phenomena: to accidents of little importance succeed, indistinctly, either crises of the same order, or frightful catastrophes; long periods of tranquillity suddenly succeed terrible convulsions. To the small upheaval of mount Viso, for example, succeeded the great catastrophe of the Pyrenees; to this the small accidents of the system of Corsica, which were followed by the great event of the Alps. The long period of the jurassic formation was disturbed by the upheaval of Côte-d'Or, as the deposit of the vosgean sandstone was almost immediately arrested by the system of the Rhine.

All was irregular in those revolutions of which we have acquired a knowledge; no fact presents itself suggesting the idea of a gradual diminution in the intensity of subterranean actions, and leading us to think the earth has lost the property of being successively broken and ridged in all directions. Nothing, therefore, can assure us that the period of calm in which we have lived for upwards of 5000 years (the period of the deluge), will not be disturbed, in its turn, unexpectedly, by the appearance of some new system of mountains; the effect of a new dislocation of the soil, the foundations of which earthquakes show not to be unshakable. Hence it follows that the idea of an end, or a renewal of things here below, as widely spread as the great inundation which has passed, is also in the order of the laws which govern the universe.

Geogeny. The history of the various systems which have been imagined to explain the origin of the universe, and of the earth in particular, might perhaps afford some attraction to the curious; but, besides occupying a great deal of time in pure romance, it is, perhaps, better to forget the many mental vagaries we should be forced to expose. A single geogeny is worthy of our attention; it is that which is related in the Book of Moses, and which, after a lapse of more than 3000 years, still presents, on one hand, the clearest application to the best established theories, and, on the other, the most succinct account of great geological facts.

What is more rational, in fact, and more in conformity with even our most precise knowledge, when we think of bringing order into the general confusion of things, than to create the vehicle by means of which the phenomena of light, of heat, &c., may be manifest, and infuse life everywhere,—than to collect the scattered elements into groups separate from each other,—than to establish here and there centres of attraction around which all may gravitate according to an immutable law? Nevertheless, this is what we find, with fewer details, no doubt, than we could give by means of our acquired knowledge, in brief and common language intelligible to all, in the first verses of Genesis, which thus state three successive and distinct facts. We there find, indeed, in outline: *Deus fecit* LUCEM (the fluid of light, of heat, &c.), FIRMAMENTUM (space, and all the masses scattered through it), SOLEM ET STELLAS (the centres of attraction), &c.

As to the organic creation, it is divided into four successive, and also rational epochs. The first established *vegetative life*, or life of nutrition, which is manifested not only in plants, but also in the inferior animals, in which we find scarcely any other phenomena than those of nutrition, growth, &c. Afterwards came the *life of relation* or sensibility, instinct, intelligence, and will, successively added, in different proportions, to the phenomena of simple existence.

This new life first takes a certain development in fishes (including reptiles, no doubt), then birds, which, together, constitute the second epoch of creation. It acquired a new extension in mammals, which appeared at a third epoch; and finally reached its highest degree in man, with whom terminated the work of the OMNIPOTENT, receiving a soul in the image of God, to distinguish him from all other creatures.

This is without doubt a wonderful example of successive organic combinations; but it is also precisely the order in which all the remains buried in different ages successively present themselves. Those we meet in deposits we regard as the most ancient, are the calcareous remains of certain polypa'ria, mussels, sometimes even the shell of some acephalous mollusks, the trilobite crusta'ceans, and the remains of plants, the accumulation of which formed the anthracite of the devonian formations. The abundance, the extent, the thickness of these combustible beds announce the great luxuriance of vegetation, which leads us to believe that plants existed for a long time, and that perhaps their first debris have disappeared in the profound metamorphisms which modified the deposits in which they might have been.

Fishes are not met with prior to the devonian formations, and it is only in the coal deposits they present a strength of organization, which is lost in the succeeding deposits, and which is not known even now on the globe. Reptiles have left their remains in the new red sandstone, or penine formations which followed; and the birds, the creation of which Genesis also places in the same epoch, have left the imprints of their feet on the sandstones.

Mammals did not appear until long afterwards; the traces of those found in the great o'olite belonged to the least perfect orders: it is only in the tertiary strata that their debris of every species are found in abundance.

Human remains are not found in any of the beds which have been upheaved from the bosom of the waters, and now forming parts of our continents; it therefore follows that this privileged being of the general creation did not appear on the globe until after the animals whose fossil debris have been found; he dates from an epoch comparatively very recent, which is placed after the upheaval of the principal Alps; his formation would consequently go back about 6800 years, according to admitted chronology. It is in deposits formed under the waters since this catastrophe that the bones of man should be found, and they will not appear from that time in the series of geological beds until new revolutions shall have transformed the sediments still found under water into dry land.

It is clear from this outline that the brief statement of sacred history is entirely in conformity with geological generalities. Observation alone enables us to add a great number of details, useless no doubt to most men, but interesting at least to the small number of those who dedicate themselves to study, if indeed they are not destined perhaps to enlighten their belief.

The assemblage of data we now possess leads us to perceive that each of the particular creations briefly indicated in Genesis, with the exception of that of man, did not take place in a single moment; that, on the contrary, it was successively, in a considerable space of time, and in proportion as the terrestrial globe itself was fashioned. Indeed, if the vascular cryptoga'mia appeared nearly from the commencement of things, the gy'mnospe'rmous phaneroga'mia did not appear until about the epoch of the coal formation, and did not exist in abundance until long afterwards; it is the same with the monocoty'ledons, the remains of which are at first few and indistinct, and not clearly seen until after the chalk; the dicoty'ledons did not appear until still later, in the midst of the tertiary formations. In all this interval of time, the species successively changed, and those which were created, have in turn also entirely disappeared, one after the other, to give place to the new.

Fishes, reptiles and mollusks, respectively present us with the same phenomena, and still more clearly show the successive extinctions of different races, and the appearance of many others. The sauroïd fishes, which lived at the time that coal was formed in Belgium and England, disappeared for ever in the new order of things, established in the penine formation. True sharks did not exist then, but appeared long after in the creta'ceous sea. Gigantic saurians, with paws in form of paddles, and flying saurians, existed in abundance in the jura'ssic epoch, but disappeared in the following period, and were replaced in it by enormous terrestrial saurians, of which there are no previous traces, and, after long having inhabited the earth by themselves, the latter were also successively lost, leaving only crocodiles after them, still very different from those of the present day. The same is true of the tri'lobites, productus, and spi'rifers, which, after having multiplied for some time, disappeared one after the other. The ammonites and belemnites succeeded them, and are found in abundance in the jura'ssic sea; then they became completely extinct, after having successively changed species, at the moment in which the chalk formation ceased to take place. All the mollusks that followed after, more and more resemble those now existing, of which there was then no trace.

Mammals present themselves under similar circumstances; the different orders and different species appeared only in succession. The first were only the feeble marsupials. Long afterwards came the pachyderms, analogous to the tapir, the first species of which were soon annihilated. Other species of the same genus succeeded them, and these were found associated with new animals, the *ma'stodon* and *dinothe'rium*, but they soon afterwards became extinct for ever. Still later came the *elephants;* they only appeared with the *carni'vora*, the *rode'ntia*, &c., the species of which were still only the prelude to those which appeared at the same time with man.

All these successive changes in the series of creatures coincide with the great disturbances of the surface of the globe. It was at the instant of the catastrophes, produced by movements of the soil, that families, genera, species of organic bodies which had until then existed, disappeared. In times of the succeeding calm, on the contrary, the new organization was developed in harmony with the new atmospheric circumstances, and new dispositions of the isothermal lines, &c.

These details, which observation enables us to add to the recital of Genesis, are in general harmony with the facts, there found briefly enunciated, and of which they are but the development; the only difficulty presenting itself is that of the application of the word *day*, which, happily, even in the eyes of legitimate judges, from Saint Augustine down, does not seem to possess the value which people have naturally attributed to it. This expression seems in fact to have been adopted, only as an indication of relative epochs, as the means of making understood and retaining the order and succession of things which were at once revealed. It is clear, indeed, that minute details categorically established by figures, which would satisfy the curiosity of a small number of men, would not be either received or comprehended by the vulgar, who, nevertheless, are entitled to this important instruction. We ourselves often resort to ways still more crooked to make ourselves better understood by all: it is in this way, for example, we speak of the rising and setting of the sun, to describe the arrival of this luminary to the meridian, to the solstice, &c., although we know very well that we must attribute these phenomena to the inverse movements of the earth.

According to geological observations, this common expression, *days*, ought to signify *epochs*, which embrace long periods of time, each being relative to a certain system of creation in which there were different formations of creatures, as well as successive extinctions of those previously existing. Each period began at a particular date, clearly determined, and marked by a catastrophe which overturned the order of things anteriorly established on the earth; it was extended, for a longer or shorter time, sometimes through succeeding epochs, and often up to the appearance of man himself. According to the conjectures of the scientific, an immense time elapsed between the formation of the first sediment and the last, without counting the period required for the consolidation and first cooling of masses of planetary matter. It was in long series of ages, which are but as instants in eternity, that the earth was fashioned, as we now behold it, by every kind of movement in the soil, by sedimentary deposits of different kinds, and finally prepared as the sojourning place of man, for whom God has disposed everything.

GEOLOGY.

GLOSSARY.

The following abbreviations are used:

Fr. French
fr. fr. from the French
Ger. German
fr. ger. from the German
Gr. Greek
fr. gr. from the Greek
It. Italian
fr. it. from the Italian
Lat. Latin
fr. lat. from the Latin
Sp. Spanish
fr. sp. from the Spanish
Plur. Plural.

ABNO′RMAL — fr. lat. *ab*, from, *norma*, rule. Not conformable to rule.

ABNO′RMOUS—Out of rule; misshapen.

ACEPH′ALOUS — (a-kef′al-us.) fr. gr. *a*, without, *kephale*, head. Without a head; headless.

ACTIN′OLITE and **ACTY′NOLITE**—fr. gr. *aktin*, a ray; *lithos*, a stone. A variety of hornblende which usually occurs in fascicular crystals. There are three varieties of this mineral; crystallized, asbestous, and glassy.

ACULEA′TUS—Lat. Aculeate; having a sharp point. (p. 49.)

ACUMINA′TA — Lat. Acuminate; pointed; peaked. (p. 59.)

ACU′TA—Lat. Acute; sharp pointed.

ACUTICO′STA—Lat. (*acutus*, pointed, and *costa*, rib.) Having pointed ribs or sides.

A′CUTILO′BA—Lat. (*acutus*, pointed; *loba*, a lobe.) Having sharp or pointed lobes. (*Fig.* 169, p. 88.)

ADU′LT—Fr. Lat. *adolesco*, I grow. Full grown.

A′GATE — fr. gr. *agathos*, good, precious. An aggregate of certain siliceous minerals, chiefly chalcedony, variously coloured. *Moss agate* or *Mocha stone* is a chalcedony containing within, moss-like delineations of a yellowish-brown or green colour.

AGGLO′MERATE — fr. lat. *agglomero*, I wind up. To gather together.

AGGLOMERA′TION—A mass made up of parts gathered together.

AGGLUTINATED — fr. lat. *ad* to, *gluten*, glue. United together; adhering.

ALÆFO′RMIS—Lat. (*ala*, wing, *forma*, shape). Wing-shaped. (*Fig.* 119.)

ALBITE — fr. lat. *albus*, white. A mineral. *See* p. 120.

ALBITIC—Of the nature of albite.

AL′GÆ—Lat. plur. of *alga*. Seaweed. Systematic name of a family of plants.

ALLU′VIAL—Of the nature of alluvium.

ALLU′VION, **ALLU′VIUM**, } fr. lat. *alluo*, I wash upon. Gravel, sand, mud, and other transported matter washed down by rivers and floods upon land not permanently submerged beneath water. A deposit formed from transported matter. (p. 94.)

ALPINE—Belonging or relating to the Alps.

ALU′MINA — fr. lat. *alumen*, alum.

Pure argil; the basis of alum; one of the earths.

