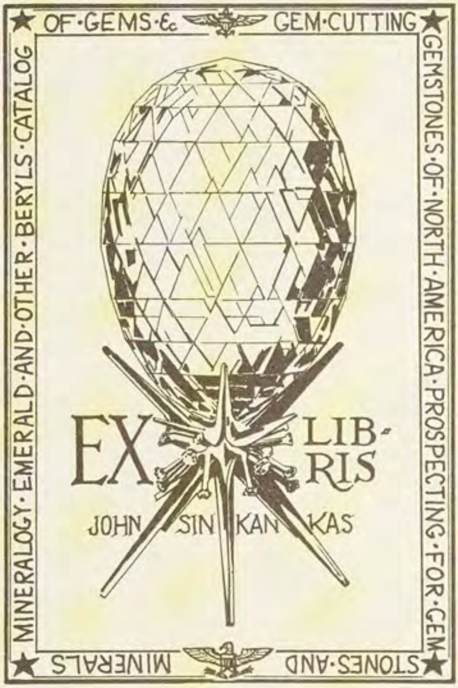
MACGILLIVRAY'S MANUALS OF NATURAL HISTORY.

GEOLOGY.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MANUAL

OF

GEOLOGY.

BY

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IN THE
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ADVERTISEMENT.

An increasing taste for the study of Natural History having been strongly evinced by the formation of numerous societies in all parts of the kingdom, to promote the cultivation of this most interesting department of science, and by the introduction of some of its more popular branches into many of our educational institutions, the Author has been led to believe that a Series of Manuals, exhibiting, in a condensed form, the more important facts and phenomena, and an account of the different theories elicited from them, might be acceptable to many who are desirous of obtaining a knowledge of its various branches in a systematic manner, and at as little expense of time and money as the subject will admit. With this view, he intends to prepare a Series of Treatises on a plan more adapted for elementary instruction than any which are at present known to him. They will be written in easily intelligible language, yet so as not to sacrifice truth to ornament, or to substitute sentimentalism for science. By carefully condensing the materials, selecting appropriate illustrations, and adding a glossary of terms, it is hoped that as much knowledge of the different subjects will be conveyed as will suffice for general instruction, and enable those who are desirous of extending their information to pursue their inquiries with advantage. In the anticipation that the study of Nature will assume a still more prominent part in national education, the Author purposes to adopt such an arrangement of his subjects as will render the manuals suitable for class-books, and to append to each chapter a recapitulatory series of questions.

Of this series are published Manuals of Botany and British Ornithology.

EDINBURGH, *25th January*, 1840.

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INTRODUCTION.

1. Geology may be defined a Science which unfolds the Physical Conditions and Composition of the Earth, describes the Phenomena exhibited by its Component Parts, explains the Mutual Action of its Elements, and accounts for the Disposition and Relations of the Materials of which it is constructed. The name of this science is a compound of two Greek words: γη, ge, earth; and λογος, logos, discourse or doctrine.

2. It has, however, been variously defined and subdivided. Thus, M. d'Aubuisson, who, like other disciples of the illustrious Werner, designates it by the term Geognosy, compounded of γη, ge, earth, and γνωσις, gnosis, knowledge, states, that "its principal object is the knowledge of the mineral masses, or rather of the various groups, or systems of mineral masses, the aggregate of which composes the solid part of the terrestrial globe. It considers the mineralogical composition, structure, form, and extent, of each of these systems; treats of their relative arrangement, of the circumstances of their mutual superposition, and of their various relations to each other. Whatever has reference to the mode and period of their formation, the changes which they have undergone, in short, whatever is connected with their natural history, belongs to it; and since our globe is formed only by their aggregate, the knowledge of its constitution, physical as well as mineral, will be the final result of this science." According to Mr. Lyell, the inquiries with which Geology is occupied are these:—"Of what materials is the earth composed, and in what manner are these materials arranged?" Mr. Bakewell informs us, that the peculiar

objects of geological research are:—"1st, The materials of which the solid crust of the globe is composed; 2d, The arrangement of rocks and strata; 3d, The changes which the surface of the earth has undergone." M. Delafosse divides Mineralogy into two branches: MINERALOGY, properly so called, which has regard to the general properties and particular characters of minerals, their methodical classification, and economical uses; and "GEOLOGY or GEOGNOSY, which considers minerals with reference to their modes of existence in nature, the part which they perform in the structure of the globe, of which they are the materials, the laws which regulate their associations and relative positions, and of which the knowledge guides the miner in searching for useful substances; lastly, with reference to the valuable documents which they are capable of supplying to illustrate the history of the earth."

3. Some authors, in treating of it, having confined their view to a particular aspect, which seemed to them especially interesting; while others have indulged in unfounded conjectures respecting the origin and duration of the object to which it refers, and not a few have striven to render it a criterion of the truth of Revelation, or have exultingly announced, that the strata of the globe disclose a philosophy contradictory to the Mosaic account of the Creation. As might be expected, many persons have imbibed a prejudice against the study, believing it to lead to scepticism; but the crude reasonings and unwarranted speculations that attend the progress of every branch of Natural History being gradually shown to be inconsistent and futile, ought not to be considered as impediments in the search for truth; and at the present day, in our happy country at least, attempts to subvert the moral government of the world find little favour with those who are moderately informed. Indeed, a reaction has very naturally taken place, so that in the minds of many the positive truths of Geology are apt to be confounded with the idle fancies of its cultivators. But this science is not more implicated with Revelation than Botany

or Zoology, against which no religious prejudice exists; and it is time that men should cease to bring them into collision.

4. The interest which Geology has recently excited among us is not confined to the class of persons who devote themselves to scientific investigations, but, in the progress of general information, has extended even to those whose chief object in reading is to find amusement. To such persons the multiplied details which form the only true basis of Natural History are of little estimation, while florid descriptions and ingenious theories are highly gratifying. On the other hand, the student, of whatever condition of life, who wishes to add to his accomplishments some knowledge of a science that may prove in various ways useful to him, is desirous of obtaining a demonstration of facts and phenomena, before attempting generalizations. These circumstances require to be kept in mind by one who would offer himself as a guide to the young geologist, and he who on this occasion comes forward as such has endeavoured to adapt his Treatise to an extended class.

5. The method which has been adopted results directly from the terms of the definition employed above. The First Section treats of the Physical Conditions and Composition of the Earth; the Second, of the Arrangement of the Component Parts of the Earth; the Third, of the Causes of the Present State and Relations of the Materials of the Earth. These sections are divided into chapters, those of the first treating of the General Nature of the Globe, the Atmosphere, the Ocean, the Distribution of the Land, its Inequalities, Elementary Substances, Simple Minerals, and more common Rocks. Geology being so directly implicated with Botany and Zoology, that the phenomena which it exhibits cannot be intelligibly stated, without supposing some previous knowledge of these sciences, it has been found necessary to present a general outline of the vegetable and animal kingdoms. The second section treats of the Distribution, Arrangement, Structure, and Composition of Rocks, and, dividing them into series, describes the Fundamental, Pri-

mary, Secondary, Tertiary, Alluvial, Overlying, and Volcanic Rocks, the stratified series being given in the order of succession from below upwards. Although the descriptions are concise, they embrace a very considerable number of facts and details, and are occasionally interspersed with theoretical explanations. In the third section it is attempted to account for the present state and relations of the Materials of which the Earth is composed. The Formations of the present period of the Globe, including soil, detritus, deposits from rivers, marine deposits, coral limestones, and volcanic products, are described. Then follow conjectures respecting the central parts of the globe, and the connexion of the igneous rocks of different ages. Lastly, various circumstances relative to the stratified rocks, the formation of caves, and diluvial currents, are explained, and a brief account of the opinions now prevalent respecting the structure of the globe is given. An Outline Geological Map of the British Islands, a Glossary of Terms, and an Index, complete the Treatise.

6. The facts, phenomena, and theoretical views, presented in this Essay, have been selected from the works of individuals who have distinguished themselves as zealous and trustworthy cultivators of geological science, and of whom the principal are Professor Jameson, Dr. MacCulloch, Dr. Buckland, Mr. Bakewell, Mr. Lyell, Mr. Murchison, Mr. Sedgwick, Mr. Phillips, M. De la Beche, M. D'Aubuisson, M. Delafosse, M. Rozet, and Mr. Milne-Edwards. Like other elementary works on the same subject, it is essentially a compilation. The author has on many occasions borrowed liberally, and on some has employed the very words of the original observers, his object having been simply to convey instruction. He has not, however, acted as a mere literary compiler, unacquainted with the objects which he describes; but having for many years devoted a portion of his time to the study of Geology, holds himself not incompetent to the task assumed.

SECTION I.

PHYSICAL CONDITIONS AND COMPOSITION OF THE EARTH.

CHAPTER I.

GENERAL IDEA OF THE EARTH: ITS FORM, DENSITY, TEMPERATURE, AND COMPONENT PARTS. THE ATMOSPHERE: ITS COMPOSITION, WEIGHT, TEMPERATURE, CURRENTS, WATER, ELECTRICITY AND AEROLITES. THE OCEAN: ITS COMPOSITION, TEMPERATURE, CURRENTS, EVAPORATION, POLAR ICE, AND THE NATURE OF ITS BED.

7. GENERAL IDEA OF THE EARTH.—The Earth or World which we inhabit, is one of a set of spheroidal bodies called Planets, which move round the Sun, or central star, in elliptical or nearly circular orbits. These bodies revolve on their axes with different degrees of velocity, and perform their journey round the sun in various periods; each, however, with unvarying regularity. The diurnal revolution of the Earth being divided into 24 hours, its annual revolution is accomplished in 365 days, 5 hours, 45 minutes, and 43 seconds. In this course, the Earth carries along with it the Moon, which revolves round it, performing twelve revolutions in the time occupied by it in passing once round the sun. The other bodies of the solar system move in the same manner as the earth, revolving round the sun in a narrow belt named the zodiac, several of them accompanied by moons or satellites, which revolve round them. The mutual attractions of these bodies are productive of regulated per-

turbations, of which the examination is of little importance in a geological point of view; but the influence of the moon, especially with reference to the tides, or periodical movements of the water, is productive of considerable changes.

8. FORM OF THE EARTH.—The Earth is an oblate spheroid, or somewhat compressed globe, of which the equatorial diameter is about 26 or 27 miles greater than the polar, the former being, according to Herschel, 7925.648, the latter, 7899.170 miles. This form is such as would be assumed by a homogeneous yielding, loose or semifluid body, rapidly revolving on its axis, as may be illustrated by thrusting a rod through a ball of soft clay or putty, and giving it a rotatory motion, in consequence of which the ball will become flattened at the poles, and in a corresponding degree enlarged at the equator. The greater convexity of the equatorial parts thus effected results from the centrifugal force being greater at the circumference than at the centre of motion. It is accordingly conjectured that the earth has been originally in some degree, in whole or in part, fluid or loose, so that its particles have been displaced by its revolution, until ultimately becoming fixed, they have permanently assumed the spheroidal form.

9. DENSITY OF THE EARTH.—The density of the matter of which the earth is composed, compared with that of an equal bulk of any given substance, may be determined by the attraction exerted by a mass of matter upon a plummet so as to draw it from the perpendicular line, this attraction being proportional to the quantity of matter in the given mass as compared with that of the earth. Dr. Maskelyne, accordingly, from an experiment of this nature made on Schichallion, a precipitous mountain in Perthshire, inferred that the mean density of the earth was to that of the mountain as 9 to 5, and hence he concluded that the interior of the earth is composed of substances, of which the density is about double that of the mass of the mountain. But Mr. Playfair, finding that the specific gravity of the mountain had been estimated too high, obtained only 5 for the density

of the earth. This result, being in accordance with astronomical considerations, has been generally adopted. It thus appears that the interior of the earth is much denser than the parts at its surface; for, taking water, at the temperature of 60° as 1, we find that the heaviest rocks with which we are acquainted have a density of only 3, while the lightest are little more than 2, and the specific gravity of the ocean slightly exceeds 1. Thus, the specific gravity of the earth, including the water, cannot be much more than $2\frac{1}{4}$, so that the parts in the interior must be correspondingly heavier to produce the mean gravity of 5.

10. TEMPERATURE OF THE EARTH.—Considering the earth as bounded by the surface of the waters, and of that part of the land which projects beyond their level, so as to exclude the atmosphere, we find that the temperature of its external parts exhibits great variation. As the sun's rays are the chief source of heat at the surface, and as the temperature varies according to the quantity of these rays, there is a gradual diminution of heat from the equator, where their direction is perpendicular, to the poles, where they fall obliquely. The heat communicated by solar irradiation is modified by the varying nature of the surface, of which the texture, colour, and capacity for caloric, together with the elevation, and other circumstances, produce in different localities differences in the quantity of heat absorbed. Thus, sandy and rocky surfaces readily absorb and give out heat; tracts covered with vegetation absorb heat by day, and as freely radiate it by night; and the snows which cover the circumpolar regions are impenetrable to the solar rays, while they also prevent the radiation of the earth's heat. The temperature of the ocean is more equable than that of the land, owing to the continual upward and downward motions of its particles, caused by the changes of heat at its surface, and the constant or periodical movements of its waters. The currents of the atmosphere induce great changes in the temperature of the circumpolar regions, and the diminution of its heat as we recede from the surface of

the globe, has a similar effect, the elevated ridges, covered with snow, that present themselves even in the tropical regions, tending to moderate, by the currents of cold air, and the numerous streams, which participate of their frigidity, the intense heat of those sunny climes. The heat derived from the solar rays is again in part dispersed into the atmosphere, so that no permanent accumulation of it takes place either generally or in particular districts. Indeed, the contrary has been inferred from various considerations, although the progressive diminution of the temperature is so slight as not to effect any perceptible change in a thousand years. But beyond a certain depth, or that of 100 feet, at which the influence of the sun's rays ceases, experiments made in mines in different parts of the world, appear to render it probable that the temperature increases towards the centre, and this in a regulated gradation, which M. Cordier has concluded to be one degree of Fahrenheit's thermometer in forty-five feet. This result of observation is in accordance with that deduced from mathematical investigations, and is further strengthened by the occurrence of abundant remains of plants belonging to warm climates, in regions now incapable of producing them on account of their low temperature. The differences of temperature in bodies are indicated by an instrument named a Thermometer, which is generally a slender glass tube, closed at both ends, terminated below by a bulb, and partially filled with mercury. The contraction and expansion of that fluid, being caused by the diminution or increase of heat, shows the temperature of an object with which the instrument is in contact.

11. Component parts of the Earth.—The materials of which the earth is composed exist in three states, the solid, the liquid, and the aeriform. The greater part of the globe may be considered as solid, since its mean specific gravity is greater than that of the rocks at its surface ; but whether the solid mass be in a state of partial fluidity or not, although various considerations would lead us to infer that it is, we cannot with certainty know, since the depth to

which we have been able to penetrate is comparatively insignificant, the distance from the highest strata to the lowest part of the excavations made in mines not exceeding eight miles. It is this external part of the globe, accessible to observation, which technically bears the name of the earth's CRUST: a term not meant to imply any theoretical idea, but simply to designate the superficial portion of the globe, the thickness of which, compared with the bulk of the earth itself, as Mr. Bakewell observes, "does not exceed that of a coat of varnish upon an artificial terrestrial globe." Taking a general view of the earth, we find that its surface, which is calculated to contain about 199,000,000 of square miles, is partly composed of land, and partly of water, the latter predominating in the proportion of 4 to 1. The globe, thus circumscribed, is surrounded by an aeriform fluid, the atmosphere, which, although, properly speaking, not a part of it, requires to be here considered, on account of the influence which it exercises upon it. We have thus three distinct subjects of investigation, the LAND, the WATER, and the AIR. The last of these, which is the proper subject of the science of Meteorology, requiring little notice in a treatise of this kind, may be first considered.

OF THE ATMOSPHERE.

12. COMPOSITION OF THE ATMOSPHERE.—The aeriform envelope of the earth, which, from its refractive powers, has been calculated to extend to the height of about 45 miles, is chiefly composed of atmospheric air, a mixture of oxygen and nitrogen in the proportion of about 1 part of the former to 4 of the latter, in volume, together with a very small quantity of carbonic acid gas, amounting only to about 3 parts in 1000. Or, in the language of the atomic theory, air is composed of 1 equivalent of oxygen, and 2 of nitrogen, the atomic weight of which gases being as 8 to 14, a given quantity of air will contain 8 parts of oxygen, and 28 of nitrogen, by weight. These proportions have invariably been found the same in all circumstances, in different climates, at

the greatest elevations, and in the lowest depressions or excavations. But there also enter into the composition of the atmosphere various other substances. All the bodies which exist in the gaseous state in ordinary temperatures, whether issuing from the interior of the globe, or emanating from the substances distributed over its surface, are found in it in greater or less quantity. Aqueous vapour, in particular, is generally dispersed in the atmosphere, increasing with the temperature of the climate and season, in the tropics often forming nearly a 30th part of its bulk, in temperate regions from a 65th part in summer to a 200^{dth} part in winter, and gradually diminishing the greater the elevation. It is, moreover, pervaded by caloric and electricity, the effects of which are every where perceptible. The component parts of the air not being combined, but merely mixed, readily enter into composition with various mineral bodies, in which they thus effect great alterations.

13. Weight and Pressure of the Atmosphere.—In common with other bodies, atmospheric air has weight; as is proved by weighing, in a very delicate balance, a bottle containing air, and afterwards the same vessel when emptied by the air-pump. Like other heavy fluids, it exercises pressure upon all substances in contact with it. Thus, it is calculated to press upon the surface of the human body with a weight of several tons. In consequence of the varying pressure of its superincumbent mass, its density varies in particular places, and at different times. As we ascend in the atmosphere, the density becomes less, because the extent and weight of the parts above are diminished: for air, being an elastic fluid, increasing in bulk and diminishing in density, whenever the external pressure is removed or lessened, and its tendency to expand being dependent upon an elastic force in itself, this elastic power is so much the more repressed, the greater the pressure upon it from without. At the level of the sea the density and weight of the atmosphere are thus much greater than at the summit of a mountain; and the differences observed at different eleva-

tions having been found sufficiently regular, serve to indicate the height of mountains. The pressure of the atmosphere upon the surface of a fluid balances, in a tube communicating with it, a column of the fluid equal in weight to a column of the atmosphere itself. On this principle is constructed the Barometer, in which the varying pressure of the air is indicated by the ascent and descent of a column of mercury about 28 inches high. In ascending a mountain, the column diminishes, because the height of the superincumbent atmosphere diminishes the higher we go. The same instrument indicates, in a particular place, the variations in density caused by difference of temperature, the absence or presence of moisture, and other circumstances.

14. Temperature of the Atmosphere.—The temperature of the atmosphere is greatest at the surface of the earth, and gradually diminishes as we ascend in it, this change being dependent upon the unequal density of its strata, which become more rarefied in proportion to their height. The diminution of the atmospheric temperature varies in different climates, being more rapid in the temperate than in the torrid zone. At the equator, the line of perpetual congelation is stated to be 15,207 feet above the level of the sea; in lat. 15°, 14,220; in 30°, 11,484; in 45°, 7,671; in 60°, 3,818; in 70°, 1,778; and in 80°, 457. This arrangement is productive of the most beneficial results, the snow-clad mountains of the warmer regions of the globe being the sources of abundant streams, which irrigate regions that would otherwise be doomed to sterility.

15. Currents of the Atmosphere.—Although the atmospheric mass is equably distributed over the surface of the globe, it is seldom any where in a state of perfect rest, some of its parts being always agitated in various degrees, so as to give rise to currents, of which some are regular and periodical, while others are accidental. Of the former kind are the trade-winds, monsoons, sea and land breezes, which are caused by the rotatory motion of the globe being greater

than that of the air, in consequence of which the latter seems to move in a contrary direction, from east to west; or from the combined attraction of the sun and moon producing tides in the atmosphere, as in the sea; or from the rarefaction of the air over the land induced by the heat of the sun's rays; or from various other causes. The irregular movements, or ordinary winds, are produced by variations of temperature, or of electrical distribution, and have frequently a circular or rotatory motion. Considerable alterations are effected on the earth's surface by winds, which sometimes destroy vegetation, cause inundations, and overwhelm fertile tracts with arid sand.

16. Atmospheric Water.—From the waters spread out on the earth's surface, vapour is continually rising into the atmosphere, in which it is partially dissolved, becoming perfectly invisible; while the rest forms masses of various forms and dimensions, constituting mists and clouds. The water diffused in the air thus exists in two states. In one, the aqueous particles are combined with those of the air; and the force of their cohesion is so great, that chemical agents must be employed to separate them. In the other, it is supposed that the aqueous vapours form minute vesicles, which reflect the light, and are thus rendered visible. These vesicles or globules must be capable of contracting and dilating, and thus vary the weight of the clouds, which alternately rise and fall. The aqueous vapours dispersed through the air cause deliquescence of bodies, such as certain salts, and especially those of which soda and potash form an ingredient, these substances having a great affinity for water. By combining with other substances, they change their state of aggregation; and thus some limestones, clays, and metallic oxides, are ultimately reduced to powder. When the clouds are condensed they descend, and on being agitated let fall the water which they contain in the form of rain, the quantity of which is often so great, as, in collecting in hollows, to carry with it soil, sand, gravel, and fragments of rocks, scooping out channels, and depositing the particles on reach-

ing the more level places, where the velocity of the water diminishes. Being absorbed by the soil, the atmospheric waters, gliding into the lowest levels, produce springs, rills, brooks, rivers, and lakes. Reduced to the solid state by the diminution of temperature, they form the snow and ice by which so large a portion of the globe is permanently or periodically covered.

17. ATMOSPHERIC ELECTRICITY.—The electric fluid which pervades all bodies, exists in great quantity in the clouds, from which it is discharged, either silently, or so as to give rise to the phenomena of lightning and thunder. Rocks are sometimes shivered by this cause, or their surface is melted; but the action of lightning is not productive of much apparent change on mineral masses. It is supposed by some that the formation of hail is owing to the electricity of the atmosphere. The cold of the upper regions congeals the water into very small particles or crystals, which, on the approach of differently electrified clouds, travel from one to the other, becoming conglomerated in their course, and forming hailstones of sufficient weight to render the power of gravitation predominant.

18. AEROLITES OR METEORIC STONES.—It is well known, that in many countries stones or mineral masses, of various sizes, have fallen from the air, accompanied with the disengagement of light, and a noise like thunder. These stones are of irregular form; their ridges and corners are often blunted, as if they had been partially melted; the surface is partly covered with a very thin vitrified layer, of a black colour; the fracture-surfaces are uneven, of a grey tint, and, on being exposed to the air, become covered with spots of rust, arising from fragments of pure iron interspersed; and, under the blowpipe, there form upon them little black globules, of the same nature as the external crust. Meteoric stones are generally harder than glass, have a specific gravity of from 3.3 to 4.3, and are more or less magnetic. They are composed of silica, iron, and magnesia, with a very small proportion of alumina, lime, nickel, chrome, and

sulphur. Large isolated masses of iron, having no connexion with the neighbouring rocks, were found in the plains of Siberia by Pallas, and in those of South America, by Humboldt. The metal in these masses being perfectly similar to that found in meteorites, and their form being irregular, these observers supposed them to be of similar origin. Shooting stars, which are frequently seen in great numbers in clear nights, are also conjectured to be meteoric stones.

Of the Ocean.