Alu′minous—Of the nature of alu′mina.

Alveola′tus—Lat. Alve′olate. Having the surface covered with numerous depressions, comparable to the alve′oli or sockets of the teeth.

Ambly′pterus — fr. gr. *amblus*, obtuse, *pteron*, wing. A fossil fish.

Ambula′cra—Lat. plur. of ambulacrum. The narrow longitudinal portions of the sea-urchin (*Echinus*), which are perforated with a number of small orifices, giving passage to tentacular suckers, and alternate with the broad tuberculate spine-bearing portions. (p. 54.)

Ambula′crum—Lat. An alley.

Ammo′nia—Lat. Relating to Ammon, a name of Jupiter. Specific name of a fossil shell. (p. 67.)

Ammo′nis—Lat. Genitive case of Ammon, a name of Jupiter.

Am′monite — fr. lat. *Ammon*. (p. 51.)

Amo′rphous — fr. gr. *a*, without, *morphe*, form. Shapeless.

Am′phibole — fr. gr. *amphibolos*, equivocal. (p. 121.)

Ample′xus — fr. lat. *amplecto*, I embrace. Generic name of a fossil.

Ampulla′ria — fr. lat. *ampulla*, a round, swelled out bottle. Name of a genus of snails.

Amy′gdaloid — fr. gr. *amugdalon*, an almond, *eidos*, form. Almond-shaped. Applied to certain rocks in which other minerals are occasionally imbedded like almonds in a cake. A particular form of volcanic rock.

Ana′logy — fr. gr. *ana*, between; *logos*, reason. Resemblance or relation things bear to each other, although not exactly alike in all respects.

Ana′logous—Having analogy, or resembling.

An′alogue—A substance or article having ana′logy to others may be called the an′alogue of those things with which its properties or points of resemblance are comparable.

Anan′chytes—A genus of fossil sea-urchins. p. 62.

Andalu′site—A mineral first observed in Andalusia in Spain. It is very hard and infusible, and consists chiefly of alu′mina and si′lica.

Anfractuo′sity—Fr. Lat. *anfractus*, the bending or winding of a way. An irregular hollow or groove.

Angle of dip. *See* p. 185.

An′hydrous — fr. gr. *a*, without, *udor*, water. Without water. Applied to salts and certain acids when deprived of water.

An′nular — fr. lat. *annulus*, ring. Shaped like a ring.

Annula′ria — fr. lat. *annulus*, ring. Generic name of a fossil plant. (p. 41.)

Anodo′nta — fr. gr. *a*, without; *odous* (genitive, *odoutos*), tooth. Systematic name of a kind of mussel. p. 149.

Anodo′ntæ—Plur. of Anodonta.

Anoplothe′rium — fr. gr. *a*, without, *oplon*, arm, or *anoplos*, unarmed; and *therion*, beast. P. 82, fig. 156.

Anticli′nal axis,
Anticli′nal line, } fr. gr. *anti*, against; *klinein*, to incline. An imaginary line towards which strata, dipping in opposite directions, rise. p. 160.

Antiqua′tus—Lat. Antiquated, out of date, abolished.

A′nthracite—fr. gr. *anthrax*, charcoal. Mineral charcoal. A kind of stone-coal difficult to inflame.

A′nthraciti′ferous — fr. lat. *anthracite*, and the Lat. *fero*, I bear. Containing or affording anthracite.

Apio′crinites — fr. gr. *apion*. a pear; *krinon*, lily. The pear encrinite (p. 149). A sub-genus of fossil encri′nites, in which the stem is rounded and dilated, at its upper part, into a pyriform shape.

Aqua'tic—fr. lat. *aqua*, water. Relating or belonging to water.

Aquili'na—Lat. Of or like an eagle; rapacious.

Arauca'ria—(From *Arauco*, a district of Chile.) Fir-trees with very rigid branches, having leaves like scales either small and sharp-pointed, or stiff, spreading, and lanceolate. The Norfolk island pine is one of this genus.

Arbore'scent—fr. lat. *arbor*, a tree. Branching like a tree.

Arcua'ta—Lat. Arched; bent like a bow.

Arena'ceous — fr. lat. *arena*, sand. Sandy; of the nature of sand.

Argil — fr. lat. *argilla*, clay, which is formed from the Greek *argos*, white; because when pure it is white. Old name of alu'mina.

Argilla'ceous—Of the nature of clay.

Argilla'ceous-schist—Clay slate, or argillite.

Ar'gillite—A slaty rock of fine texture, with a faintly glistening, or earthy surface of fracture, and mostly of a dark colour. Roofing slate, and *nova'culite* or hone-slate are varieties of argillite.

Argilo-arena'ceous—Partaking of the nature of both clay and sand.

Arieti'na—Lat. Belonging or relating to a ram.

Arkose—A name given to different metamorphic sandstones. (p. 178.)

Articula'tion — fr. lat. *articulus*, a joint. A joint betwixt bones.

A'saphus — fr. gr. *asaphes*, obscure. A name devised to express the obscure nature of a genus of trilobites, fossil crustaceans—(p. 28.)

Asbe'stus, or **Asbestos** — fr. gr. *asbestos*, unconsumable. A fibrous soft mineral, composed of easily separable filaments of a silky lustre. It consists essentially of si'lica, magnesia and lime.

Asta'rte'—Name of a genus of fossil bivalve shells. (*Figs.* 104, 105, 176.)

Astre'a — fr. gr. *aster*, a star. A genus of polypa'ria. (p. 141.)

Astre'æ—Plur. of Astrea.

Athle'ta — Specific name of mollusk.

Au'gite — fr. gr. *auge*, lustre. A mineral, the same as pyroxene.

Au'gitic-porphyry — Crystals of Labrador feldspar, and of augite in a green or dark-grey base.

Avala'nche — Mass of hardened snow, detached from lofty mountains, which overturns everything in its way, often causing great destruction. Applied also to slides of earth and clay.

Avi'cula — fr. lat. *avis*, a bird. Name of a genus of bivalve mollusks. (*Figs.* 63, p. 52.)

A'xis of eleva'tion—Line of elevation.

Bac'cilar — fr. lat. *bacca*, a berry. Berry-like.

Ba'culites — fr. lat. *bacculum*, a stick. A genus of tetrabranchiate cephalopods, the chambered shells of which are quite straight, but differ from those of the orthoceratites in having sinuous or undulated partitions with lobated margins: in this structure they are allied to the Ammonites. (p. 72.)

Bag-shot sand. A siliceous bed which overlies the London clay formation, corresponding in age with the Paris basin.

Bala'ni—Plur. of balanus.

Bala'nus — Lat. A barnacle. (p. 85.)

Ballons—Fr. *ballon*, a ball. Rounded mountains are so called. A system of upheaval—p. 191.

Barra'nco — Sp. A ravine.

Basa'lt — A rock essentially composed of feldspar, and augite of a compact texture, and dark green, grey or black colour. It occurs in columnar masses. When light-coloured, with the feldspar predominating, it is sometimes called *greystone.* Basalt closely resembles *greenstone.*

Basa'ltic — Of the nature of basalt.

Basset — Outcrop, or emergence of strata at the surface.

Bastero'ti—Specific name of a fossil (p. 90).

Batra'chian (*Ba-trak'-ean*) — fr. gr. *batrachos*, frog. A kind of reptile resembling a frog in its mode of organization.

Bele'mnites — fr. gr. *belemnon*, a dart. A genus of fossil dibranchiate cephalopods, the shells of which are chambered and perforated by a siphon, but internal. They are long, straight, and conical; and commonly called "thunder stones" (p. 55 and 74).

Belle'raphon. p. 38 and *fig*. 33.

Bicorda'tus—Lat. Bicordate; double heart-shaped.

Bi'furcated—fr. lat. *bis*, two, *furca*, fork. Divided into two branches.

Biocula'ta — fr. lat. *bis*, two, *oculus*, an eye. Two-eyed.

Bitu'men — fr. gr. *pitus*, the pitch-tree; because it resembles pitch. A variety of inflammable mineral substances, which, like pitch, is included under this term.

Bitu'menized — Converted into bitu'men.

Bitu'minous—Of the nature of bitumen.

Bitu'minous shale — A slaty rock containing bitumen.

Bi'valve — fr. lat. *bis*, two, *valvæ*, doors. Shells composed of two pieces united by a hinge are termed bivalves.

Blende — Sulphuret of zinc, a common shining zinc ore.

Blumenba'chii—The name of Blumenbach latinized.

Bosse—French. A hillock; a rounded projection or elevation.

Botry'oidal—fr. gr. *botrus*, a bunch of grapes, and *eidos*, resemblance. Clustered like a bunch of grapes; covered with smooth, rounded masses.

Boulder formation. p. 93.

Brac'hiopod (*Bra'ke-o-pod.*) — fr. gr. *brachion*, arm, *pous*, foot. A mollusk with a two-lobed mantle and bivalve shell. (*See* Conchology, p. 88.)

Brachy'phy'llum — fr. gr. *brachus*, short, *phullon*, leaf. A genus of fossil plants. (*Fig*. 94, p. 61.)

Bradford clay — An English bed of the great o'olite, usually consisting of a pale greyish clay, containing a small proportion of calcareous matter, and inclosing thin slabs of tough brownish limestone. It abounds in fossil apiocrinites.

Brash — A provincial word used in England to describe the alluvial mass or quantity of broken and angular fragments of subjacent rock, found usually between the vegetable mould and the regular rocks. It is also called *rubble*.

Bre'ccia (*bresh'-ca*) — It. A rock composed of an agglutination of angular fragments. When the fragments are rolled pebbles, it constitutes a conglomerate rock called *pudding stone*.

Brevifo'lia—Lat. from *brevis*, short, *folium*, leaf. Short-leaved.

Brongniartii — Specific name of a fossil in honour of M. Brongniart, the eminent French naturalist. (p. 60.)

Buc'cinum — Lat. A trumpet or horn. Name of a genus of mollusks. (p. 90.)

Bu'chii —The name of Von Buch latinized.

Buckla'ndii—Specific name of certain fossils, given in honour of the eminent geologist Dr. Buckland.

Bupre'stes—Lat. Noxious insects. Certain beetles.

Cala'mites—fr. gr. *kalamos*, a reed. Common fossil plants in the coal strata. Cala'mites usually consist of jointed fragments which are supposed to be portions either of the trunk, or branches of a plant, which appears from some of the larger specimens, to have attained the dimensions of a tree. Both stem and branches were deeply ribbed along their whole length, and the ribs or furrows were crossed by horizontal rings at irregular intervals (p. 42).

Calc-sinter—Ger. *sintern,* to drop. A German term for limestone deposited from springs and waters containing it. Travertin.

Calca'ire gross'ier—Fr. Marine limestone.

Calca'ire sili'ceux — Fr. Fresh water or siliceous limestone.

Calca'reous — fr. lat. *calx,* lime. Containing lime.

Calca'reous grits—Sandy beds, intermixed with calcareous matter, found in the o'olite (p. 62).

Calce'ola — fr. lat. *calceolous,* a little shoe. A fossil bivalve shell (p. 33).

Calci'ferous — fr. lat. *calx,* lime, *fero,* I bear. Containing lime.

Cal'cined—fr. lat. *calx,* lime. Converted into calx or a friable substance by the action of fire.

Calcina'tion — The reduction of bodies to a calx or friable condition by the action of fire.

Cal'vus—Lat. Bald. Specific name of a productus.

Caly'mene — fr. gr. *kekalumene,* concealed. A name of a genus of trilobites (p. 29).

Cambrian system—p. 27.

Cannæfo'rmis —Lat. fr. *canna,* a reed, *formis,* form. Reed-shaped (p. 42).

Canis—Lat. Dog.

Car'bon — fr. lat. *carbo,* a coal. The pure inflammable principle of charcoal; in its state of absolute purity, it constitutes the *diamond.*

Car'bonate — A compound of carbonic acid with a salifiable base; carbonate of lime, for example, is a compound of carbonic acid with lime, constituting chalk, limestone, marble, &c

Carbona'ceous—Belonging or relating to carbon.

Car'bonic acid — An acid, compounded of carbon and oxygen.

Car'bonous — Of the nature of carbon.

Carboni'ferous — fr. lat. *carbo,* a coal, *fero,* I bear. Containing carbon.

Car'bonised—Converted into carbon.

Carbonisa'tion — The action of forming or converting a substance into carbon.

Car'buret—A combination of carbon with a metal or other substance; steel and black lead are carburets of iron.

Car'buretted — Converted into a carburet; containing carbon.

Car'dium—Lat. A cockle. A genus of bivalve shell (p. 81).

Carina'ta—Lat. from *carina,* a keel. Carinate; having a keel-like elevation.

Carni'vora — Lat. Carni'vorous. Carni'vorous animals.

Carni'vorous — fr. lat. *caro,* (genitive *carnis,*) flesh, *voro,* I eat. Flesh-eating.

Ca'ryophy'llia — fr. lat. *caryo'phyllus,* the garden pink. A genus of Ma'drepo'ra (p. 141).

Cas'cade — fr. fr. A cataract; a water-fall.

Cate'na—Lat. A chain. Specific name of an ammonite (p. 152).

Ca'tenated—fr. lat. *catena,* a chain. Linked together.

Catenipo'ra — fr. lat. *catena,* a chain, *pora,* pore. Generic name of a polyp (p. 31).

Ca'tylus *or* catillus — Lat. A little dish. A genus of fossil shells (p. 74).

Cauda'tus—Lat. Caudate; having a tail.

Cave'rnous — fr. lat. *cavus,* a hollow. Containing hollows; excavated.

Ce'mented — Joined together by cement.

Cementa'tion—When a solid body is surrounded by the powder of other substances, and the whole heated to redness, the process is termed *cementation*. Iron is converted into steel by cementation with charcoal.

Ce'ntigrade (Thermometer) — fr. lat. *centum*, hundred, *gradus*, a degree. Division into a hundred parts. The scale of the centigrade thermometer is made by dividing the space between the points of freezing, and boiling water, into one hundred parts or degrees.

Cephala'spis (*kef-al a'spis*) — fr. gr. *kephale*, head, *aspis*, shield. A genus of fossil fishes (p. 37).

Ce'phalopod (*ke'f alo-pod*) — fr. gr. *kephale*, head, *pous*, in genitive case *podos*, foot. A mollusk which has the head situated between the body and feet.

Ceri'thia—Plur. of cerithium.

Ceri'thium—A genus of turriculated univalve mollusks, both recent and fossil (p. 80 and 151).

Ce'roid — fr. gr. *keros*, wax, *eidos*, resemblance. Wax-like.

Cestra'cion — French. fr. gr. *kestraios*, name of a fish. A genus of the family of sharks (p. 45).

Ceta'cea — Lat. fr. gr. *ketos*, a whale. Name of an order of mammals.

Ceta'ceæ—Plur. of ceta'cea.

Ceta'ceous — Relating or belonging to ceta'cea.

Chalce'dony — fr. gr. *kalkedon*, Chalcedon, in Asia, where the finest specimens were originally found. A semi-transparent siliceous mineral, apparently found by the infiltration of siliceous matters in a state of solution. The chalcedo'nic varieties of quartz include Chalcedony, Crysoprase, Cornelian, Sard, Agate, Onyx, Cat's-eye, Flint, and Hornstone.

Chalk — fr. ger. *kalk*. Earthy carbonate of lime. Chalk has been discovered, it is said, for the first time in the United States, in Alabama, 1845.

Chalk marl — Marl belonging to the cretaceous formation.

Cha'ma (*ka-ma*) — fr. gr. *chaô*, I gape. A cockle (p. 67 and 151).

Cha'ra—(Origin of this word is unknown.) A genus of aquatic plants.

Chelo'nians — fr. gr. *chelone*, a sea-tortoise. Animals of the tortoise tribe.

Chert — A siliceous mineral resembling flint. It is usually found in limestone.

Chlo'rite — fr. gr. *chlôros*, green. A soft, green, scaly mineral, slightly unctuous.

Chlo'ritic chalk—Chalk containing chlorite.

Chlo'ritic schist—Schist containing chlorite.

Chrome — fr. gr. *chrôma*, colour. The oxide of a metal called *chromium*. Oxide of Chrome is green and furnishes a valuable colour for porcelain.

Chrono'logy—fr. gr. *chronos*, time, *logos*, discourse. The science which treats of the divisions of time, and the order and succession of events.

Cica'trices—Plur. of cica'trix.

Cica'trix—Lat. A scar.

Cida'ris — Lat. A cap or turban. Name of a genus of Echini'deæ (p. 150).

Cinders — Matters remaining after combustion.

Clavella'ta — Lat. (fr. *clavulus*, a little nail.) Marked by little projections or points; knotted.

Cleavage — The mechanical division, the laminæ of rocks and minerals, to show the constant direction in which they may be separated.

Clinkstone—*See* pho'nolite.

Clyme'nia — fr. gr. *klumenon*, the marigold? A genus of fossil cephalopods of the Devonian system (p. 33), with a chambered shell analogous to that of the ammonite.

Coal measures—The formations in which coal is found.

Coccinelloïdes — fr. lat. and gr. *coccinella*, cochineal, *eidos*, resemblance. Resembling the cochineal insect.

Cocco'steus — Name of a genus of fossil fishes (p. 32).

Coleo'ptera — fr. gr. *koleos*, sheath, *pteron*, wing. Name of an order of insects.

Colu'mba—Lat. A dove. Specific name of a fossil-shell.

Columna're—Lat. Columnar. In form of a column.

Coming to day —When a vein or stratum crops out or appears on the surface it is said to come to the day.

Comminuted—Fractured into small pieces.

Commu'nis–e—Lat. Common.

Comparative anatomy—The comparative study of the various parts of the bodies of different animals.

Compto'nia — A genus of plants named in honour of Henry Compton, Lord Bishop of London (p. 88).

Conce'ntric — Having a common centre.

Conce'ntricus—Lat. Concentric.

Conchi'ferous (*con-kif-erous*) — fr. lat. *concha*, shell, *fero*, I bear. Shell-bearing.

Conchy'lian (*con-kil'-ean*) — Consisting of or containing shells.

Concre'tionary formation — (p. 183).

Conde'nsable gas—Any gas that is susceptible of being condensed into a fluid, or solid.

Conduit—A water-pipe; a canal.

Cone of elevation—(p. 107).

Conformable stratification — When the strata are parallel to each other (p. 185).

Co'ngeners — fr. lat. *con*, with, *genus*, race. Species belonging to the same genus.

Conglo'merate — fr. lat. *conglomero*, I heap together. A rock composed of pebbles cemented together by another mineral substance, either calcareous, siliceous, or argilla'ceous.

Co'nica—Lat. Conical.

Co'nifer — fr. lat. *conus*, a cone, *fero*, I bear. A tree or plant which bears cones, such as pines, fir-trees, &c.

Conoïdea — Lat. Conoidal. Cone-shaped.

Conoidal — fr. lat. *conus*, a cone, and the Gr. *eidos*, resemblance. Cone-shaped; like a cone.

Contempora'neous — fr. lat. *con*, with, *tempus*, time. Existing at the same time.

Conto'rted—fr. lat. *con*, together, *torqueo*, I twist. Twisted together; bent.

Co'prolites — fr. gr. *kopros*, dung, *lithos*, stone. Fossil excrement (p. 44).

Coral — fr. gr. *koreô*, I ornament, *als*, the sea. The hard calcareous support formed by certain polypi.

Coral rag — Certain beds of the middle o'olite, consisting chiefly of corals (p. 63).

Cor'alline — Belonging or relating to coral.

Coralloi'des — Lat. from *coral* and the Gr. *eidos*, resemblance. Coral-like. Specific name of a devonian fossil (p. 33).

Cor-an'guinum—Lat. *cor*, heart, *anguinum*, snake-like. Specific name of a fossil (p. 75).

Cornbrash — An o'olitic bed consisting of clays and sandstones. Its name is probably derived from the excellence of the corn-land, which results from the decomposition of the limestones, and their mixture with the sandstones and clay.

Cornu'tus—Lat. Horned.

Corona'ta—Lat. Crowned.

Costa'tus—Lat. Ribbed.

Crag formation—(p. 84).

Crassate'lla — A genus of bivalve shells.

Cra'sus—Lat. Thick.

Cra'ter — fr. lat. *crater*, a great cup or bowl. The mouth of a volcano (p. 107).

Cra'ter of elevation—(p. 107).

Crate'riform—In form of a crater.

Crena'tum—Lat. Crenate; having rounded teeth.

Creta'ceous — fr. lat. *creta*, chalk. Of the nature of chalk; relating to chalk.

Crinoïdeæ — fr. gr. *krinon*, lily, *eidos*, resemblance. A family of radiate animals.

Crioce'ratites — fr. gr. *krios*, a ram, and *keras*, a horn. A fossil cephalopod (p. 67).

Cri'ses—Plur. of crisis.

Cri'sis — Gr. The point of time when any affair comes to its height.

Crocodi'lian — Any animal of the tribe of crocodiles.

Crop out —When a rock, in place, emerges on the surface of the earth, it is said to crop out.

Crusta'cean — Any animal of the class of crusta'cea; a crab.

Cryptoga'mia—fr. gr. *kruptos*, concealed, *gamos*, marriage. Name of a class of plants.

Cry'stal — fr. gr. *krustallos*, ice. This term was originally applied to those beautiful transparent varieties of si'lica, or quartz, known under the name of *rock-crystal.* When substances pass from the fluid to the solid state, they frequently assume those regular forms which are generally termed crystals. A crystal is any inorganic solid of homogeneous structure, bounded by natural planes and right lines symmetrically arranged.

Cry'stalline — Relating to, or resembling crystals.

Crystallisa'tion—The process of forming crystals.

Ctenoïdeans — fr. gr. *kteis*, in the genitive, *ktenos*, a comb. An order of fishes (p. 48).

Cuculla'tus—Lat. Hooded.

Cuprous—Belonging to copper.

Cuvieri —The name of Cuvier latinized.

Cy'athocri'nites — fr. gr. *kuathos*, a cup, *krinon*, lily. A genus of crinoideæ (p. 38.)

Cy'athophylla — Plur. cyathophyllum.

Cy'athophyllum — fr. gr. *kuathos*, a cup, *phullon*, a flower. A genus of polypa'ria (p. 31).

Cyca'deæ—(From cycas, one of the genera.) An order of plants.

Cy'cas — A name employed by the ancients to designate a little palm. (*Fig.* 306, p. 196.)

Cy'clades—Plur. of cyclas.

Cy'clas — fr. gr. *kuklos*, a circle. A genus of gasteropods.

Cycloideans — fr. gr. *kuklos*, a circle. An order of fishes (p. 49).

Cy'mbium — fr. gr. *kumba*, a boat. specific name of a shell.

Cy'prea — fr. gr. *kupris*, Venus. A genus of gasteropod mollusks.

Cy'pris — fr. gr. *kupris*, Venus. Name of a genus of crustaceans.

Cyre'na — A genus of bivalve mollusks.

Da'ta — fr. lat. *datum*, given, a gift. Admitted facts.

Debacle — Fr. Sudden escape of water from a lake, following a bursting of its barrier (p. 128).

De'bris (*de'-bree*) — Fr. Wreck, ruins, remains (p. 14).

Defra'ncii —The name of Defrance latinized (p. 74).

Degrade — fr. lat. *de*, privitive, *gradus*, step, degree. To lessen, to cut down.

Degrada'tion —The act of lessening; reduction.

Dejections—Matters evacuated from the bowels.

Delta—(p. 16 and 134).

Deltoïdea — Lat. fr. gr. letter Δ, *eidos*, resemblance. Resembling a delta Δ (p. 65).

Denta'tum—Lat. Dentate; having sharp teeth.

Denude — fr. lat. *denudo*, I strip. To lay bare.