19. Composition of the Ocean.—It is calculated that the Ocean occupies about three-fourths of the surface of the globe. Laplace estimated its average depth at twelve miles, but it is now generally believed not to exceed five; and no actual measurement by soundings has extended beyond a mile and a quarter. But although the surface of the waters greatly exceeds that of the land, their bulk, compared with that of the latter, is only as 1 to 10,000. The colour of the sea is generally green or blue, of various tints, but differs according to its depth, the nature of the bottom, the quantity of minute animals which it contains, and the state of the atmosphere. Its taste is salt, with some degree of bitterness; and it has been found to contain muriate of soda in the proportion of 2½ per cent., sulphate of soda, muriate of magnesia, and muriate of lime, in that of ½ per cent. The proportion of salt varies, however, the water of the Mediterranean, for instance, containing 4.18 per cent., while that of the Baltic contains only 1.18. According to one of the most recent analyses, that of M. Laurens, the water of the Mediterranean contains in 1000 grains, of water 959.06, chloride of sodium or common salt 27.22, chloride of magnesium 6.14, sulphate of magnesia 7.02, sulphate of lime 0.15, carbonate of lime 0.09, carbonate of magnesia 0.11, carbonic acid 0.20, potash 0.01, some iodine, and a trace of extractive matter. Dr. G. Schweitzer found the water of the English Channel, near Brighton, to contain in 1000 grains, of water 964.74372, chloride of sodium 27.05948,

chloride of magnesium 3.66658, chloride of potassium 0.76552, bromide of magnesium 0.02929, sulphate of magnesia 2.29578, carbonate of lime 0.03301. Some idea may be formed of the vast quantity of saline matter contained in the sea from an estimate made by Mr. Bakewell, who says, that, "if the average depth of the sea be five miles, and it contain 2½ per cent. of salt, were the water entirely evaporated, the saline residue would form a stratum of salt more than 500 feet in thickness, covering three-fifths of the surface of the globe." Dr. Marcet, having examined sea-water from different parts of the globe, obtained the following results: "1. That the Southern Ocean contains more salt than the Northern Ocean, in the ratio of 1.02919 to 1.02757. 2. That the mean specific gravity of sea-water, near the equator, is 1.02777, or intermediate between that of the northern and southern hemispheres. 3. That there is no notable difference in sea-water, under different meridians. 4. That there is no satisfactory evidence that the sea at great depths is more salt than at the surface. 5. That the sea, in general, contains more salt where it is deepest and most remote from land; and that its saltness is always diminished in the vicinity of large masses of ice. 6. That small inland seas, though communicating with the ocean, are much less salt than the ocean itself. 7. That the Mediterranean contains a rather larger proportion of salt than the ocean."

20. Temperature of the Ocean.—The temperature of the surface of the sea increases from the polar regions, where it is always below zero, to the equator. While the temperature of the air diminishes as we rise from the earth's surface, that of the sea increases from below upwards. The maximum density of water being at 40° Fahr., and its motions being free, it arranges itself according to its density, so that the portion which is nearly of that temperature occupies the lowest place, while that which is more heated ascends. But it would appear that the diminution of heat has a limit beyond which the temperature remains the same, or even increases with the depth: thus—in 14° 22′ N. lat.

Captain Beechey found the temperature to diminish from 88° at the surface, to 48°.5 at the depth of 1800 feet, and at 2400 feet to rise again to 49°.5. In some parts of the ocean, as between Greenland and Spitzbergen, and in the Gulf Stream, the temperature has been found much greater at depths of from 100 to 200 fathoms than at the surface. In the southern hemisphere, the diminution of temperature, as we proceed from the equator to the pole, takes place more rapidly than in the northern.

21. Polar Ice.—It is probable that around the poles there is a continuous expanse of ice, the borders of which only have been examined by navigators. According to Mr. Scoresby, it is designated by various appellations, having reference to the form and extent of its masses. A Field is a continued sheet, so large, that its boundaries cannot be seen from the mast-head. When a field drives to the southward, and is exposed to the effects of a grown swell, it breaks into pieces, forty or fifty yards or less in diameter; such pieces extending so widely as not to be seen over from the mast, are termed a Pack. When the collection of pieces can be seen across, if it assume a circular form, it is called a Patch, or, if an elongated form, a Stream. Pieces of very large dimensions, but smaller than fields, are called Floes. Small pieces broken from larger masses by attrition, are called Brash-ice. Hummocks are protuberances raised upon any plane of ice above the common level; and Calves are portions of ice extending below the surface of the water. Icebergs are vast isolated masses of ice, sometimes rising to the height of 100 or even 200 feet above the surface, and extending beneath it to a much greater depth; the portion of salt-water ice that protrudes from the sea at a freezing temperature, being to that below the water as 1 to 4 nearly. Ice-fields are generated in the open sea; but icebergs are formed by glaciers, which sometimes terminating a precipitous edge on the coast, and being gradually protruded, at length break off, and fall into the sea. Fields of ice are almost constantly driving in summer, their general motion

being south-westward. They not unfrequently acquire a rotatory movement, in consequence of which their circumference attains a velocity of several miles an hour. A field, thus in motion, coming in contact with another, produces such a shock, as can hardly be conceived. It is remarkable that sea-ice contains very little salt.

22. Motions of the Sea.—The waters of the ocean are subject to various movements, of which some are general, others local or peculiar to certain spaces. The tides, which are of the former kind, are periodical alternating currents, depending upon the attraction of the moon, and varying in velocity according to the breadth or narrowness of the sea, the latitude, and other circumstances, the height being in some places, as the Bay of Fundy, as much as 120 feet, while in others the rise is scarcely perceptible. In general, the height is greater the narrower the channel, but in inland seas, such as the Baltic, Mediterranean, and Caspian, there are hardly any tides. Another general motion of the sea is that from east to west, more perceptible in the equatorial regions, and arising from the rotatory motion of the earth. The difference of temperature also between the polar and equatorial regions causes reciprocal movements from the one to the other.

The most extensive and remarkable of the partial movements of the ocean, is that known by the name of the Gulf Stream, which, setting out from the Indian Sea, doubles the Cape of Good Hope, passes along the African coast to the equator, crosses the Atlantic, enters the Gulf of Mexico, whence it emerges by the Straits of Florida, proceeds north-eastward, is deflected off Newfoundland, passes south-westward along the coasts of Britain, France, and Spain, and again joining the great equatorial current, crosses the Atlantic. A powerful current, which seems to join the Gulf Stream, passes through Davis' Straits, and proceeds southward along the coast of North America. On the western coast of South America, a current runs in the opposite direction. At the entrance of gulfs or inland seas, there is usually a superficial current from the ocean, while a current flowing beneath or at the sides carries off their waters. Such is the case in the Straits of Gibraltar, and the Sound of the Baltic.

Another kind of motion in the sea is that caused by the action of the wind, which, striking the surface obliquely, pushes some of the water on the surface over that in its vicinity, giving rise to waves. The motion of the sea thus caused does not, in the strongest gales, extend beyond 70 or 80 feet below the surface. The height of the waves varies according to the strength of the wind, and in very strong gales amounts to 30 feet. On a flat coast, the waves in advancing curl their ridges, and produce breakers; and on an abrupt rocky shore, being repelled by the impenetrable barrier presented to them, rise to a great height, and recoil. Considerable disintegrating effects are produced on rocky shores by the action of the waves, and on flat coasts they effect various changes.

These movements of the ocean produce a constant circulation of its waters, tending to prevent putrefaction, to equalize its temperature, and to moderate the heat or cold of the adjacent coasts. Various productions of the West Indies, carried along by the Gulf Stream, are deposited on the coasts of Europe: and it is said by some that this circumstance first gave Columbus the idea of the existence of a western continent; although it seems evident enough that he had no such idea, his object having been simply by crossing the Atlantic to reach the shores of India.

23. Evaporation of the Sea.—The superficial waters of the ocean, as well as of lakes and rivers, are continually changing into vapour by the action of the atmospheric temperature. This vapour, dissolved in the air, is again deposited in the form of rain and snow, whence a continual circulation, necessary for the existence of plants and animals. In consequence of this restoration of the waters of the sea by rain and rivers, it maintains a constant equality of surface, seeming from one age to another to undergo no

change of level, although local causes, or general causes producing local effects, give rise to apparent alterations. Were the proportion of the surface of the sea to that of the land different, the productive power of the earth would be materially changed; as in that case the quantity of moisture supplied by evaporation would be increased or diminished, so as not to correspond with the general temperature, in producing the present prosperous state of vegetation.

24. Bottom of the Sea.—In so far as can be ascertained, the bottom of the ocean presents inequalities similar to those on the surface of the land. If, as Mr. Phillips remarks, the depths of the sea be proportional to the heights of the land, in the ratio of their respective extent, the deepest depression would be about fifteen miles; but we have no means of ascertaining the actual depth by experiment; and it would perhaps be more reasonable to suppose the depths of the ocean to correspond with the elevation of the land, and thus not much to exceed 25,000 feet. But there is no foundation for the supposition that the surface of the continents and that of the bed of the sea have an inverse relation. In a section of the globe, the outline of the dry land, and that of the bottom of the sea, instead of being inversely proportioned, the highest points of the former and the lowest points of the latter representing each other, is continuous and probably similar, with this difference only, that the valleys in the sea-bed are perhaps more liable to be filled or raised by loose matters conveyed by the currents, than the valleys of the land, of which the materials tend to diminish, as the rains and streams carry to them a quantity of detritus less than that which they remove, to deposit it in the plains or the sea. The most simple and reasonable idea is, that the solid surface of the globe is every where continuous, but that only about a fourth part of it rises above the level of the sea, the other three-fourths being covered by its waters. Indeed, all that we know of the bottom of the sea is, that it consists of depressions and elevations, valleys and mountains, the latter often presenting them-

selves as islands and reefs, while the sounding line detects the inequalities concealed from view, tracing the gradual risings of sand-banks, and the steep acclivities of rocks.

Recapitulation.

7. What relation has the earth to the planets and sun? In what period is its annual revolution accomplished? What body does it carry along with it? Are the movements of the planets analogous to those of the earth? Has any of the heavenly bodies much perceptible influence on the earth?—8. What is the earth's form? How much does its equatorial exceed its polar diameter? Give an illustration of the nature of this flattening. How is it supposed to have been induced?—9. How was the earth's density ascertained? What is the density of rocks and water at the earth's surface, compared with its mean density?—10. Whence does the earth derive its superficial heat, and how is it modified? How do different kinds of surface operate in modifying the heat? Why is the temperature of the ocean more equable than that of the land? Have the currents of the atmosphere any influence on the earth's heat? Does any permanent accumulation of heat take place in particular districts? At what depth does the influence of the sun's rays cease? What renders it probable that the central parts of the earth are warmer?—11. In what states do the materials of which the earth is composed exist? What proportion of the globe is solid? Why is it inferred to be so? What is meant by the earth's crust? To what depth has it been perforated? What proportion does the surface of the water bear to that of the land? Has the globe any envelope?—12. State the height of the atmosphere, and its chemical composition. What other substances exist in it? What are the proportions of water in the air in different climates? Why does the air so readily combine with many bodies?—13. How is it

proved that air has weight? Is the density of the air uniform? What instrument is used for measuring its weight? —14. Is the temperature of the atmosphere equable? At what height is the line of perpetual congelation in different latitudes?—15. State the nature and causes of atmospheric movements. What effects have winds on the earth's surface?—16. Whence arises the water diffused in the air? In what states does it exist? What effects has it on mineral bodies? What does it produce when absorbed by the soil, and when congealed on the earth's surface?—17. Does electricity exist in the atmosphere? What effects are produced by lightning on rocks? How is hail formed?—18. Describe meteoric stones, their form, composition, and specific gravity. Why were the large masses of iron observed by Pallas and Humboldt supposed to be meteoric?—19. What is the relative extent of the ocean? its average depth, and its mass, compared with that of the land? Give an account of the colour of the sea, its taste, and composition. What results did Dr. Marcet obtain from the examination of sea-water from different parts?—20. What general circumstances have been observed relative to the temperature of the ocean?—21. Give a general account of the polar ice. —22. Is the sea in a state of rest unless when agitated by winds? Of what kind are its motions? Give an account of its general movements, and of its local currents. What effects are produced by these movements?—23. How is the loss by evaporation compensated? Does the mean level of the sea change? How would an alteration in the proportion of the sea and land affect vegetation?—24. What is the nature of the bottom of the ocean? How is it known to be analogous to the surface of the land?