Denuda'tion — A removal of a part

of the land, so as to lay bare the inferior strata.

Deposi′tion — fr. lat. *depono*, I let fall. The falling to the bottom of matters suspended or dissolved in water or other liquid.

Depre′ssus—Lat. Pressed, sunk.

Deus—Lat. God.

Devo′nian system—(p. 32).

Diade′ma—Lat. A diadem, a crown. A genus of echini′deæ (p. 54).

Di′agram—fr. gr. *dia*, through, *graphô*, I write. A figure drawn for illustration.

Dia′llage — fr. gr. *diallage*, difference. A mineral of foliated structure easily divisible in *one* direction, its natural joints and fractures exhibiting a very *different* lustre and appearance.

Dice′ras — fr. gr. *dis*, two, *keras*, horn. Generic name of a fossil bivalve (p. 64, *fig.* 106).

Dicoty′ledons — fr. gr. *dis*, two, *kotuledôn*, seed-lobe. A division of plants, according to the Natural Order.

Dicotyle′donous—Relating to dicotyledons.

Digo′na — fr. gr. *dis*, two, *gone*, angle. Having two angles.

Dilata′ta — Lat. Dilated, swelled out.

Dilu′vial—Relating to dilu′vium.

Dilu′vion, } fr. lat. *diluo*, I wash
Dilu′vium, } away. A superficial deposit (p. 92).

Dinothe′rium — fr. gr. *dinos*, circular, *therion*, a beast (p. 86).

Di′orite — A variety of trap rock consisting of albite and hornblende.

Dip—Direction of the inclination of strata. "To take a dip," is to measure the degree that a stratum inclines or dips from a horizontal line (p. 185).

Direction of strata—The Strike, or line of bearing (p. 185).

Dirt-bed—(Portland) p. 145.

Disa′ggregated — fr. lat. *de*, privitive, *aggrego*, I gather together. Separated, divided, broken up.

Disaggrega′tion—The breaking up of a mass into small parts.

Discordant stratification—Unconformable stratification.

Disengaged—Separated from, freed.

Disi′ntegrate — fr. lat. *de*, privitive, *integer*, entire, whole. To separate or break up an aggregate into parts.

Disintegra′tion—The act of separating or dividing a whole into parts.

Dislocate — fr. lat. *de*, privitive, *locus*, place. To put out of place.

Dislocation — Displacement of a part.

Disposi′tion — fr. lat. *dispono*, I arrange. Arrangement, method, order.

Disru′ption — fr. lat. *disrumpo*, I break off. The act of breaking asunder.

Distortion — fr. lat. *de*, from, *tortum*, twisted. The act of distorting or twisting out of place.

Dolichode′irus (*doli-ko-dy-rus*) — Lat. fr. gr. *dolichos*, long, *deire*, neck. Long-necked (p. 57).

Do′lomite—Named after Dolomieu. Magnesian marble: granular magnesian carbonate of lime. It contains about 45 per cent. of carbonate of magnesia. It is commonly more friable or crumbling than pure limestone, and less durable as a building material.

Dolomisa′tion—The conversion of common into magnesian limestone or dolomite (p. 170).

Dome — fr. lat. *domus*, house. A rounded projection.

Do′mite—A tra′chytic rock (p. 171).

Drift—(p. 92).

Dunes—Fr. Downs (p. 124).

Duvalii—Name of Duval latinised.

Dyke or Dike—(p. 118).

Earthquakes—(p. 97).

Ebulli′tion—The act of boiling.

Echi′nidæ } fr. gr. *echinos*, a
Echini′deæ } hedge-hog, *eidos*, resemblance. Systematic name of the order of sea-urchins.

Echi′noderms — fr. gr. *echinos*, a

hedge-hog, *derma*, skin. A class of invertebrate animals, with a crusta'ceous integument armed with tubercles or spines (p. 52).

Edenta'ta — Edentate. An order of mammals without teeth.

Ede'ntate—fr. lat. *e*, without, *dens*, tooth. Without teeth.

Efferve'scence — fr. lat. *effervesco*, I grow hot. The commotion produced in fluids by the sudden escape of gas in the form of bubbles.

Effu'sion — fr. lat. *effundo*, I pour out. The pouring out of a liquid.

E'legans—Lat. Elegant.

Emboss — fr. fr. *bosse*, a protuberance. To cover with lumps or bunches.

Encri'nites — fr. gr. *krinon*, a lily. A genus of echi'noderms (p. 52).

E'ntomo'stracans — fr. gr. *entomos*, incised, *ostrakon*, a shell. A division of the class of crusta'cea.

E'oce'ne—(p. 78).

Epidemic — fr. gr. *epi*, upon, *demos*, the people. A prevailing disease.

E'poch—The time from which dates are numbered.

E'poch of formation—(p. 192).

Equa'lis—Lat. Equal.

Equa'tion—fr. lat. *æquare*, to equal. Equivalent. A mean proportion between extremes.

Equili'brium—fr. lat. *æque*, equally, *libro*, I balance. Equal balance.

Equise'ta—Plur. equisetum.

Equiseta'ceæ — fr. *equise'tum*, one of the genera. A natural order of plants.

Equise'tum — fr. lat. *equus*, horse, *seta*, hair. A genus of plants.

Ero'de — fr. lat. *erodo*, I gnaw. To wear away, to corrode.

Ero'sion—The act of wearing away.

Ero'sive—Corroding, wearing.

Erratic block formation — (p. 93).

Eru'ption — fr. lat. *e*, from, *rumpo*, I burst. The act of bursting from any confinement.

Esca'rpment — fr. it. *scarpa*, sharp, formed fr. lat. *carpere*, to cut or divide. The steep face often presented by the abrupt termination of strata where subjacent beds "crop out" from under them.

Escharoides — fr. gr. *eschara*, a fire-place, a gridiron, *eidos*, resemblance. Specific name of a coral (p. 31).

Euom'phalus—(p. 39).

Eu'photide—A rock composed essentially of feldspar and diallage.

Evolu'tus—Lat. Unfolded.

Excoria'tion — fr. lat. *ex*, from, *corium*, skin. An abrasion, mark of a part having been rubbed from the surface.

Exo'gyra — fr. gr. *exô*, without, *guros*, circle. Not circular. (Figs. 109, 115, 125, 135.) A genus of unimuscular bivalves, allied to the oyster.

Explo'sion—A sudden bursting with noise and violence.

Extremities — The limbs; legs, arms, &c.

Exuda'tion — fr. lat. *ex*, from, *sudo*, I sweat. Transpiration.

Exu'viæ—Lat. The sloughs or cast-skins, or shells of animals.

Fasci'culis—Lat. Plur. of fasciculus.

Fasci'culus—Lat. A bundle.

Fastigia'ta—Lat. Sharpened at top like a pyramid.

Fathom—A measure of six feet.

Fault — fr. ger. *fall*, an accident, sinking, fall (p. 158).

Fau'na — fr. lat. *faunus*, the name of a rural deity among the Romans. All animals of all kinds peculiar to a country constitute the *fauna* of that country.

Fecit—Lat. He made.

Feld'spar, or felspar — fr. ger. *feldspath*. An important mineral composed of si'lica, alu'mina, and potash, with traces of lime, and often of oxide of iron. It enters into the composition of granite.

Feldspa'thic—Of the nature, or belonging to feldspar.

Felis—Lat. A cat.

Feneo'nis—Specific name of a fossil zamia (p. 65).

Ferru'ginous—fr. lat. *ferrum*, iron. Containing iron.

Ficoi'des — fr. lat. *ficus*, a fig-tree, and gr. *eidos*, resemblance. Specific name of a fossil plant.

Firmame'ntum — Lat. The firmament.

Fis'sile — fr. lat. *findo*, I split. Easily split.

Fis'sure —A crack, a separation ; a split.

Flo'ra — fr. lat. *flora*, goddess of flowers. All the plants of all kinds of a country constitute the *flora* of that country.

Flu'viatile —Belonging or relating to a river.

Folia'cea—Lat. Foliated.

Folia'ted — fr. lat. *folium*, a leaf. In form of leaves; leafy.

Foramini'fera — fr. lat. *foramen*, hole, *fero*, I bear. Name of a tribe of minute shells.

Forma'tion — Any group of rocks formed during a particular epoch, or of common origin.

Fos'sil — fr. lat. *fodio*, I dig. Any organic body, or the traces of any organic body, whether animal or vegetable, which has been buried in the earth by natural causes (p. 21).

Fossili'ferous—Containing fossils.

Fos'silized — Converted into a fossil.

Fu'lcrum — Lat. A prop. The fixed point on which a lever moves.

Fum'arole—Fr. Subterraneous emission of hydrogen gas in consequence of the ebullition of certain sulphurous waters. The hole or orifice through which the gas escapes.

Fumes—Vapours.

Fusion —The act of melting ; state of fusion, is being melted.

Fu'siforme'—Lat. Fusimorm, spindle-shaped.

Gale'na — fr. gr. *galene*, lead-ore. Sulphuret of lead, that is a compound of sulphur and lead.

Ganöideans — An order of fishes (p. 48).

Ga'rnet — A mineral consisting of silicates of alu'mina, lime, iron, and manganese. There are several varieties of this mineral. Garnet occurs imbedded in mica slate, granite, and gneiss, and occasionally in limestone, chlorite slate, serpentine, and lava.

Gas — fr. ger. *geist*, spirit. The name given to all permanently elastic fluids or airs different from the atmospheric air.

Ga'seous—Of the nature of gas.

Gault—A kind of clay (p. 71).

Gela'tinous—Jelly-like.

Ge'nera—Lat. Plur. of genus.

Gene'ric—Relating to genus.

Ge'nus — Lat. A kindred, breed, race or family.

Ge'odes — fr. gr. *geôdes*, earthy. Nodules of iron stone, hollow in the centre. Rounded pebbles having an internal cavity, lined with crystals, are also so called.

Ge'ogeny — fr. gr. *ge*, the earth, *geinomai*, I beget. Science embracing the theories of the formation of the entire universe.

Geogno'stic—Relating to geognosy.

Geog'nosy — fr. gr. *ge*, the earth, *gnôsis*, knowledge. Knowledge of the mineral substances which constitute the mountains and strata of the earth.

Geolo'gical—Relating to geology.

Ge'ologist—One skilled in geology.

Ge'ology — fr. gr. *ge*, the earth, *logos*, discourse. That branch of natural history, which treats of the structure of the terrestrial globe. It is divided into *descriptive* geology; *dyna'mic* geology, which treats of the forces by which the surface of the earth has been modified ; *practical* and *economic* geology, embracing the application of geological science to mining, road-making, architecture, and agriculture.

Gey'sers —From an Icelandic word signifying raging or roaring. Celebrated spouting fountains of boiling water in Iceland (p. 136).

Gibbo'sity — fr. lat. *gibba*, a bunch. A protuberance.

Giga'nteum
Giga'nteus } Lat. Gigantic.

Glaber—Lat. Smooth, bald, bare.

Gla'ciers — Fr. Masses or beds of ice formed in high mountains, derived from the snows or lakes frozen by the continued cold of those regions (p. 150).

Globa'ta. — Lat. Globate, rounded.

Gneiss — Ger. A rock resembling "granite in its constitution and general characters; but it contains more mica and the colours are banded, but owing to the arrangement of the minerals, especially the mica, in parallel planes. In consequence of this structure the rock splits into coarse slabs, along the planes of the mica, besides having the cross fracture or cleavage of granite. It is often described as a stratified or stratiform granite. A rock intermediate between granite and gneiss is called *gneissoid granite.* Gneiss is used for building and flagging" (p. 25).

Gon'iatites (p. 38).

Goodhallii — The name Goodhall latinized.

Gra'lleæ — Lat. Wading-birds.

Gra'nite — A crystalline aggregate of quartz, feldspar, and mica. The ingredients of granite vary in their proportions, and the rock is described as *mica'ceous, feldspathic* or *quartzose,* according as mica, feldspar, or quartz is the predominating mineral. It is called *Porphyritic* granite when the feldspar is uniformly disseminated in large crystals; they appear like white blotches, often of a rectangular shape, over a worn surface of the rock.

Grani'tic—Belonging or relating to granite.

Gra'nular—Consisting of grains.

Gra'phite — fr. gr. *graphô,* I write. A mineral composed of carbon and iron, constituting carburet of iron. It is known as plumbago and *black lead;* it is used in the manufacture of lead-pencils.

Grau'wacke, and **Graywacke** — Ger. Grey rock. A name given to some of the older shales in the geological series, and also to the sandstones that accompany them.

Gra'vel—Small rounded stones varying in size from a small pea to a walnut, or something larger.

Gravitate — fr. lat. *gravis,* heavy. To tend towards the centre of the earth, as all bodies do from their weight.

Greensand—A formation of the creta'ceous group (p. 70).

Greenstone — A tough variety of trap-rock, consisting chiefly of hornblende.

Gre's bigarre'—Fr. A fine-grained solid sandstone, sometimes white, but more frequently of a red, blue, or greenish colour. It is the same as *bunter sandstein.*

Grit—A coarse-grained sandstone.

Grundstein — Ger. Greenstone or diorite.

Gry'phea — fr. gr. *grupos,* incurved. A genus of fossil bivalves.

Gry'phites — Generic synonym of the *productus aculeatus* (p. 49).

Gry'phite limestone—A marl, so called from containing gry'phea.

Gry'phitenkalk — Ger. A name sometimes given to *zechstein* (p. 49).

Gymnospe'rmous — fr. gr. *gumnos,* naked, *sperma,* seed. Having naked seeds.

Gy'pseous—Of the nature of gypsum.

Gy'psum (*jip-sum*). — Native sulphate of lime. The transparent varieties constitute *selenite,* and the fine massive Alabaster. Gy'psum is converted into plaster of Paris by heat.

Ha'mites — fr. lat. *hamus,* a hook. A genus of extinct cephalopods, inhabiting chambered shells, losing their spiral form after their commencement, and then continued for a considerable extent with a single bend on themselves like a hook. They are found in the greensand of England.

HE'LICES—Plur. of helix.

HE'LIX—Lat. A snail.

HE'TEROCERCAL — fr. gr. *'eteros,* opposite, *kerkos,* a tail. Having the spine prolonged into the tail (p. 49).

HETERO'PHYLLA — fr. gr. *'eteros,* opposite, *phullon,* leaf. Specific name of a fossil plant (p. 53).

HIBBERTI — Name of Hibbert latinized.

HIEROGLY'PHICS — fr. gr. *ieros,* sacred, *gluphô,* I write. Sculpture or scripture writing.

HI'PPURITES—fr. gr. *ippouris,* horsetail: a certain fish. A genus of extinct mollusks, supposed to be bivalve. The principal valve is of a sub-cylindrical or elongated, conical form, traversed by one or more internal longitudinal ridges, and closed by a small sub-circular valve like an operculum (p. 68).

HIPPOPO'TOMI—Lat. Plur. of hippopotamus.

HIPPOPO'TAMUS—fr. gr. *'ippos,* horse, *potamos,* a river. The River-horse.

HOLO'PTICUS, and HOLOPTY'CHIUS—fr. gr. *olos,* the whole, *ptuchios,* folded. A fossil fish of the ganoid order, the enamelled surface of whose scales was marked by large undulating furrows. It had sharp conical teeth (p. 44).

HO'MOCERCAL — fr. gr. *omos,* joined, *kerkos,* a tail. Applied to the tail appended to the termination of the spine, as in most of the fishes now existing (p. 49).

HO'RNBLENDE — A mineral of dark green or black colour, abounding in oxide of iron, and entering into the composition of several of the trap rocks. There are three varieties; common, hornblende-schist, and basaltic hornblende.

HORNBLENDE-SCHIST—A slaty variety of hornblende.

HU'MUS — Lat. Moist earth. Vegetable earth or mould.

HU'MERUS — Lat. Shoulder. Name of the bone placed between the shoulder and elbow.

HY'BODONS — fr. gr. *ubos,* bent outwards, and *odous,* tooth. A division of the shark family (p. 44).

HY'DRATED — fr. gr. *'udôr,* water. Containing water.

HYDROCHLO'RIC ACID—An acid composed of hydrogen and chlorine, formerly known as muriatic acid.

HYDROSTA'TICS — fr. gr. *'udôr,* water, *staô,* I stand. The science which explains the properties of the equilibrium and pressure of liquids.

HY'PERSTHENE — Labrador hornblende. It contains iron, si'lica and magnesia. Hypersthene rock differs from common hornblende only in its foliated crystallization and its pearly or metallic-pearly lustre. It is a very tough rock, with a structure resembling gneiss.

HYPNOIDES — fr. gr. *upnon,* a sort of moss, *eidos,* resemblance. Specific name of a fossil plant.

HY'POGENE — fr. gr. *upo,* under, *geinomai,* I am formed. A class of rocks which have not assumed their present form and structure at the surface of the earth, but are apparently of igneous origin and thrust up from below.

HYPO'THESIS — fr. gr. *upo,* under, *tithemi,* I place. A theory, or supposition. A rational conjecture.

HYPO'THETICAL — Of the nature of hypothesis.

I'CHTHYOSAU'RUS—The fish lizard (p. 57).

IG'NEOUS — fr. lat. *ignis,* fire. Relating or belonging to fire.

IGUA'NODON—From *iguana,* and the Gr. *odous,* tooth. An extinct genus of gigantic herbivorous reptiles, discovered in the south of England.

IMBRICATA'RIA — Lat. As if imbricated, or tile-like.

IMBRICA'TA — Lat. Imbricate, tile-like. Arranged like tiles.

Impre'ssa—Lat. Impressed, engraven, marked.

Inæquiva'lvis — Lat. Inequivalve. Having unequal valves.

Incande'scence — fr. lat. *incandescere,* to grow very hot, to be inflamed. The condition of great heat, showing a certain light, as if the heated substance itself were burning. Melted.

Incande'scent—Greatly heated.

Incohe'rent — fr. lat. *in,* not, *con,* with, *hæreo,* I adhere. Loose, wanting cohesion.

Inclination of beds — Dip (p. 185).

Incrusta'tion — fr. lat. *crusta,* a crust. A covering like a crust.

Inequila'teral — fr. lat. *inæqualis,* unequal, *latus,* (in the genitive, *lateris,*) side. Having unequal sides.

Infiltration — fr. lat. *filtrare,* to filter. The act of filtering through, producing an accumulation of liquid.

Inoce'ramus — fr. gr. *en,* with, *keramos,* earthen ware? A genus of bivalve fossil shells, which are chiefly characterised by their hinge and the fibrous structure of their constituent substance. The shell, in consequence of the vertical arrangement of the fibres, readily breaks to pieces, and it is often extremely difficult to extricate a specimen with the hinge and beaks tolerably entire.

In place—In their original position where they were formed.

Inquina'ta—Lat. Stained, dirty.

Inserted—Attached.

In situ—Lat. In place.

Intercalated — fr. lat. *intercalo,* I place between. Placed between.

Intercala'tion — The placing one substance between others, as one stratum between two others.

Interposed — fr. lat. *inter,* between, *pono,* I place. Placed between.

Intertropical — Between the tropics.

Intrusion —The act of thrusting or forcing in.

I'solated — fr. it. *ïsola,* an island. Separated like an island.

Isothe'rmal — fr. gr. *isos,* equal, *therme,* heat. *Isothermal lines* are those which pass through those points on the surface of the earth, at which the mean annual temperature is the same.

Ja'sper—A siliceous mineral of various colours.

Joints of dislocation—(p. 187).

Jura'ssic — Belonging to the Jura mountains.

Keu'per — Ger. The upper portion of the new red sand-stone formation (p. 52).

Kimmeridge clay—(p. 64).

Kimmeridge coal—(p. 65).

Ku'pferschi'efer — Ger. Copper-slate (p. 47).

La'bradorite — Labrador spar. It consists of silicate of alu'mina, lime, and soda, with traces of oxide of iron. It is a variety of feldspar.

Labyri'nthica — Lat. Labyrinth-like.

Labyri'nthodon — fr. gr. *laburinthos,* a labyrinth, *odous,* tooth. An extinct genus of batrachians, characterised by teeth of a peculiarly complicated structure. The remains of this genus peculiarly characterise the Keuper formation in Germany and the corresponding sand-stones in England (p. 196, and *fig.* 307).

Lace'rtian — fr. lat. *lacerta,* a lizard. Any animal of the lizard tribe.

Lacu'strine — fr. lat. *lacus,* a lake. Belonging or relating to lakes.

Lævis—Lat. Smooth, bare, bald.

Lamano'nis—Specific name of a fossil plant.

Lambe'rti — The name of Lambert latinized.

La'mina — Lat. Plur. laminæ. A plate.

Landslip or laneslide. — The removal of a portion of land down an inclined surface, from its attachment being lessened by the action of water beneath, or by an earthquake.

Lapi′lli — fr. lat. *lapillus*, a little stone. Small volcanic cinders.

Latera′lis—Lat. Lateral.

La′va — The substances which flow in a melted state from a volcano. Lavas vary in consistence and texture.

Le′nta—Lat. Slow, heavy, stupid.

Lepidode′ndra—Plur. of lepidodendron.

Lepidode′ndron—fr. gr. *lepis*, scale, *dendron*, a tree. A genus of fossil plants, having a scaly bark.

Lepte′na—A synonym of the genus productus (p. 30).

Leymerii—The name Leymerie latinized.

Lias—(p. 54).

Li′gneous — fr. lat. *lignum*, wood. Woody; of the nature of wood.

Li′gnite—fr. lat. *lignum*, wood. A kind of coal.

Li′ma — Lat. A file. Name of a genus of bivalves.

Linea′ris—Lat. Linear, line-like.

Line of bearing—Strike (p. 185).

Liquefa′ction—The act of becoming liquid.

Lithu′ites and litu′ites—fr. lat. *lituus*, a crooked staff. Fossil chambered shells, curved or bent at one end (*fig*. 8).

Lithogra′phic—fr. gr. *lithos*, stone, *graphô*, I write. Lithographic stone, used for the purposes of litho′graphy (p. 65).

Litho′phagi — fr. gr. *lithos*, stone, *phagô*, I eat. Small worms found in slate which give it a red colour.

Littora′lis — Lat. Littoral; belonging or relating to the shore.

Loam—A mixture of sand and clay.

Lodes — Veins containing metallic ores.

Loess — A German geological term, applied to a tertiary alluvial deposit, which occurs in patches between Cologne and Basle. The term is applied by the English to that peculiar yellow loam with calcareous concretions.

London clay—(p. 78).

Longiro′stris—lat. fr. *longus*, long, *rostrum*, beak. Long-billed.

Longisca′ta — Lat. A little longer.

Ly′copo′dia′ceæ — fr. gr. *lukos*, a wolf, *pous*, foot. A natural order of plants which includes the ly′copo′dium.

Lyellii — The name of Lyell latinized.

Lymne′a or limnea—fr. gr. *limne*, a pool. A genus of fresh-water snails.

Lu′cem—Lat. Light.

Lugdunensis — Lat. Belonging or relating to Lyons.

Lumachella—*See* note p. 67.

Ma′drepo′ra — Lat. Compound of the French *madré*, spotted, and Lat. *porus*, pore. A genus of corals (p. 141).

Madrepore—A kind of coral.

Madrepo′ric—Of the nature of madrepore.

Magne′sia—A white, tasteless earthy substance.

Magne′sian — Relating to, or containing magnesia.

Magne′sian limestone — Limestone which contains magnesia. An extensive series of beds lying above the coal measures.

Magne′tic—Having properties of the magnet or load-stone.

Mag′num—Lat. Great.

Mam′mal—Any animal that suckles its young.

Mammali′ferous—Containing mammals.

Mammi′llary — fr. lat. *mammilla*, a little nipple. Studded over with small rounded projections.