CHAPTER II.

DISTRIBUTION OF THE LAND. — INEQUALITIES OF THE EARTH'S SURFACE; PLAINS, TABLE-LANDS, HILLY GROUND, MOUNTAINS. — MOUNTAIN MASSES OR CHAINS. — RIDGES OF MOUNTAIN-CHAINS; THEIR DECLIVITIES, VALLEYS, BRANCHES, SUMMITS, RELATIONS, AND LIMITS.—WATER-COURSES OR VALLEYS OF RIVERS, BASINS OF LAKES, WATER OF SPRINGS, RIVERS AND LAKES.

25. Distribution of the Land.—If we glance over a map of the globe, we immediately perceive that while the ocean, which covers so great a portion of the surface, is continuous, although running out into numerous branches, the land, on the contrary, is divided into two great continents, and a multitude of smaller masses of varied extent. The Eastern or Old Continent is formed of Asia, Africa, and Europe, while the Western or New Continent is composed of two portions, connected only by a very narrow isthmus, and bears the general name of America. From the vast island of Australia to the smallest rock of the ocean, there are all imaginable varieties as to form and extent. It is obvious that the mass of dry land in the northern hemisphere greatly preponderates over that of the southern, and it was long conjectured that, to balance the globe fairly, there must be a great southern or antarctic continent, which, however, as is shown by the tracks of navigators, has no existence. In the Old Continent, which has its greatest extension from west to east, the masses of elevated land, or mountain-ranges, stretch for the most part in the same direction, while in the New Continent, which extends from north to south, the chains of mountains have a similar course; and in islands and peninsulas it has been observed that the ridges of land frequently occupy the greatest diameter. Many ex-

ceptions, however, are found to this rule, which yet expresses an important fact. Perhaps, on the whole, it would be more correct to say, that mountain-chains are, for the most part, parallel to the coast-lines.

26. Inequalities of the Earth's Surface.—On taking a general view of the land, as forming either of the great continents, we find that its surface sometimes presents vast expanses unbroken by abrupt eminences, is often elevated into ridges intersected in various directions by deep depressions, and is frequently formed by a succession of hills and valleys producing gentle undulations. The hollows that occur in the land are sometimes deeper than the bed of the sea on the nearest coast, but in this case they are filled with water, forming lakes; and there is in Asia Minor an extensive track considerably below the level of the ocean. Of this area of 18,000 square leagues the lowest part is formed by the Caspian Sea and Lake Aral, which are, according to recent observations, 100 feet below the level of the Black Sea. In a general view, the surface of the dry land may be said to be composed of plains, hilly ground, mountain-chains, and valleys.

27. Plains.—It is very seldom that a perfectly flat tract has any considerable extent, but plains unmarked by elevations exceeding a few hundred feet occupy vast portions of the land. Of these nearly level tracts some are little elevated above the sea, while others are situated at a height of several thousand feet. The former are those to which the name of plains is usually given, while the latter are termed plateaux, or table-lands. One of the most extensive plains known is that which, commencing on the shores of the North Sea, extends over Poland, and occupies the greater part of Russia. It is divided by the Uralian Mountains from the great plain of Northern Asia, which stretches from the Frozen Ocean to the Altaic Chain. A vast extent of Africa is composed of arid sand, covering a nearly flat region, extending from Mount Atlas to the Niger, and from the Atlantic to the Nile. It is separated by that river and the Red Sea, from the sandy deserts of Asia, which occupy

a great portion of Arabia and Persia, and stretch over Central Asia, to the confines of China. In South America, a succession of plains, some covered with perpetual verdure, others at one season presenting the appearance of an ocean of arid sand, at another overspread with a luxuriant vegetation, extends from Patagonia and Paraguay to Caraccas, separated by mountain ridges of varied elevation, and traversed by vast rivers, the shores of which exhibit a vegetation unexceeded in variety and magnificence. In North America, the entire range of country from the Alleghanies to the bases of the Rocky Mountains, including the sources of the Arkansas and Missouri, and traversed by the numerous streams which pour their waters into the Mississippi, is a vast plain covered with luxuriant herbage or forests.

Plains are differently named in different regions, and present various characters, impressed partly by the nature of their vegetation. In South America, they are named Pampas; in North America, Prairies and Savannas; in Europe, Heaths, Landes, or Plains; in Northern Asia, Steppes; in Africa, Deserts.

28. Table-Lands.—One of the most remarkable elevated tracts of nearly flat land is that which, at the height of about 7000 feet, forms a great portion of Mexico. Other platforms of less extent occur among the Southern Andes, and on the summit of the Rocky Mountains. In Asia, it is supposed that a vast table-land exists between the mountains of Thibet in the south, and the Altaic chain in the north, having an elevation of 10,000 feet, and an extent of 1,500,000 square miles. In southern India, the kingdom of Mysore, which has a general elevation of about 3000 feet, belongs to this class of plains. In Europe, the plain of Castille, nearly 2000 feet above the sea, is the most considerable.

29. Hilly or Undulated Ground.—Between these elevated plains and those not much raised above the level of the ocean, are often seen hilly or mountainous tracts, traversed by valleys of varied extent. Few of the table-lands have a continuously even surface, and many of them are in-

terspersed or margined with ridges and peaks, among which are interposed still more elevated platforms of small extent. The lower plains themselves are furrowed by grooves forming the beds of rivers, or exhibit long ridges of little elevation and shallow valleys. Between them and the mountainous regions often intervene large tracts of hills or low mountains, which are not grouped into ridges or chains, but seem to be dispersed without order.

30. MOUNTAINS.—A Mountain is a mass of land rising suddenly from the general level, and attaining a height of more than two thousand feet. A Hill is merely a small mountain, and the lowest elevations of this kind are named hillocks or mounds. A mountain presents several parts, easily understood: the plane formed by intersecting it at the place where it projects from the surface is its BASE; the circumference of the base is called the FOOT of the mountain; the acclivities are its SIDES or flanks; and its most elevated part, the SUMMIT or top. The sides of mountains present all degrees of inclination, but their slopes are for the most part very gentle. It has been found that an inclination of seven or eight degrees is the maximum for wheel-carriages; that at fifteen or sixteen degrees the acclivity is very steep, being the maximum for beasts of burden; that at thirty-five degrees a person cannot ascend without cutting steps; and that the ascent of a slope of more than forty-four degrees is impracticable even with the aid of steps. The summits of mountains vary in form, but may be reduced to a few principal kinds. When a mountain is of a conical form, with the summit narrow, it is named a CONE, Fig. 1, *a*; when of the same form, but more massy, and with the summit depressed and rounded, it is a DOME, *b*. Mountains of those forms are always of volcanic origin. When a mountain appears as if its summit were cut off, leaving a level and horizontal surface, it forms a PLATFORM, *c*, or is said to be truncated. When the summit rises with an acclivity more abrupt than the rest of the mountain, it is usually, whether conical or not, named a

PEAK, *d*; and when very slender pointed rocky protuberances form the summits, they are called by the French AIGUILLES or Needles, *e*, but by us generally peaks.

Fig. 1 *a* *b* *d* *c* *e*

Various other modifications may occur. For example, a mountain is not unfrequently saddle-backed, Fig. 2, *a*, that is, having its summit rounded, but more or less concave in the middle; and frequently it is formed into an extended ridge, *b*. When one end of a mountain is very abrupt, the other being of the ordinary form, or passing gradually into the plain, the abrupt portion is named an ESCARPMENT, *c*.

Fig. 2. *a* *c* *b* *d*

A CLIFF is a precipice overhanging the sea or a lake, *d*.

The form of a mountain depends entirely upon its composition. Thus, conical and dome-shaped hills, as already remarked, are of volcanic origin; those with extended flat summits are frequently of sandstone or other stratified rocks. The summits of mountains are scarcely ever mere points, but are flattened or convex to a greater or less extent; and their feet are the parts which are least inclined. It is seldom that isolated mountains are met with rising abruptly from a level country, Fig. 3. *a*, the usual manner in which elevations of the ground appear being in the form of groups or masses, variously arranged, *b*.

Fig. 3.

31. Mountain Masses.—Although the elongated ridges of land formed by mountains are generally named chains, that term is very inappropriate, and must have been suggested more by the manner in which geographers are wont to mark them on maps than by their natural appearance. In describing these ridges, we may follow D'Aubuisson, who has given a very detailed account of them in his Traité de Geognosie. If we suppose, in the midst of a flat country, a

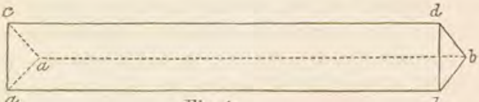


Fig. 4.

great mass of elevated ground, of an elongated form, and of which the transverse section is a triangle, Fig. 4, *a a c*, this solid will represent a mountain-chain. The two lateral surfaces, *c b*, *c b*, will be the sides or declivities; their intersection, or upper edge, *c d*, the ridge; the lower part of each, *a b*, *a b*, will be the foot; the two small surfaces, or bases of the prism, *a a c*, *b b d*, will be the two extremities; its length will be the distance from one extremity to the other, *c d*; its breadth, the transverse distance from one foot to the other, *a a*; and the height will be the vertical elevation of the ridge above the base, or above the level of the sea; lastly, the direction will be indicated by the points of the horizon towards which the ridge is directed.

Fig. 5.

Let us now imagine, on each of the two declivities, deep grooves descending from the ridge to the foot, Fig. 5, *a c*, *a c*, *a c*. These grooves form the PRINCIPAL VALLEYS, and divide the mass of the chain into several BRANCHES or subordinate masses, *b d*, *b d*, running out nearly at right angles, and disposed in a manner somewhat resembling that in which the ribs are attached to the back-bone of a quadruped. Their ridge *b d*, *b d*, gradually falls or diminishes in height from the ridge of the chain to its foot, and forms a SECONDARY RIDGE; its two sides are the DECLIVITIES. If, on the declivities of this secondary chain, we imagine grooves running in a direction similar to that of the first, they will give rise to shorter valleys, and will bifurcate the branches already existing by dividing them in their extreme part into two or more branches. The declivities of the two neighbouring branches, which form the walls of the same valley, unite at their lower part, in a more or less sinuous line, which occupies precisely the bottom of the valley, and is that in which the water runs, *a c*, *a c*. The grooves which have given rise to the valleys, when they end at the ridge, have, as it were, taken a portion out of it, so as to present a notch or gorge, *a*, *a*, *a*. Between two neighbouring gorges, the ridge, remaining of its original height, forms a protuberance or cime *b*, *b*, *b*, so that, viewed in its length, it presents an alternation of prominences and notches, *a b*, *a b*, *a b*. The prominences, *b*, *b*, are the points whence proceed two opposite branches, one on each slope; and the gorges, *a*, *a*, unite two opposite valleys.

The secondary branches, *b d*, *b d*, are subdivided in the same manner by grooves running off at right angles from the ridge; and sometimes the sub-division proceeds still farther. Mountain-chains, however, do not in nature present the regularity here assumed to render their general arrangement intelligible. The great chains of the Alps and Pyrenees manifest an obvious tendency to this mode of division; but in our country, the small ranges of the Grampians and other hills, although occasionally thus divided, are for the most part formed of ridges and valleys disposed in a very irregular manner.

32. Ridges of Mountain-chains.—The ridge of a chain, being the line at which its two declivities meet, forms the separation of the brooks which take their rise upon it, or the water-shed. In small chains the ridge is generally narrow, but frequently it is of great breadth; insomuch, that in the neighbourhood of Mexico the summit of the Cordilleras is occupied by a platform fifty leagues in extent. In regular chains, it sometimes extends pretty nearly in a line, but frequently forms numerous and often abrupt sinuosities.

33. Slopes of Mountain-chains.—The declivities of mountain-chains vary from two to six degrees. That of the southern slope of the Alps, from the central ridge to the Plains of Lombardy, is three degrees and three-fourths, and that of the northern slope of the Pyrenees is from three to four degrees. It is very seldom that the two sides of a chain have the same inclination, one being generally shorter and more inclined than the other. Bergmann concluded, that in chains of which the direction is from north to south, the western declivity is the most abrupt, and in those running east and

west the southern slope. M. Andreossy remarks, that whenever a mountain-chain occurs on a descending plain, the slope facing the upper part of the plain is the most abrupt. Saussure observed in the Alps, that "the inner chains turn their back to the outer part of the Alps, and present their escarpment to the central chain," and that in mountains formed of inclined strata, the most gentle declivity is usually that in the direction of the inclination. He also observed that the mountains which surround the Lake of Geneva have their escarpment turned towards it. M. D'Aubuisson remarks that the Lakes of Constance, Lucerne, and Lake Major, present the same fact; which is seen repeated by the chains bordering the Mediterranean; the mountains of Spain, the Pyrenees, the Cevennes, the Alps, the mountains of Greece, Asia Minor, Syria, and Mount Atlas, having a much more rapid declivity towards the sea than in the opposite direction, as had been observed by M. Ramond. M. Malte-Brun asserts that the land bordering the South Sea from the Cape of Good Hope to Cape Horn, along the eastern coast of Africa, the southern and eastern coasts of Asia, and the western coast of America, has its steepest slopes seaward. Dr. Traill, in his Treatise on Physical Geography, repeats these observations, adding some others, and concludes his remarks thus: "The escarpment of the great chain of Africa, termed that of Lupata, which seems to be prolonged from the lofty mountains of Abyssinia to the south of the Mozambique Channel, would appear from the little we have learned of its structure, to face the basin of the Indian Ocean; and we know that the steepest declivities of the western Ghauts of India, are directed towards the same basin. The mighty spine of the American Continent, from the shores of the Arctic Frozen Ocean to the extremity of South America, through a course of more than 8600 British miles, presents a series of rugged precipices to the vast basin of the Pacific; and, if we might indulge in one sweeping generalization, it would seem that the chains stretching from the Persian Gulf eastward through Thibet, and thence bending to the north-east through Mongolia and Northern China to Tscheoutskoinos on the Frozen Ocean, present their fronts to the Pacific Ocean."

34. Valleys.—The primary or principal valleys of a mountain-chain are those which, commencing at the central ridge, run out nearly at right angles, being bounded on either side by a branch, which in like manner runs out from the central ridge. The valleys of one declivity being generally continuous with those of the other, have their junction at the depressions of the ridge, so that they run across the chain. These primary grooves are also named transverse valleys. They receive nearly at right angles the smaller valleys which intersect the branches, and these smaller valleys themselves are joined by others of inferior size, so that one of the primary valleys is composed of a multitude of subordinate hollows, in connexion with a deep elongated cavity, intervening between two ranges of hills. In fact, a large valley may be compared to the stem of a tree, of which the branches represent the primary valleys, and the twigs those subordinate hollows which ramify among the hills, each generally giving passage to a stream of water. The bottom or water-line of the valley rises as we approach the main ridge, for the most part gently, until towards the extremity, when the ascent often becomes precipitous. Sometimes it here enlarges and assumes a circular form, as is exemplified by the valley of Anzasca, at the foot of Monte Rosa in the Alps, which is a nearly circular basin, two leagues in diameter, with walls rising vertically to a vast height. Hollows of this kind are not uncommon in the Highlands of Scotland, and are there named Corries.

Great valleys generally contract and enlarge at irregular intervals, owing to the encroachments of the mountains by which they are bounded. The valley of the Nile in Upper and Middle Egypt, according to M. Rosierés, is a series of basins of this kind; and Saussure has pointed out five in the valley of the Rhone, from its commencement to Geneva.

Notwithstanding these alternate enlargements and contractions, the sides of valleys usually present a remarkable parallelism, the projecting angles of one side usually corresponding with the retiring angles of the other. The direction of the valleys of a chain is in the line of greatest declivity of the plane on which they occur, or, as has already been said, nearly at right angles to the direction of the chain. But at the extremities of mountain-chains, where the primary ridge descends, the valleys branch off in a divergent manner.

Valleys are observed of all sizes, extending in length for many miles, and in breadth from half a mile to five or more. A level space of great breadth, separating two mountain-ranges, is not, however, properly speaking, a valley, but a plain. This may also be said of "circular valleys," such as that of Bohemia, 200 miles in diameter, and Cashmere, 90 miles in diameter, which are rather plains surrounded by mountains. Vast plains traversed by great rivers, such as the Mississippi and Amazons, are also improperly named valleys, a term which ought to be restricted to narrow elongated depressions laterally bounded by mountains.

35. Branches of Chains.—The transverse or lateral valleys of mountain-chains are formed or bounded by the primary branches or ridges of mountains, which come off from the central or main chain. The ridge of these branches descends as it recedes, but not uniformly, it being usually of great height for a considerable extent, and towards the end rapidly falling. Even at great distances from their commencement, there sometimes occur, in branches, eminences whose summits surpass in height those of the central ridge. Branches of a chain are sometimes seen to run out beyond the foot of the chain, advancing far into the plain. When they run out into the sea and terminate abruptly, they form capes or promontories. Sometimes, on the other hand, a branch falls short of the rest, leaving, as it were, an empty space between two branches. If the sea bathes the foot of a chain, such a vacuity forms a gulf, or bay.

36. Summits of Mountain-Chains.—The cimes, or summits of chains, or of masses of mountains, are protuberances rising abruptly from the main ridge, or from the ridges of the branches. Although the most elevated points usually occur on the main ridge, they are sometimes situated at a considerable distance from it. It is on the principal ridges, however, that almost all the very high mountains occur, such as Mont Blanc, Mont Cervin, and Mont Rose, in Europe; Dhawala-giri, Jaumatri, and Elburz, in Asia; Illimani, Chimborazo, and Cotopaxi, in America. These projecting summits present various forms, according to the mineralogical nature of the mountains, being rounded or conical in volcanic ranges; abrupt, turreted, or pointed, in granitic ridges; and irregularly serrated in slaty rocks. These summits form the most elevated points of the earth's surface. In Europe, Mont Blanc, 15,781 feet above the level of the sea; in Africa, the mountains of Geesh, estimated at 15,000 feet; in America, the Pico d'Illimani, 24,450 feet; and in Asia, Dhawala-giri, 26,862 feet, are situated in the midst of mountain-ranges. Yet many volcanic peaks, of great elevation, are perfectly insulated. For example, Mouna Roa in the Sandwich Islands, 16,020 feet high, the Peak of Teneriffe, 12,236, and Mount Ætna, 10,963 feet.

37. Relations of Mountain-Chains to each other.—It is seldom that a mountain-chain is of the regular and isolated character above described, the masses of elevated ground being connected into vast systems, variously grouped and ramified. Thus, the Old Continent is traversed from east to west by a great band of mountain-land. In Europe its central point is at St. Gothard, whence the elevation declines in all directions; northward, to Holland and the Baltic; eastward, to the Black Sea; westward, to the Atlantic Ocean; and southward, to the Mediterranean. All these declivities are cut by the beds of rivers into chains or ridges, which evidently belong to the same system—that of the Alps. These chains are connected, directly or indirectly, by their main ridge, with the central elevated region. Thus,

Mount Jura is regarded by Saussure as subordinate to the Swiss Alps; the Vosges are connected with Jura; and the Ardennes with the Vosges. The Cevennes, forming, as it were, a stage to rise to the Alps, are thus subordinate to them. The series of chains which border the Danube to the north is connected with those to the south, which form the Alpine system, properly so called, by the mountains of Upper Suabia, in the midst of which that river has its sources. The districts to which the various chains are thus united are the nuclei of the system; and the great valleys which proceed from them, separate the chains, and give passage to the rivers, are of a higher order than those which break up the chains into branches. They are the LONGITUDINAL VALLEYS of Saussure. Such, for example, are that of the Danube in the first order, and those of the Rhine and Rhone in the second.

If we pass over to Asia, following the great elevated band, we find it towards the Himalayan Mountains, in Northern India, assuming a breadth and a height superior to those of any other part of the globe. All around this great platform the land gradually lowers; northward, to the Frozen Sea; eastward, to the Chinese Ocean; southward, to the Indian Ocean; and westward, to the Caspian Sea. These declivities are furrowed by rivers, the valleys of which intervene between mountain-ranges, cut up by secondary valleys into subordinate groups.

38. LIMITS BETWEEN THE DIFFERENT CHAINS.—According to d'Aubuisson, mountain-chains are separated from each other in the following ways:—1. By the interposition of seas. Thus, the extremity of the European Alps, or Mount Hæmus, is separated from Caucasus by the Black Sea. 2. By the great or principal valleys, which commence at the nucleus of a system of mountains. Thus, the Cevennes are separated from the French Alps by the valley of the Rhone; and the Vosges, from the Black Forest, by the valley of the Rhine. 3. By plains interposed between the extremities or the sides of two chains. Thus, the Tyrolese

Alps are separated from the Boehmerwald and other mountains which surround Bohemia, by the plains of Bavaria. 4. By the interposition of hills. The Vosges are separated from Jura in this manner, as are the Pyrenees from the Cevennes. 5. By a transverse section of the central ridge of a chain, as the narrow passage by which the Rhone separates Jura from the French Alps, and the narrow defile by which the Danube issues from the Bannat to enter Wallachia.

39. Water-courses.—The waters deposited from the atmosphere, being absorbed by the soil, penetrate into the fissures of rocks, and reappear at lower levels in the form of springs; or they pass along the surface, or in the subjacent soil, and collect in the lower parts of valleys. These rills and brooks gradually enlarge. Those of several valleys unite, forming rivers, which themselves uniting constitute larger streams. The surface of continents and islands is thus grooved by the beds of rivers, each of which receives the waters that fall in a certain extent of country bounded by ridges of chains or water-sheds, and of which the lowest part is that at which the river joins the sea. In proportion as the land recedes from the mouth and sides of the river, it gradually rises, until we reach the sources of the small rills near the ridges of the mountains, hills, or rising grounds. Beyond these ridges, the land lowers, and the waters that flow on these new declivities, go to other rivers; so that the district of a river is surrounded, and separated from those of other rivers by a series of ridges. Such a cavity is named a basin. A continent thus divided and subdivided into basins of rivers, with their subordinate branches, would, as D'Aubuisson remarks, present the most natural division; and political boundaries are better designated by mountain-ridges than by rivers.

40. Basins of Lakes.—In their course towards the sea, the waters sometimes meeting with depressions of the surface deeper than the general slope of the water-line of valleys, accumulate there so as to form lakes. Basins of

this sort, generally of small extent, are common in mountainous regions, often very near the central ridges of chains. In such situations they are frequently seen in the Alps, and in the small mountain-ranges of Scotland and England. Many of those cavities which are now dry, have formerly been filled with water, as is indicated by the smoothness of the bottom, or by the remains of beaches left on their sides, the waters having escaped by bursting the lower barrier, or by means of fissures formed by earthquakes. Lakes of larger extent are seen in valleys, in the course of rivers; and even beyond the limits of mountain-ranges, rivers sometimes pass through or unite lakes of various dimensions. The great lakes of North America, situated in a nearly flat country, are of this nature. Several lakes of great extent, such as Lake Aral, the Caspian Sea, and the Dead Sea, have no communication with the ocean, but form independent basins, receiving rivers, the waters added by which are removed by evaporation. While many parts of the earth are abundantly supplied with lakes, there are vast districts, such as South America, in which scarcely any are met with.