Mammoth — An extinct species of elephant.

Mante′llia — A genus of fossil cyca′deæ, named in honour of Mr. Mantell.

Ma′rgareti′fera — fr. lat. *marga-*

ritum, a pearl, *fero*, I bear. Pearl-bearing.

Marine—fr. lat. *mare*, the sea. Relating to the sea.

Marl — Argillaceous carbonate of lime. There are several varieties of marl.

Ma'rshii — The name of Marsh latinized.

Marsu'pial — fr. lat. *marsupium*, a pouch. Any animal having a peculiar pouch in front or on the abdomen.

Ma'stodon—fr. gr. *mastos*, a nipple, *odous*, tooth. A genus of extinct quadrupeds allied to the elephant.

ma'trix—Lat. The stony substance in which metallic ores and crystalline minerals are imbedded. *Gangue*.

Maximum—Lat. Greatest.

Meandri'na—A genus of polyps.

Meandrin'æ — Plur. of meandrina.

Medicage'nela—Specific name of a chara, a kind of fossil moss.

Medu'llary rays—fr. lat. *medulla*, marrow. The vertical plates of cellular tissue which radiate from the centre of the stem through the wood to the bark in exogynous plants.

Megali'chthys—fr. gr. *megas*, great, *ichthus*, fish. An extinct genus of fishes, including species of great size.

Mega'lodon — fr. gr. *megas*, great. *odous*, tooth. A genus of peculiar fossil bivalve shells.

Megalo'nyx — fr. gr. *megas*, great, *onux*, a claw. A large fossil mammal, found in Virginia.

Megalosau'rus—(p. 58).

Megathe'rium—(p. 92).

Mela'nia—fr. gr. *melas*, black. A genus of fluviatile univalves.

Mela'phyry, and **Mela'phyre**—fr. gr. *melas*, black. A kind of porphyry the constituents of which are united by a black cement (p. 173).

Mephit'ic—fr. mephitis, the goddess of foul smells. Applied to impure or foul exhalations.

Metalli'ferous—Containing metal.

Metamo'rphic — Relating to metamorphism.

Metamo'rphism—fr. gr. *meta*, indicating change, *morphe*, form (p. 177).

Metamo'rphoses—Plur. of metamorphosis.

Metamorphosis—Change of form.

Mi'ca — fr. lat. *mico*, I shine. A mineral generally found in thin elastic laminæ, soft, smooth and of various colours and degrees of transparency. It is one of the constituents of granite.

Mica'ceous—Of the nature of mica.

Mica-schist—Mica-slate (p. 25).

Mi'croscope—fr. gr. *mikros*, little, *skopeô*, I view. An optical instrument which enables us to examine objects too small to be seen by the unassisted eye.

Mi'croscopic—Minu'te; perceivable only by aid of a microscope.

Mi'lliolites, or **Mili'ola**—fr. lat. *milium*, a millet seed, and gr. *lithos*, stone. A genus of foramini'ferous fossil shells found in the neighborhood of Paris.

Millstone grit — Coarse grained, quartzose sandstone.

Mine—Ger. Any subterraneous work or excavation which has for its object the extraction of any mineral products, as metallic ores, coal, &c.

Mineral — Any *inorganic* natural object, whether solid, liquid or gaseous.

Minera'logy — That branch of natural science which treats of the properties of minerals.

Mi'nima
Mi'nimum } Lat. Least.

Minus—Lat. Little.

Minu'ta—Lat. Minute, very small.

Mi'ocene—(p. 78 and 83).

Modern formation—(p. 95).

Mola'sse—Fr. A fine grained sandstone, usually soft and loose, but sometimes sufficiently hard for building purposes.

Mollusk—fr. lat. *mollis*, soft. Any animal of the class of mollusca.

Moni'le—Lat. Belonging or relating to a necklace.

Monilefo'rmis — lat. fr. *monile*, a necklace, *forma*, form. In form of a necklace.

Mo'nocoty'ledons — fr. gr. *monos*, single, *kotuledôn*, seed-lobe. A class of plants having but one seed-lobe in the embryo.

Morai'nes — Longitudinal deposits of stony detritus found at the bases, and along the edges of all the great glaciers (p. 131).

Mosasau'rus—(p. 75).

Mucrona'tus—Lat. Pointed, sharp-pointed.

Multilo'cular — fr. lat. *multus*, many, *loculus*, a partition. Having many chambers or partitions.

Mu'ral—fr. lat. *murus*, a wall. Belonging or relating to a wall.

Mu'rex—Lat. A shell fish. A genus of univalve mollusks.

Murica'ta — Lat. Full of sharp prickles or points.

Mu'schelkalk—Ger. (p. 50).

Muscle — An organ of motion; the flesh of animals.

Mu'ssel—A bivalve mollusk.

Muta'bile'—Lat. Mutable, changeable.

My'a—A genus of bivalve mollusks.

Na'gelflue — Ger. A coarse conglomerate.

Nau'tilus—A genus of cephalopods.

Navi'cula—Lat. A little boat.

Neoco'mian and **neocomien** — Fr. The lower beds of the cretaceous system in the south of France and elsewhere, are described by the French geologists under this name.

Neptu'nian — From Neptune, god of the sea. Belonging or relating to water.

Neri'nea — A genus of fossil univalves, resembling both Cere'thium and Turritella (p. 63).

Nervures—Veins of leaves. Also, the tubes for expanding the wings of insects.

Neuro'ptera—fr. gr. *neuron*, a nerve, *pteron*, wing. An order of insects.

Neuro'pteris — A genus of fossil plants (p. 41).

New red sand-stone—(p. 47).

Nidifo'rmis — Lat. In form of a bird's nest.

Nilso'nia—A genus of fossil plants.

Nodo'sus—Lat. Knotty.

No'dule—fr. lat. *nodus*, a knot. A rounded irregular lump or mass.

Nor'mal—fr. lat. *norma*, a rule. According to the peculiarities of a family or genus, without the least departure.

Norwich, or Norfolk crag — A tertiary formation which rests on the London clay or chalk, and includes marine shells (p. 84).

Nu'cleus — Lat. A kernel. The solid core of a body.

Nu'cula — fr. lat. *nux*, a nut. A genus of bivalve shells with numerous teeth like those of a comb.

Nummuli'tes — fr. lat. *nummus*, money, and fr. gr. *lithos*, stone. Fossil money. An extinct genus of cephalopods, of a thin lenticular shape, divided internally into small chambers. Nummulite limestone obtains its name from the presence in it of these shells in great abundance. In Alabama there is a mountain range entirely composed of one species of nummulite.

Nutri'tion—The animal function by which the various organs receive nutritive substances (previously prepared by the several organs of digestion), necessary to repair their losses and maintain their strength.

Oblo'ngus—Lat. Oblong.

Obova'ta—Lat. Obovate.

Obo'vate — fr. lat. *ob*, for, opposite, *ovum*, egg. Reverse of ovate or egg-shaped.

Obsi'dian — Named after Obsidius. A glassy lava. Volcanic glass. It consists of si'lica and alu'mina with a little potash and oxide of iron.

Octoplica'ta—Lat. *octo*, eight, *plica'ta*, folded. Having eight folds.

Old red sandstone—(p. 37).

O'olite—fr. gr. *ôon*, an egg, *lithos*, stone. A granular variety of carbonate of lime, frequently called *roestone* (p. 58).

O'olitic — Belonging or relating to o'olite.

Opale'scent — Resembling o'pal, a beautiful mineral, characterized by its iridescent reflection of light.

Ope'rculum—fr. lat. *operio,* I cover. The lid which protects the gills of fishes, and closes the opening of certain univalve shells.

Orbicula'ris—Lat. Orbicular.

Orbit—fr. lat. *orbis,* a circle. The circular cavities in which the organs of vision are lodged, are named the orbits.

Ores—fr. ger. *erzc.* Mineral bodies from which metals are extracted.

Organ — fr. gr. *organon,* an instrument. Part of an organized being, destined to perform some particular function ; the ears are organs of hearing, the muscles organs of motion, &c.

Orga'nic—Relating to organs.

Organized—Possessing organs.

Organiza'tion — A mode of structure.

Orga'nisans — Lat. fr. gr. *organoô,* I arrange, or provide with organs. Organizing, constructing.

Orthis — A genus of fossil bivalve shells (p. 29).

Orthoce'ras — }
Ortho'ceratite } (p. 38).

Oscilla'tion — fr. lat. *oscillum,* an image, hung on ropes and swung up and down in the air. The act of moving backwards and forwards like a pendulum.

Oscilla'tory—Swinging backwards and forwards like a pendulum.

Ostra'cea—Family of bivalves which includes the oyster.

Os'trea — Genus of bivalves; an oyster.

Outcrop—The emergence of a rock, in place, at the surface.

Outlier — A hill or range of strata occurring at some distance from the general mass or formation to which it belongs.

Ova'tus—Lat. Ovate, egg-shaped.

Overlying—When one stratum lies over, or overlaps another, it is said to be overlying.

Oxford clay—(p. 62).

O'xide — fr. gr. *oxus,* acid, *eidos,* form. A compound, which is not acid, containing oxygen.

O'xygen—fr. gr. *oxus,* acid, *gennein,* to generate. Vital air.

Pa'chyde'rma — Lat. fr. gr. *pachus,* think, *derma,* skin. Thick-skinned.

Pa'chyde'rmata — Lat. Pa'chyde'rms.

Pachyde'rms—An order of quadrupeds, including the elephant, horse, pig, &c., distinguished by the thickness of their hides.

Pa'chyde'rmatous—Relating to pa'chyde'rms.

Pa'chygna'tus—Lat. fr. gr. *pachus,* thick, *gnathos,* jaw. Specific name of the labyrinthodon (p. 197).

Palæoni'scus—(p. 48).

Pa'læonto'logist — One skilled in palæontology.

Palæonto'logy—fr. gr. *palaios,* ancient, *on,* creature, *logos,* a discourse. That branch of zo'ological science which treats of fossil organic remains.

Palæ'ozoic—fr. gr. *palaios,* ancient, *zoe,* life. Relating to ancient life.

Paleothe'rium—(p. 83).

Palmaci'tes — A genus of fossil plants.

Paludi'na—fr. lat. *palus,* a marsh. A genus of fresh water gasteropods.

Paludi'næ—Plur. of paludina.

Paludine—Belonging to a marsh.

Parallel — Extended in the same direction and preserving always the same distance.

Paralle'lism—The state of being parallel.

Paralle'piped — A solid contained by six planes, three of which are parallel to the other three.

Pa′rasite—An adherent, a hanger on.

Parasi′tic—Of the nature of a parasite.

Pari′etes — fr. lat. *paries*, a wall. The sides or parts forming an enclosure.

Paris basin—(p. 79).

Peat
Peat-bog } (p. 143).

Peco′pteris — fr. gr. *pekos*, sheepskin, *pteris*, a fern. A genus of fossil ferns.

Pe′cten—Lat. A comb. A genus of bivalve mollusks.

Pectina′ta — Lat. Pectinate; like the teeth of a comb.

Pe′llicle—fr. lat. *pellis*, a skin. A thin skin, or crust.

Penine formation—New red sandstone (p. 47).

Penta′merus or **Pentame′rus**—fr. gr. *pente*, five, *meros*, a part (p. 31).

Penta′ngula′tus — Lat. Having five angles.

Percolate — fr. lat. *per*, through, *colo*, I strain. To strain or drip through.

Pe′ridot — Prismatic chrysolite (p. 121).

Pe′rlite—Pearlstone, a gray variety of obsidian.

Permanent gas — Any gas which remains in the aëriform state under ordinary circumstances.

Pero′xide—The highest degree of oxidizement of which a metal or other substance is susceptible without becoming an acid.

Pes-pelica′ni—Lat. Pelican foot.

Phaneroga′mia — fr. gr. *phaneros*, evident, *gamos*, marriage. The division of the vegetable kingdom in which all the plants bear flowers, and are multiplied by means of true seeds.