41. WATER OF SPRINGS, RIVERS, AND LAKES.—Water in the natural state is never perfectly pure, being mixed with air and various saline matters. Even when collected as it falls from the atmosphere, it is more or less impregnated with these substances, and after having filtered through the soil and rocks, it is often found to contain a large proportion. The salts usually dissolved in water are muriates of soda and lime, sulphates of soda, potash, lime, and magnesia, and carbonates of lime, soda, and iron. Many springs also contain great quantities of gas, especially nitrogen gas, mixed with some oxygen and carbonic acid. Vast quantities of water are diffused in the interior of the globe in the various strata, and their interstices and cavities, whence they issue in the form of springs, and are sometimes ejected by volcanoes. Springs issuing from crystalline or sandy rocks are generally limpid and pure; but

such as traverse deposits of limestone or gypsum, usually hold in solution carbonate and sulphate of lime, which render them disagreeable for drinking, and unfit for domestic uses. When springs that have traversed rocks or other deposits containing soluble matter, are much impregnated with salts, they are named mineral waters; and those which issue of a higher temperature than the ground, are called thermal waters or hot springs. It is remarkable that some hot springs contain silica in solution, although that substance is not soluble by any means that we can employ. Many springs contain petroleum and other bituminous matters, which in India are obtained in great quantities, for economical purposes, by sinking wells into the strata.

The water of rivers is also charged, especially in time of floods, with great quantities of earthy matter, which is afterwards deposited in the form of mud and sand. It has been estimated that the waters of the Nile contain one part in bulk of mud in every 132 parts; those of the Rhine one part in 100: and those of the Yellow River in China, one in 200. It may, therefore, easily be conceived what vast accessions to the soil, towards the mouths of rivers, are made by the deposits which they leave after floods.

Standing water is usually impregnated with various saline substances, as well as matters derived from the decomposition of animal and vegetable substances. Lake water in cold or temperate countries is often clear and well adapted for culinary and other domestic purposes; but in warm climates, where vegetation is rank, it is impregnated with decomposed vegetable matters, and is seldom sufficiently pure to be so employed. Many lakes have their waters extremely saline, and in some salt is obtained in great quantity when the waters have been evaporated by the summer heat. The Caspian Sea and the Sea of Aral are great salt lakes, which probably have at one time communicated with the Euxine; and the water of the Dead Sea contains 24½ per cent. of muriates of lime, magnesia, and soda, with a little sulphate of lime.

RECAPITULATION.

25. How is the land divided? In which of the hemispheres does it preponderate? In what direction do the mountain-chains or masses of elevated land extend?—26. Give a general account of the inequalities of the surface.—27. Are plains perfectly level? Distinguish between plains and table-lands. Give an account of the great plains of Europe and northern Asia, the African Desert, those of Asia, and South and North America. What names are given to plains in different regions?—28. Mention some of the principal table-lands.—29. What is the nature of hilly ground? —30. Define a mountain. What are its parts? At what degree are acclivities of impracticable ascent to animals and men? Mention some of the varieties of mountains. What is an escarpment or cliff? Are mountains usually single or isolated?—31. Give a general account of a mass or chain of mountains. Describe the principal valleys and branches, with their prominences and depressions. What is the nature of the main-ridge? Are mountain-chains often arranged in this regular manner?—32. Describe more particularly the main-ridge, stating its breadth and continuity.—33. Are the general slopes of mountain-chains very rapid? Are they often nearly equal? In what direction are the escarpments or abrupt surfaces? State some facts relative to the disposition of mountain-slopes around lakes, seas, and the ocean.—34. Describe the principal or transverse valleys. Why may a large valley be compared to a tree? What is the nature of the water-line? How do valleys usually terminate on the main-ridge? Are great valleys generally of uniform breadth? What is their direction? Do they vary much in extent? What is the difference between valleys and plains?—35. Describe particularly the branches of mountain-chains, their comparative elevation, and extent?—36. Give an account of the summits of chains. Are the highest points of the globe situated on the ridges of chains? What

are their forms? What are the most elevated summits of Europe, Africa, America, and Asia? Are very elevated mountains ever isolated?—37. How are mountain-chains connected? Describe the great mountain-masses of Europe and Asia.—38. In what manner are mountain-chains separated?—39. What is the nature of water-courses? Describe the basin or valley of a great river.—40. What is the nature of lakes? Where are they usually met with?—41. Is water often pure in the natural state? What are the salts usually dissolved in it? What is the nature of springs? With what substances is the water of rivers and lakes charged?

CHAPTER III.

MATERIALS OF THE GLOBE: SIMPLE OR ELEMENTARY SUBSTANCES; MORE COMMON ELEMENTARY SUBSTANCES, VIZ. OXYGEN, HYDROGEN, CHLORINE, &C.—CHARACTERS OF MINERALS. MOST ABUNDANT SIMPLE MINERALS: QUARTZ, FELSPAR, MICA, TALC, &C.—MORE COMMON ROCKS: QUARTZOSE ROCKS, FELSPATHIC ROCKS, MICACEOUS ROCKS, TALCOSE ROCKS, HORNBLENDIC ROCKS, AUGITIC ROCKS, ARGILLACEOUS ROCKS, CALCAREOUS ROCKS, CARBONIFEROUS ROCKS.

42. Materials of the Globe.—Were we to inquire of a person who had not particularly directed his attention to the subject, of what materials the earth is composed, he might reply that soil, sand, gravel, and stone or rock of various kinds, constitute its component parts. This answer, although correct, affords too vague an idea, and nothing less than a very minute scrutiny will enable us to acquire a satisfactory acquaintance with the materials in question.

Of the composition of the interior of the globe we have no means of obtaining any information, our observation being confined to the thin external layer, technically named its Crust. In it we discover so great a diversity in the form, colour, texture, and hardness of the different parts, that at first we might be apt to consider the task which we had undertaken one of peculiar difficulty; but all these substances may be reduced to a few simple elements.

43. SIMPLE SUBSTANCES.—Those substances which, never having been decomposed, are assumed as simple, or elementary, amount to fifty-four. Of these, five are gaseous: hydrogen, oxygen, nitrogen, chlorine, and fluorine; five are volatile non-metallic substances: bromine, iodine, sulphur, phosphorus, and selenium; two are fixed or unvolatile non-metallic bodies: carbon and boron. Of the remaining substances, which are metallic, seven are earthy metals, which, combined with oxygen, produce the earths: silicium, aluminum, magnesium, yttrium, glucinum, zirconium, and thorium; six are alkaline metals, which, combined with oxygen, yield alkalies; potassium, sodium, lithium, calcium, barium, and strontium; fifteen are metals which retain oxygen at high temperatures: lead, tellurium, copper, bismuth, titanium, cobalt, cerium, uranium, antimony, columbium, tungsten, chromium, vanadium, molybdenum, and arsenic; nine are metals, which give out oxygen at high temperatures; mercury, silver, gold, platinum, palladium, rhodium, iridium, osmium, and nickel; and five absorb and retain oxygen at high temperatures: tin, iron, zinc, cadmium, and manganese. The most abundant of these elementary substances are oxygen, which forms more than half the ponderable matter of the globe, hydrogen, chlorine, sulphur, phosphorus, carbon, silicium, aluminum, calcium, sodium, potassium, magnesium, iron, and manganese. For a full account of the properties of these substances, the reader is referred to elementary works on chemistry.

44. MORE COMMON ELEMENTARY SUBSTANCES.—(1.) OXYGEN: A gaseous, transparent, colourless, inodorous

substance, which, itself uninflammable, brilliantly supports combustion; the most abundant of the elements, forming more than half of the globe, existing in air, water, most earthy substances, and in nearly all the products of the animal and vegetable kingdoms. The combination of oxygen with most substances is usually accompanied with the disengagement of heat, rendering them incandescent; the flame often developed in such cases is gaseous matter so heated as to become luminous. What is named combustion, or burning, in ordinary language, is the combination of oxygen with certain bodies, accompanied with heat, light, and flame. When the operation is completed, the body is said to be burnt or oxidized. Oxygen is also the principal agent in the respiration of animals.

(2.) Hydrogen: A gaseous, transparent, colourless, substance, the lightest known, does not support combustion; forms one-ninth of the water of the globe, and occurs in almost all animal and vegetable substances. Hydrogen, when pure, is not fit for respiration or combustion; but when mixed with oxygen, it inflames, if sufficiently heated, and gives rise to water, whence its name. It occurs in nature only in combination with other bodies, and principally with oxygen, carbon, and nitrogen. United with oxygen in the proportion of 2 to 1 in volume, it forms water; with oxygen and carbon, most vegetable substances; and with oxygen, carbon, and nitrogen, most animal matters. The gas used for lighting buildings and streets is hydrogen, combined with a small quantity of carbon.

(3.) Chlorine: A gaseous, transparent, greenish-yellow substance, having a disagreeable taste, a pungent, suffocating odour, uninflammable, but supporting combustion, destructive of animal and vegetable colouring matter. Chlorine is extremely soluble in water, to which it imparts its properties; and has a great affinity for hydrogen, with which it forms an acid gas, known by the name of hydrochloric or muriatic acid. Chloride of lime is now generally employed in place of chlorine gas.

(4.) SULPHUR: A solid, brittle, yellow, inflammable substance, combining readily with numerous inflammable bodies and metals, melting at 216°, subliming at 600°; an abundant product of volcanoes. Combined with oxygen so as to form sulphuric acid, it unites with lime, and forms gypsum.

(5.) PHOSPHORUS: A solid, semi-transparent, colourless substance, undergoing slow combustion at ordinary temperatures; burning brilliantly in air. Combined with lime, is a principal constituent of the bones of vertebrated animals, and is found in some kinds of limestone.

(6.) CARBON, in its purest state, forms the diamond, when it is transparent, colourless, or of various tints; in its ordinary form, is charcoal, a solid, black, porous, brittle substance, inflammable, producing carbonic acid gas when heated in air or oxygen, absorbs large quantities of gases, is insoluble in water, destroys animal and vegetable colouring matters, as well as the offensive taste and smell of putrid substances; enters into the composition of all animal and vegetable substances, as well as of many slaty rocks, to which it gives a dark colour; in the form of coal, occurs in extensive beds; united with oxygen, forms carbonic acid, which, combined with lime and solidified, forms more than two-fifths of all limestone rocks.

(7.) SILICIUM: A dark-brown, inflammable substance, without metallic lustre. Its acid, or oxide, usually named silica, which is hard, insoluble, insipid, inodorous, and infusible, exists nearly pure in large masses, forming rock or crystal, quartz-rock, and flint, communicates great hardness to rocks, of which it constitutes a large proportion, and renders them infusible. When fused with an alkali, it dissolves in acids. It is very abundant in the mineral kingdom.

(8.) ALUMINUM: A metallic substance resembling platinum. Its oxide, or alumina, is white, tasteless, inodorous, insoluble in water, but uniting with it, so as to form hydrates; is found nearly pure in the sapphire and ruby; is extensively distributed in the mineral kingdom, existing in all kinds of clay, and forming an ingredient in many slaty rocks.

(9.) Calcium: A white metallic substance, oxidated by being heated in the air, and forming lime, which, combined with carbonic acid, forms limestone and chalk, and with sulphuric acid, forms gypsum. Lime, or oxide of calcium, has so great an affinity for water, that it cannot be preserved in a state of purity, unless protected from the atmosphere. When water is poured upon it, a slight effervescence is produced, heat is evolved, it swells, and at length falls into powder, when it is called slaked lime, whereas in its unaltered state it is named quicklime. Slaked lime forms the basis of mortars and cements, in which it is mixed with siliceous sand or gravel.