Phanero′gamous—Belonging or relating to phaneroga′mia.

Pheno′mena—Plur. of phenomenon.

Pheno′menon—Gr. Appearance, visible quality, event.

Pho′las — fr. gr. *pholeos*, a lurking place. A genus of mollusks.

Pho′lades—Plur. of Pholas.

Pho′lodomy′a — A genus of mollusks.

Pho′nolite — Clinkstone, a species of compact basalt, which is sonorous when struck (p. 171).

Phospho′ric
Phosphore′scent } fr. gr. *phos*, light. Emitting light in the dark.

Pistillifo′rmis—Lat. In form of a pistil.

Placöideans—(p. 48).

Placu′nea — Lat. fr. gr. *plakoeis*, broad, flat, even.

Plænerkalk—Ger. (p. 71).

Plagio′stoma — fr. gr. *plagios*, oblique, *stoma*, mouth. A genus of bivalve mollusks.

Plano′rbis—fr. lat. *planus*, flat, *orbis*, a circle. A genus of marsh snails (p. 83).

Pla′nus—Lat. Flat.

Plastic clay—(p. 78).

Plaster of paris—A substance prepared by heating gypsum.

Pla′teau—Fr. An elevated plane, or table land.

Pla′teaux (**pla′-to**)—Plur. of plateau.

Plati′na or **plati′num**—fr. sp. *plata*, silver, on account of its colour. A metal of a whitish colour, exceedingly ductile, malleable, and of difficult fusion.

Platyso′mus—(p. 48).

Plei′siosau′rus—(p. 57).

Pleis′tocene — fr. gr. *pleistos*, the most, *kainos*, recent. The newer pliocene formation or newest tertiary.

Pleu′ronectes—fr. gr. *pleura*, side, *nektes*, swimmer. A genus of fishes.

Pleuro′toma — fr. gr. *pleura*, side, *tome*, a notch. A genus of univalve mollusks, having a notch in the side of the shell.

Pleurotoma′ria — A tribe of mollusks.

Plica′tula—fr. lat. *plica*, a fold. A genus of mollusks (p. 72).

Pli′ocene—(p. 78 and 89).

Plutonic—After Pluto, the god of fire. Relating to fire.

Poikili'tic—fr. gr. *poikilos*, variegated. A name applied to the new red sandstone formation in consequence of the varieties of colours it exhibits.

Po'lyp—fr. gr. *polus*, many, *pous*, foot. A radiated animal which has a cylindrical or oval body, or sac, with an opening at one extremity, around which are long feelers.

Polypa'ria, and **polypia'ria**—Groups of polyps or animalcules which form coral.

Polypa'rium—The skeleton or framework formed by coral animalcules. When this frame-work is of a stony hardness it constitutes *coral*. In fossils the *polyparium* alone remains.

Po'rous—Containing pores.

Porphyri'tic—Of the nature of porphyry.

Por'phyröid—Resembling porphyry.

Porphyry—fr. gr. *porphura*, purple. Originally applied to a *red* rock found in Egypt. A compact feldspathic rock containing disseminated crystals of feldspar, the latter when polished, forming small angular spots, of a light colour, thickly sprinkled over the surface. The rock is of various colours, dark green, red, blue, black, &c.

Porre'cta—Lat. Extended.

Portland o'olite—(p. 64).

Posido'nia—(p. 52).

Pozzuola'na and **pouzzuolani**—Volcanic ashes used in the manufacture of mortar which hardens under water: exported from Pozzuoli, near Naples.

Precipita'tion—The action, by which a body abandons a liquid in which it is dissolved or suspended, and becomes deposited at the bottom.

Prisma'ticum—Lat. Prismatic.

Produ'ctus—A genus of extinct mollusks (p. 29, 30, and 39).

Pteri'chthys—(p. 32).

Pteroda'ctyli—Lat. Plur. of pterodactylus.

Pteroda'ctylus—(p. 57).

Ptero'phyllum—fr. gr. *pteron*, wing, *phullon*, leaf. A genus of fossil plants.

Pudding stone—Conglomerate.

Pumice—Vesicular obsidian.

Py'rites—A compound of sulphur and iron.

Py'roxene—(p. 121).

Pyroxenic—Of the nature of pyroxene.

Quadersandstein—Ger. The lower cretaceous beds in Germany: any sandstone fit for building purposes.

Quaquaversal—Turning each way.

Quarry—A stone mine; a place where stones are dug.

Quartz—Ger. Rock crystal. A constituent of granite and some other rocks.

Qua'rtzose—Of the nature of quartz.

Radia'ta—Lat. Radiate: the name of a class of zo'ophytes.

Ra'diate—fr. lat. *radius*, a ray. Furnished with rays.

Ra'dius—Lat. A ray. The semidiameter of a circle; a ray drawn from the centre to the circumference.

Radia'tion—The emission of rays of light, or of heat, from a luminous or a heated body.

Ra'diolites—A genus of fossil shells; the inferior valve of which is in the shape of a reversed cone, the superior valve convex (p. 69).

Raft—Trunks of trees and other vegetable debris matted together, by natural causes, and sunk in a river or stream.

Rag—(p. 59).

Rapi'lli—Small volcanic cinders.

Reaction—The force exerted by two bodies which act mutually on each other.

Rea'lgar—Red sulphuret of arsenic. A compound of sulphur and arsenic.

Refrigera'tion—The act of cooling.

Resinous—Containing resin.

Retu'sus—Lat. Retuse; blunted.

Revolu'ta—Lat. Turned again.

Rock—Any mineral aggregate (p.13).

Rodentia — fr. lat. *rodere*, to gnaw. An order of mammals.

Rodents—Gnawers; animals of the order of rodentia.

Rolled flints—(p. 129).

Rostella'ria — fr. lat. *rostellum*, a little beak. A genus of univalve mollusks (p. 85).

Rothomage'nsis — Lat. from *rothoma'gum*, a temple of Roth, a divinity of that part of Gaul, now called Normandy; hence too the name of the city Rouen. Belonging or relating to Rouen. Specific name of an ammonite.

Rothe-todte-liegende—Ger. New red sandstone (note, p. 47).

Rota'ta — Lat. Rotate; wheel-shaped.

Rotu'ndus—Lat. Round.

Rubble — Angular and broken fragments of subjacent rock lying beneath the superficial mould.

Rudi'stes—fr. lat. *rudis*, unacquainted, because the characters of the animal were unknown. Name of a family of extinct mollusks in the shells of which neither the hinge, the ligament of the valves, nor the muscle of attachment is discoverable. The family contains six genera: *Spherulites*, *Radiolites*, *Calceola*, *Birostrites*, *Discina*, and *Crania*.

Ru'gosa—Lat. Rugose, wrinkled.

Rugosity—A wrinkling.

Rumina'ntia — Order of mammals which chew the cud.

Ruminants—Animals that chew the cud.

Rya'colite—(p. 120).

Saccharoïd — fr. lat. *saccharum*, sugar, and gr. *eidos*, resemblance. Resembling loaf-sugar.

Sal-ammo'niac — A compound of ammonia and hydrochloric acid. Muriate of ammonia.

Salï'ferous formation—(p. 47).

Salt — Any combination of an acid with a salifiable substance.

Sandali'na—Lat. Sandal-like.

Sandstein—Ger. Sandstone.

Sandstone—Any rock consisting of aggregated grains of sand.

Sau'rians — fr. gr. *sauros*, a lizard. Animals of the lizard tribe.

Sauröid—fr. gr. *sauros*, a lizard, *eidos*, resemblance. Resembling a lizard.

Saxi'genous — fr. lat. *saxum*, rock, and gr. *geinomai*, I produce. Rock producing; rock forming.

Sca'bra—Lat. Rough.

Scaphi'tes — fr. gr. *skaphe*, a boat. The boat ammonite (p. 73).

Schist — Ger. fr. gr. *schistos*, split. Slate.

Schisto'se—Slaty.

Sco'riæ — Lat. plur. of *scoria*, dross. Volcanic cinders. Cinders and slags of basaltic lavas of a reddish brown and black colour.

Scoria'ceous — Of the nature of scoriæ.

Sco'riform—In form of scoriæ.

Seams —Thin layers or strata interposed between others.

Secondary formation—(p. 36).

Secreted — Separated by the action of organs.

Se'diment — fr. lat. *sedeo*, I sit, that which subsides, or settles to the bottom of any liquid; dregs.

Sedime'ntary—Belonging or relating to sediment.

Sel'enite—A variety of gypsum.

Sella—Lat. A saddle.

Semicry'stalline — Partly crystalline.

Sensibly—Perceptibly.

Se'pia—A kind of paint or ink prepared from the cuttle-fish.

Septa—Lat. plur. of septum.

Septa'ria—"Flattened balls of stone, which have been more or less cracked in different directions and cemented together by mineral matter which fills the fissures."

Septum—Lat. A partition.

Seria'le'—Lat. fr. *seria*, a jar. Jar-like.

Ser'pentine—A magnesian rock of various colours and often speckled like a serpents back. It is generally dark green.

Ser'pula—fr. lat. *serpo*, I creep. A genus of anneli'dans which inhabit a calcareous tube, usually adherent to the shells of mollusks.

Ses'sile — fr. lat. *sessilis*, dwarfish. Without a pedicle or support.

Shale — An indurated slaty clay, or clay-slate.

Shingle—Loose, water-worn gravel and pebbles.

Sigilla'ria — fr. lat. *si'gillum*, a seal. Fossil plants found in the coal formation.

Si'lex—fr. gr. *chalis*, a pebble. The principal constituent of quartz, rock-crystal, flint, and other *silicious* minerals.

Si'lica—Silicious earth; the oxide of *silicon* (the elementary basis of silica), constituting almost the whole of *silex* or flint. It combines with many of the metallic oxides, and is hence sometimes called *sili'cic acid*.

Si'licate — A compound of silicic acid and a base; silicate of iron is a compound of silicic acid and oxide of iron; *plate-glass* and *window-glass* are silicates of soda and potassa, and *flint-glass* is a similar compound with a large addition of silicate of lead.

Sili'cious—Containing silica.

Sili'cified—Petrified or mineralized by silicious earth.

Silt — The name given to the sand, clay, and earth which accumulate in running waters.

Silu'rian system—Series of rocks formerly known as the *greywacke series* (p. 28).

Sinua'ta—Lat. Hollow, excavated.

Si'nus — Lat. A hollow or excavation.

Sinuo'sity—A hollow, an irregular, winding excavation or hollow.

Si'phon — fr. gr. *siphôn*, a tube. A cylindrical canal, perforating the partitions of multilocular shells.

Si'phuncle—A small siphon.

Slate — A well known rock, which is divisible into thin plates or layers.

Socia'lis—Lat. Social; relating to companions.

Solfata'ra — It. A volcanic vent emitting sulphur and sulphurous compounds (p. 115).

Solem—Lat. The sun.

Somma—It. (p. 103).

Spata'ngus—fr. gr. *spataggos*, a species of echinus. A genus of sea-urchins, having the mouth situated laterally, and but four rows of pores.

Species — A kind; a subdivision of genus.

Specific weight, or **Specific gravity**—The relative weight of one body with that of another of equal volume.

Spæno'pteris — fr. gr. *sphen*, a wedge, *pteris*, a fern. A genus of fossil plants.

Sphe'nophy'llites — fr. gr. *sphen*, wedge, *phullon*, leaf, *lithos*, stone. A family of fossil plants.

Sphe'rulites — fr. gr. *sphaira*, a sphere, *lithos*, a stone. A variety of obsidian or pearlstone which occurs in rounded grains.

Spino'sa }
Spino'sum } Lat. Spinous; covered with spines.

Spi'rifer—(p. 30).

Stala'ctites—fr. gr. *stalassô*, I drop. Conical concretions of carbonate of lime attached to the roofs of calcarious caverns, and formed by the gradual dropping of water holding the carbonate in solution.

Stala'gmites — Stalactical formations of carbonate of lime, found on the floors of calcareous caverns.