(10.) Sodium: A metallic substance, soft and malleable at 32°, fused at 200°, volatilized at a red heat. Chloride of sodium, or common salt, is found in great abundance, being a principal ingredient in the waters of the ocean, and forming masses of rock-salt.

(11.) Potassium: A metallic substance, white, with brilliant lustre, like mercury, hard and brittle at 32°, soft and malleable at 50°, fluid at 150°; volatilized below red heat. Nitrate of potassa, or common nitre, is procured from the soil in warm climates; and oxide of potassium occurs in various minerals.

(12.) Magnesium: A metallic substance, resembling silver, fusing at a red heat, and then, on burning in air or oxygen, producing magnesia, or oxide of magnesium, which is white, inodorous, and forms an ingredient in many rocks, to which it usually communicates a soapy or greasy feel.

(13.) Iron: The most abundant of the true metals, has a grey colour, a tenacity exceeding that of all the other metals; is malleable and ductile; occurs in the form of oxides and clay iron-ore, which is an oxide united with carbonic acid, alumina, and silica; is also plentiful as a sulphuret; constitutes an ingredient in graphite; and forms a constituent part of many rocks, which most frequently owe their colour to it.

(14.) MANGANESE: A metal similar to iron, brittle, and with difficulty fused, occurs in the state of oxide in some rocks, to which it generally gives a purplish-red colour.

45. MOST ABUNDANT SIMPLE MINERALS.—The masses of solid matter of which the crust of the globe is composed, are resolvable into certain mineral substances, which, although compounds in a chemical point of view, are mineralogically considered as simple. Of these substances, uniform and homogeneous in their mass, and thus viewed as SIMPLE MINERALS, a small number only enter into the composition of the great masses, or rocks, which form the proper subject of examination of the geologist. In order to render himself acquainted with these, it will be necessary that the student obtain good specimens of about twenty-five minerals, the expense of which needs not exceed four or five pounds.

46. DISTINCTION BETWEEN MINERALS AND ROCKS.—"The knowledge of minerals in their simple state," says Dr. MacCulloch, "is an indispensable requisite in the investigation of rocks. It is also necessary that this knowledge should not be limited to mere experience respecting the aspect of such minerals in their most simple and perfect forms. The student must be able to recognise them by their essential characters, even when under their most irregular modifications; often, when very minute, or when intermixed and confounded with others, or when obscured by unexperienced variations of colour." To understand the short descriptions about to be given of the most important simple minerals that enter into the composition of the strata and masses of rock that compose the crust of the globe, it may be of advantage to attend to a few preparatory explanations. By a SIMPLE MINERAL is understood a homogeneous substance, whether simple in an elementary point of view or not, which presents itself in certain definite forms, and has a texture, mode of breaking, and other phy-

sical properties, such as hardness and colour, by which it may be distinguished from other substances. The science which treats of these bodies is named MINERALOGY, and by some ORYCTOGNOSY; while to GEOLOGY belongs, among other subjects, the consideration of their aggregation into rocks. A ROCK, in the geological sense, is a mass of mineral matter, of sufficient extent to be considered an essential portion of the solid part of the globe. It does not mean, as in common language, an abrupt or perpendicular stony surface, for it may be horizontal or perpendicular, or inclined, concealed from view beneath the surface, or rendered apparent by being elevated in a mountain or cliff. It is merely a great body of stony or earthy matter of any form or in any position. Nay, even great hardness or tenacity is not essential to the definition, for a bed of clay, gravel, or sand, is, in this sense, as much a rock, as one of granite, marble, or slate.

47. QUALITIES OF MINERALS.—In describing Simple Minerals, or the substances of which rocks are composed, reference is made to their physical and chemical properties.

The FORM affords one of the most important characters, and is often of itself sufficient to distinguish the species. When a mineral assumes a particular symmetrical form, such as that of a cube or prism, it is said to be crystallized, and the individual pieces of regular form are named CRYSTALS. AMORPHOUS minerals are those which do not assume a definite form.

The HARDNESS, or resistance which a mineral opposes to the separation of its parts, is measured by scratching one substance with another. Thus, gypsum is scratched by calcareous spar, the latter by quartz, which in its turn yields to diamond. The degrees of hardness are expressed by numbers, according to the following scale: 1. Talc; 2. Gypsum; 3. Calcareous spar; 4. Fluor spar; 5. Apatite; 6. Felspar; 7. Quartz; 8. Topaz; 9. Corundum; 10. Diamond.

The SOLIDITY has reference to the TENACITY, or the resistance opposed to mechanical force tending to break it; the FRAGILITY, to the ease with which it may be fractured; the FRIABILITY, to an imperfect state of aggregation, rendering it easily divisible into a multitude of grains; and the FLEXIBILITY and ELASTICITY denote qualities not requiring to be defined.

When a mineral substance is broken, by the blow of a hammer for example, the surface exposed, or FRACTURE, may be even, or splintery, or scaly, or conchoidal, that is, concave like a shell.

Viewed with reference to light, a mineral may be TRANSPARENT, when it allows enough of light to pass through to enable one clearly to distinguish a body placed behind it; TRANSLUCENT, when it cannot be seen through, although it admits light; OPAQUE, when, even if cut very thin, it does not transmit light. The LUSTRE, or the degree in which the surface reflects the light, is various: glimmering, glassy, pearly, resinous, silky, metallic, adamantine.

The TEXTURE may be regular or irregular; LAMELLAR, when it presents the appearance of thin plates; FIBROUS, as if composed of threads or small cylinders; RADIATING, when the fibres converge towards a point. These explanations will suffice for our purpose; and the student who is desirous of more extended information, will find it in most systems and manuals of mineralogy.

SIMPLE MINERALS OF MOST FREQUENT OCCURRENCE.

48. QUARTZ.—Among the most abundant of the simple minerals that enter into the composition of rocks is Quartz, a substance so hard as to give sparks with steel, scratch glass, and break into sharp-edged fragments, having conchoidal or splintery surfaces. Its lustre is glassy; its transparency, often perfect, varies; it emits a phosphorescent light and peculiar odour when two pieces are rubbed together; is infusible when not mixed, but with alkalies melts into glass; is not acted upon by any other acid than the fluoric; and presents itself in various forms. Common

quartz may be crystallized in six-sided prisms, or it may be amorphous; its colours, white, grey, brown, red, blue, or black; its lustre, shining or glassy. It is less transparent than rock-crystal, which generally occurs in six-sided prisms terminated by six-sided pyramids, or two six-sided pyramids united, or prisms variously terminated, and is hyaline or of the colour of water, white, yellow, red or brown. Amethyst presents the same forms, but is distinguished by its blue or purple tints. A translucent variety, of a roseate or bluish-white tint, is named Rose Quartz; another, opaque and black, is Lydian stone. Hornstone, Flinty-slate, Flint, Calcedony, Jasper, and Agate, with many other varieties, belong to this kind of mineral, which is very extensively distributed in nature, constituting an ingredient in many species of rock, and in an unmixed state forming beds and veins. It is of importance to obtain a knowledge of all the varieties of this substance, which presents itself under so many aspects, that the student often finds it difficult to distinguish them in nature. Their great hardness, which turns the edge of a knife, and their more or less glassy lustre, will generally aid in recognising them. Quartz of all varieties is composed of silica or oxide of silicium, with a variable proportion of alumina, which is more abundant in jasper and hornstone than in the purer transparent varieties.

49. Felspar.—This substance presents itself in two principal forms, Common Felspar, and Glassy Felspar. The former is a very abundant mineral, entering largely into the composition of many rocks. It is somewhat less hard than quartz, so that it may be with difficulty scratched with a knife, and is more easily broken, presenting a laminar structure, with a glistening lustre, an uneven or splintery surface, rhomboidal fragments, and translucent edges. It is usually massive, but sometimes crystallized in the form of an oblique or rectangular four-sided prism, flatly bevelled on the extremities, or a broad six-sided prism. The colours

are white, grey, yellowish or reddish-white, light-red, sometimes greenish. It is composed of silica, alumina, and lime, with a little iron, and some potash; but some varieties have soda in place of potash. It is fusible without the addition of an alkali, and forms glass. The variety called Glassy Felspar, which is crystallized in rectangular four-sided prisms, of a white colour, with glassy lustre, and transparent, occurs in several kinds of rock. Compact Felspar, or that in which the individual crystals are so minute as to present a compact or somewhat granular appearance, is stated by Dr. MacCulloch to contain both soda and potash, for which reason he considers it entitled to a separate consideration. It is of various colours, and exists either simple, or forming a constituent of many compound rocks. A variety, called Clinkstone, also forms rocks, either by itself, or in combination. Disintegrated by the action of the weather, and having lost its alkali, felspar forms the substance called Kaolin or Porcelain-clay.

50. Mica.—The mineral which naturally comes next in order, on account of its being frequently associated with the former two in the composition of rocks, is one which the student having once examined, can never be at a loss to recognise. In its usual form it consists of extremely thin laminæ, easily separable by introducing the edge of a knife between them, elastic, transparent, with shining lustre, and readily scratched by the knife. When in thick plates, its colours are white, grey, pink, brown, and black. It occurs crystallized in six-sided prisms, and with the blowpipe is melted into a glass. This substance is abundant in a certain class of rocks, some of which are granular or crystalline, and others slaty.

51. Talc.—Although laminated like mica, and often similar in colour, Talc is easily distinguished by being much softer, and although flexible, not elastic. It feels as if greasy to the fingers; is sectile, translucent, splendent or shining, with a pearly lustre; its colours usually greenish-

white or silvery. Talc is much less abundant than mica, but occurs in the same manner, as a constituent of certain rocks.

52. Chlorite.—This substance, so named on account of its green colour, is allied in characters to talc and mica. It occurs massive or amorphous, sometimes crystallized in oblique four-sided prisms, or irregular six-sided tables; is sectile, opaque, translucent on the edges, harder than talc, somewhat greasy to the touch, rather easily frangible, and of various shades of green, from dark to light-greyish. It occurs dispersed in rocks, or forms beds of itself.

53. Green Earth.—This is apparently an earthy or granular variety of chlorite, which occurs massive, dispersed in rocks, or enclosed in some simple minerals, as rock-crystal, and often in the globular cavities of certain rocks. It has a dull earthy fracture, is opaque, feels somewhat greasy, and like chlorite, talc, and mica, is composed chiefly of silica, alumina, magnesia, and oxide of iron.

54. Hornblende.—Amphibole or Hornblende is a mineral of a black or dark-green colour, less hard than felspar, easily scratched with a knife, affording a light-green streak, rather brittle, opaque, or translucent only on the edges, having a granular uneven fracture, and yielding a kind of clayey smell when breathed upon. It is chiefly composed of silica, alumina, lime, and oxide of iron, and melts under the blowpipe into a greyish-black glass. It occurs crystallized in oblique, four-sided prisms. Hornblende, besides being an ingredient in compound rocks, forms beds, or even whole mountains.

55. Actinolite.—This substance, which is nearly allied to Hornblende, is generally of a lighter green, and occurs massive, or in divergent slender crystals, often confusedly arranged. It varies from opaque to translucent, is brittle, easily frangible, with uneven or splintery fracture, glistening or shining. Less common than Hornblende, it occurs in rocks of the same nature, but seldom forms masses of great extent.

56. Asbestus.—Some varieties of actinolite indicate a transition to Asbestus, a fibrous substance, composed of very long filiform crystals, which, when very delicate, are flexible. It is of various colours, white, grey, brownish, or green; generally rather brittle, difficultly frangible, glistening, with a pearly or silky lustre, and disposed in parallel or divergent fibres. It is usually associated with a substance named Serpentine, or is found in connexion with actinolite or hornblende; but is not abundant.