Stau'rotide—fr. gr. *stauros*, a cross, *eidos*, form. Cross-stone. Prismatic garnet. It is very abundant in New England.

Stellas—Lat. Stars.

Stigma'ria — fr. gr. *stigma*, an impression. A vegetable fossil (p. 42).

Stra'ta—Lat. plur. of stratum.

Stra'tum—Lat. A layer, a bed.

Stratifica'tion—An arrangement in beds or layers.

Stra'tified—Arranged in strata.

Striæ — Lat. Diminutive channels or creases.

Striated—Marked with striæ.

Strike—The direction of strata; the line of bearing (p. 185).

Sub—Lat. Under.

Subapennine—Applied to a portion of the pliocene strata. Low hills which border the Apennines.

Sublima'tion — The process by which volatile substances are raised by heat, and again condensed into the solid form. The substances so obtained are called *sub'limates.*

Submarine—Beneath the sea.

Submerged — Immersed or covered by water.

Subplica'ta—Lat. Somewhat plaited.

Subsidence—(p. 99).

Substratum — An under-layer or bed.

Sulca'ta } Lat. Sulcate; grooved
Sulca'tus } or furrowed.

Sulphatisa'tion — The act of converting into compounds containing sulphur.

Sul'phuret — A compound of sulphur with an other solid.

Sulphu'ric } Relating to sulphur.
Sulphurous } Applied to acids composed of sulphur and oxygen.

Superposed — fr. lat. *super*, above, *pono*, I place. Placed above.

Syenite and sienite — A granitic rock from *Syene* or *Siena*, in Egypt. It consists of quartz, feldspar and hornblende. It is tougher than granite and a more durable building stone.

Synclinal—fr. gr. *sun*, with, *klinein*, to incline. Synclinal axis (p. 160).

System of upheaval — (p. 189 and 191).

Tabular—In form of a table; horizontal.

Talc—A foliated magnesian mineral of an unctuous feel, often used for tracing lines on wood, cloth, &c. which are not so easily effaced as those of chalk.

tal'cose—Of the nature of talc.

ta'lus—A sloping heap of fragments accumulated at the foot of a steep rock.

Temperature—A definite degree of sensible heat.

Tendon—f. gr. *teinô*, I stretch. A fibrous cord at the extremity of a muscle, by which the muscle is attached to a bone.

Terebe'llum—fr. lat. *terebro*, I bore. A genus of gasteropod mollusks.

Terebra'tula—(p. 30).

Ter'minal—Belonging to the end.

Tertiary formation—(p. 77).

Testa'ceous — fr. lat. *testa*, a shell. Consisting of carbonate of lime and animal matter.

Testudina'ria—A tribe of chelonian reptiles.

The'rmal — fr. gr. *therme*, heat. Warm, hot.

The'rmometer—fr. gr. *therme*, heat, *metron*, measure. An instrument for measuring heat.

Thin out — Strata are said to *thin out* when they diminish in thickness.

Tissue—fr. lat. *tela*, a web. A web, or web-like structure, constituting the elementary structures of animals and plants.

Tra'chyte — fr. gr. *trachus*, rough. A variety of lava. A feldspathic rock, which often contains glassy feldspar and hornblende. When the feldspar crystals are thickly and uniformly disseminated, it is called *trachytic porphyry.*

Transition formation — (p. 26).

Trap — From the Sweedish *trappa*, a flight of stairs, because *trap rocks* frequently occur in large tabular masses rising one above another like the successive steps of a stair case. Applied to certain igneous rocks composed of feldspar, augite and hornblende.

Tra'ppean—Relating to trap rocks.

Trapezoidal—In form of a trapezium.

Tra'vertin—fr. it. *travertino.* Limestone deposited from water holding carbonate of lime in solution. It is found in the sweet springs of Virginia, and at the hot springs of the Washita, in Arkansas, as well as in many other places.

Tre'molite—A mineral, often of a fibrous structure, generally containing si'lica, magnesia, and carbonate of lime, originally found in the valley of Tremola on St. Gothard.

Trenchant—Cutting.

Trias—fr. lat. *tres,* three (p. 49).

Tria'ssic—Of the nature of trias.

Trigona'lis—Lat. fr. gr. *treis,* three, *gônia,* angle. Having three angles or corners.

Trigo'nia—fr. gr. *trigônos,* three-cornered. A genus of bivalve mollusks most of which are extinct.

Trigo'nula—Lat. Having three little angles.

Trilobite—(p. 28).

Tritura'tion—fr. lat. *tritus,* rubbed. The act of rubbing or grinding.

Truncate—Terminating very abruptly, as if a portion had been cut off.

Trunca'tus—Lat. Truncate.

Tu'fa—It. A volcanic rock, composed of an agglutination of fragmented scoriæ.

Turbo—Lat. A twisting. A genus of univalve gasteropods.

Turbina'ta
Turbina'tum } Lat. Shaped like a top.

Turri'culated—Resembling a tower with turrets.

Turrilites—(p. 73).

Turrite'lla—Lat. A little tower or turret. A genus of gasteropods.

Unconformable stratification—(p. 185).

Undula'tion—A wave; arranged in a wave-like manner.

Undula'tus—Lat. Waved; having a waved surface.

Unilo'cular—fr. lat. *unus,* one, *loculus,* partition. Having but one chamber or compartment.

U'nio—Lat. A pearl. A genus of mussels.

Uniones—plur. of unio.

Unstratified—Not stratified.

Upheaval—(p. 99).

Uptilted—Tilted up; raised at one end.

Ursus—Lat. A bear.

Valleys of dislocation—(p. 164).

Valleys of elevation—(p. 161).

Va'rians—Lat. Varying, changing.

Vas'cular—Containing numerous vessels.

Vegetative life—Life of nutrition.

Vegetable earth—(p. 14).

Veins—(p. 118).

Ve'nerica'rdia—fr. *Venus,* and *ca'rdium.* A genus of bivalve mollusks.

Ventrico'sa—Lat. Ventricose; inflated, swelled in the middle.

Ve'rtebra—fr. lat. *vertere,* to turn. A joint or bone of the spine.

Ve'rtebræ—Plur. of vertebra.

Ve'rtebral column—The spine or back-bone.

Ver'tetbrate—Having vertebræ, or a spine.

Vesicula'ris—Lat. Vesicular; containing vesicles.

Vi'rgula—Lat. A little rod.

Vi'ridis—Lat. Green.

Vi'treous—fr. lat. *vitrea,* glass. Resembling glass.

Vi'treo-res'inous—Partaking of the nature of glass and resin.

Vo'latile—fr. lat. *volo,* I fly. Capable of assuming the state of vapour, and *flying off.*

Vola'tilize—To become volatile.

Volcan
Volcano } (p. 104).

Volca'nic—Relating to a volcano.

Volt′zia	A genus of fossil co′nifers.
Volu′ta	Lat. A whorl. A genus of gasteropods.
Vo′sgean	Belonging or relating to Vosges.
Vulga′ris	Lat. Common.
Wal′chia	A genus of fossil co′nifers (p. 43).
Weald	Name of a part of Kent and Surrey in England.
Wealden deposit	(p. 69).
Whinstone	A Scotch name for greenstone and other trap rocks.
Za′mia	fr. gr. *zemia*, loss or damage. A genus of the order Cyca′deæ plants.
Zechstein	Ger. A magnesian limestone, lying under the red standstone.
Zo′ophyte	fr. gr. *zoôn*, an animal, *phuton*, plant. A plant-animal, which seemingly partakes of the properties of both plants and animals.

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The publishers have just received, for one school, in Bangor, Maine, an order for seventy-five copies each of the above valuable works, which is an evidence of the high estimation in which they are held in that section of country, by some among the best teachers in New England.

Portland, August 22, 1845.

DEAR SIR:—Your note, accompanying Dr. Ruschenberger's Elementary Books on Natural History, for the use of schools, &c., was duly received, for which please accept, for yourself and the publishers, my sincere thanks.

Having examined several of the volumes, I take great pleasure in expressing my approbation of the work. It is better adapted to the purposes of elementary instruction than any other cheap work with which I am acquainted.

Among its many merits I regard that of the constant adherence of the author to the language of science as peculiarly worthy of notice. Although the descriptions of the various objects treated of may appear obscure at first sight, every difficulty is removed by the copious glossary which accompanies each volume. While the student is acquiring accurate instruction in natural history, he is, at the same time, and with no additional labour, adding essentially to his vocabulary.

With these remarks I would most cordially recommend the work as well adapted to fulfil the objects for which it is published.

With much respect yours truly,
J. W. MIGHELS,
Member of the Natural History Societies in Boston and Portland, also of the American Association of Geologists, &c. &c. &c.

Brunswick, Maine, Sept. 19, 1845.

Our schools have long felt a want of suitable text books on the several branches of Natural History; but this desideratum has been happily supplied by Dr. Ruschenberger's series, published by Messrs. Grigg & Elliot, of Philadelphia.

These truly scientific, yet cheap works, can scarcely fail of diffusing a more extended taste for those too long neglected branches of education, which, when properly pursued, will breathe new life and vigour into our systems of education.

Elementary works on Natural History are too often spoiled by an attempt to divest them of scientific terms, thus rendering the simple and determinate language of science a confused and unmeaning gibberish. But these works are a noble exception, simple in their arrangement, and precise in their definitions. Professor PARKER CLEAVELAND, LL. D.
Bowdoin College, Brunswick, Maine.

I heartily concur in the above opinion of Dr. R.'s works, and shall use my influence to have them introduced to Brunswick Seminary.

Yours truly,
G. C. SWALLOW, A. M.
Principal Brunswick Academy, Brunswick, Maine.

Portland, Aug. 21, 1845.

DEAR SIRS:—Dr. Ruschenberger's series of "First Books of Natural History" is a most valuable acquisition to all classes of readers, especially to the young.

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Though closed is my course of thirty-five years teaching, I am tempted to begin the work anew with these delightful books as auxiliaries. They should be in the HANDS OF ALL TEACHERS who can instruct, and all pupils who can learn.

Yours most truly,
B. CUSHMAN, A. M.
Portland, late Principal of the Academy.

Illinois College, Sept. 5, 1845.

It is three years since I first became acquainted with Ruschenberger's Series of First Books of Natural History, and I have examined those of the series which have appeared since that time. I have also used these books in the instruction of my classes in college, and I am happy to state that I consider them as vastly superior, for the purposes of instruction, to any book or series of books on the same subject in our language. I take pleasure, therefore, in expressing the opinion that the extensive introduction of these books into the courses of instruction in the Colleges of the United States would prove of incalculable advantage to the progress of sound education among us.

SAMUEL ADAMS, M. D.
Professor of Chemistry and Natural History, Illinois College.

I cheerfully concur in the opinion which Dr. Adams has expressed, and shall use the influence I may have to facilitate the introduction of these works into SCHOOLS and PUBLIC SEMINARIES.

J. M. STURTEVANT,
Jacksonville, Sept. 8, 1845. *President of Illinois College.*

Pa. Literary, Scientific, and Military Collegiate Institute.

GENTLEMEN:—I have examined, with attention, the First Books of Natural History, by Dr. Ruschenberger, and unhesitatingly express my approbation of its superior merits. I think it well adapted to the wants of our Seminaries of Learning generally, and that it should also constitute a part of every private library. As such, I confidently recommend it to the patronage of an enlightened public.

A. PARTRIDGE,
Pres. of the Pa. L. S. M. C. Institute.

Messrs. GRIGG & ELLIOT, *Philadelphia.*

Woodward College, Cincinnati, Ohio.

GENTLEMEN:—I have examined Dr. Ruschenberger's series of school books in the different branches of Natural History. The volumes are, in every respect, exceedingly well got up, and their cheapness will place them within the reach of all classes.

It is judged expedient to introduce the subject of Natural History among the studies of our Common Schools. I know not a work so well adapted as Dr. Ruschenberger's, not only by its plainness of style, but by its numerous and excellent engravings. The last are essential to the understanding of such works, and yet their cost has hitherto been so great as to exclude them from common schools.

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