57. Serpentine.—This substance, which forms beds or irregular masses, is compact, or somewhat fibrous, easily frangible, readily yields to the knife, has a greasy feel, a conchoidal or splintery fracture, is dull or glistening, opaque or translucent on the edges, green of various tints, often interspersed with yellowish, brown, red, or grey dots and patches.

58. Steatite.—Soapstone or Steatite, which is allied to serpentine and talc, obtains its name from its greasy or soapy feel. Its colours are white, red, or yellow; its fracture splintery, or granular; its surface dull; its fragments angular, and translucent on the edges. It may easily be cut with a knife, or, like talc, is even so soft as to yield to the nail. This substance is remarkable for leaving a trace on glass.

59. Augite.—Very similar to hornblende, with which it has often been confounded, Augite or Pyroxene is a mineral of a black or dark-green colour, crystallized in six-sided prisms, bevelled on the extremities, with a conchoidal or uneven fracture, and opaque, but translucent on the edges. It occurs as a constituent of rocks of the igneous series, or those supposed to owe their origin to the action of the earth's internal heat, such as basalt and lava, in which the crystals are often perfect.

60. Hypersthene.—Of a greenish-black colour, with glistening and pearly lustre, easily frangible, with angular fragments and uneven fracture, this substance occurs in masses, or dispersed in rocks, but is not common. It is

composed of silica, oxide of iron, magnesia, and a little alumina, and when polished has a red colour with metallic lustre.

61. Diallage.—Nearly allied to hypersthene, having a glistening, pearly lustre, and a green or brownish colour, brittle, with angular fragments, translucent on the edges, and composed of silica, alumina, lime, magnesia and oxides of iron, copper, and chrome; this substance is not common, but when polished is much valued as an ornamental stone.

62. Schorl.—This mineral, which generally occurs crystallized in prisms, having three, six, or nine sides, often imperfect and confusedly aggregated or dispersed in quartz or other substances, is of a pure black colour, with a shining or glassy lustre, and an irregular somewhat conchoidal fracture. It is brittle, easily frangible, somewhat harder than quartz, and by friction shows signs of electricity. It is chiefly composed of silica, alumina, and oxide of iron.

63. Calcareous Spar.—Carbonate of Lime when crystallized is named Calcareous Spar, when aggregated in imperfect crystals Granular or Crystalline Limestone, when of a more minutely granular texture Compact Limestone, and when less hard, with an earthy appearance, Chalk. It crystallizes in numberless forms, rhomboidal, pyramidal, and prismatic, in which state it varies in colour from white to grey, red, blue, yellow, brown, and blackish, is easily scratched with a knife, effervesces with acids, refracts double, breaks easily into rhomboidal or angular fragments, and has a shining glassy lustre. In this crystalline state it occurs abundantly in veins. Aggregated in the form of crystalline limestone it forms rocks, and presents almost every variety of colour. Of this kind are the most ornamental marbles. Compact limestone has the same properties, but is duller, minutely granular, with conchoidal fracture. Both kinds are burnt into lime, the action of heat expelling their carbonic acid. Chalk, which is generally white, but sometimes yellowish, red, or grey, is also a carbonate of lime, but dull, opaque, earthy, soft, and leav-

ing its streak or powder on any substance harder than itself. All these substances are composed chiefly of lime and carbonic acid. It is of importance to examine many varieties of limestone, as it presents numerous modifications in colour and texture.

64. GYPSUM.—Lime combined with sulphuric acid exhibits various appearances. It may be crystallized in prisms or tables, when it is named Selenite. In this state it is white, grey, yellow, or brown, shining, very easily frangible, so soft as to be scratched by the nail, and refracting double. It also occurs granular, opaque, or translucent, with glimmering lustre; or compact, dull, with splintery fracture; or fibrous, shining, and translucent. Some varieties might seem to the beginner to resemble talc or mica; but it is always distinguishable by its softness, and other characters. It is of this substance that stucco, or plaster-of-Paris, is made.

65. DOLOMITE.—Carbonate of lime and carbonate of magnesia are the principal components of this substance, which is granular, columnar, or compact, and of various tints from pure white to grey and brown. It effervesces very feebly with acids, and may thus be distinguished from carbonate of lime.

66. ROCK-SALT.—This substance, composed of chloride of soda, with a small proportion of sulphate of lime and muriates of lime and magnesia, presents various appearances, as to form, texture, lustre, and colour; but is easily recognised by its taste, and other qualities, which are those of common salt.

67. BITUMEN.—Common Bitumen, or Mineral Pitch, is a substance of a brown or blackish colour, soft, opaque, sectile, glistening, with resinous lustre, and highly inflammable. Petroleum and Naphtha, which are of the same nature, are fluid. Amber is a resinous substance, of a yellow colour, transparent, brittle, inflammable, and probably a secretion from trees.

68. COAL.—The common varieties of Coal are easily re-

cognised, being hard, black, brittle, and laminated. Glance coal is of the same nature, with more lustre, and burns without flame or smoke. Brown coal is dull, fibrous or earthy, and is clearly composed of vegetable remains partially mineralized. Peat, which consists of partially decomposed roots and stems of various woody and herbaceous plants, may be considered as forming one extremity of the series, which ends with glance coal.

69. Oxide of Iron.—Iron in various states is abundantly distributed in rocks, generally imparting a brown, reddish, or yellow tint. The forms which iron-ore assumes are very numerous. Sometimes it is fibrous, brown, brittle, opaque, with somewhat resinous lustre, and yellowish streak, when it is named Brown Hematite, or Hydroxide of Iron. Red Hematite, or Peroxide of Iron, is of various colours, compact or fibrous, opaque, with a red streak. Magnetic iron-ore, or protoxide of iron, highly magnetic, black, shining, opaque, brittle, and hard. "The presence of iron," as Mr. Bakewell observes, "not only increases the weight, and darkens the colour of numerous rocks and stones, but is one principal means of their decomposition, for iron exists in stones in two states of oxygenation, as the black or the red oxide; and when the former is exposed to air and moisture, it absorbs a greater portion of oxygen, and is converted into a brown ochrey incrustation, which peels off, and exposes a fresh surface of the stone to a similar process."

70. Manganese.—Oxide of manganese, chiefly of the grey kind, occurs massive, in nodules, dendritic, fibrous, granular, or crystallized in prisms, and generally communicates to rocks in which it is dispersed, a dull purplish-red colour.

71. Garnet.—This substance, which, although it does not of itself form entire rocks, is yet so plentifully distributed in those of a certain series, that it may be included among the more common minerals, presents itself under various forms, but usually in that of a rhomboidal dodeca-

hedron. Its colours are dark red, brownish-red, light red or pink, brown, yellow, green, and black. It is hard, brittle, easily frangible, with a conchoidal fracture, and glassy or resinous lustre. Common Garnet is less hard, and less transparent than Precious Garnet, which is often perfectly diaphanous. It is frequently so brittle as to be splintered with very slight effort. The usual manner in which Garnet occurs, is in small crystals dispersed through slaty and granitic rocks.

Rocks to be first examined.

72. More common Rocks.—When the beginner has examined these substances, so as to be able to recognise them in most of their different states, he may proceed to inspect specimens of the masses of mineral matter, of which they form component parts. It is absolutely requisite that he should possess, or have access to, specimens; for it is in vain to attempt the acquisition of geological knowledge by mere reading. In examining simple minerals and rocks, a lens, a knife, a little nitric acid, and a small chipping hammer, will be found very useful. Having rendered himself familiar with the few minerals above briefly described, he will readily distinguish the following rocks, which are arranged here, not in the order in which they occur in nature, but in that in which they may be most easily studied. Some rocks are of uniform texture, and composed of a single mineral species, while others are aggregates of two or more minerals. These circumstances might give rise to a division of rocks into simple and compound. The latter are of two kinds, aggregated or conglomerated: that is, having their component parts crystalline and coherent, without the intervention of another substance, or evidently formed of fragments, generally in some degree worn or rounded, of minerals or rocks, cemented by a substance filling the vacuities. It will be better, on the present occasion, however, to arrange the rocks of which we have to speak, agreeably to their composition, into Quartzose, Fel-

spathic, Micaceous, Talcose, Hornblendic, Augitic, Calcareous, Carbonaceous, Saliferous, and Ferriferous; adding those which are of a fragmentary or conglomerated nature.

73. Quartzose Rocks.—Those rocks of which quartz is the principal, or a very prominent ingredient, are the following:

(1.) Quartz-Rock.—Composed of quartz, sometimes intermixed with felspar. One kind of quartz-rock is of a compact, somewhat foliated structure, translucent, with uneven splintery fracture, glassy lustre, and white or greyish colour. Another kind, more common, is granulated, glistening, translucent on the edges, with uneven or conchoidal fracture, white, grey, reddish, or bluish, often containing felspar, sometimes scales of mica, and frequently tinged red with iron. It passes into mica-slate by the increase of mica, and into sand-stone, by gradually becoming more granular.

(2.) Jasper.—Opaque, close-grained, dull, or glistening, of various colours, red, yellow, brown, variegated, with conchoidal or uneven fracture.

(3.) Flint.—Compact, yellowish, reddish, grey, or black, uniform, patched, or spotted, with conchoidal fracture, smooth, faintly glistening, having a horny aspect, the edges translucent, brittle, splintery.

(4). Flinty Slate or Lydian Stone.—Compact, of a minutely granular splintery texture, tenacious, with conchoidal fracture, sometimes slaty, with flat or even fracture, opaque, dull or slightly glimmering, grey, or black, often veined with white quartz, harder than steel, and when polished used as a touchstone for ascertaining the comparative purity of gold and silver.

(5). Obsidian.—Opaque, glassy, splendent, very brittle, easily frangible, with conchoidal, smooth fracture, translucent on the edges, the colour black, grey, greenish or bluish.

(6.) Pitchstone.—Very similar to obsidian, but less glassy, of various colours, black, brown, blue, grey, or greenish, brittle, easily frangible, with splintery, uneven, or conchoidal fracture, slightly translucent on the edges.

Often porphyritic, that is, having crystals (of glassy felspar) interspersed.

(7.) PUMICE.—This substance, which, on account of its porosity, is so light as to float on water, is of the same nature as lava, obsidian, or pitchstone, but fibrous, vesicular, glistening like threads of melted glass, and of a greyish, brownish, or whitish colour.

It must here be remarked that Obsidian, Pitchstone, Lava, Trachyte, and Pumice, may with equal propriety be referred to the Felspathic series.

(8.) SANDSTONE.—Some sandstones are so close-grained, hard, and compact, as to resemble quartz. Others are more granular, but with little other matter than quartz in their composition. Some again, having the grains larger, pass into conglomerates. Common quartz-sandstone is white, grey, red, blackish, yellowish, or greenish; white or grey when pure, yellow or red when impregnated with iron, green when mixed with green earth, black when having carbonaceous matter interspersed; often glistening with scales of mica; hard or soft, opaque, brittle, easily broken, with conchoidal, uneven, granular fracture.

74. FELSPATHIC ROCKS.—The rocks of which felspar is the chief constituent are not less numerous nor extensively distributed than those composed of quartz.

(1.) GRANITE.—This rock is essentially composed of felspar, quartz, and mica, or hornblende, and presents various appearances dependent upon the size and colour of the crystals of these substances. The felspar is generally the most abundant ingredient, and its laminated crystals or fragments, which are opaque and shining, vary in size from several inches to minute grains, and in colour from red or flesh-colour to white, grey, or blackish. The quartz is translucent, white, grey, or brown, and is easily distinguished by its hardness and glassy lustre. The mica, in plates of various sizes, is white, silvery, pink, red, brown, or black. The hornblende is dark-green or blackish. The prevailing tint is determined by the colour of the felspar.

Often there are distinct crystals of felspar imbedded in the granular mass, when the granite is said to be porphyritic.

(2.) Syenite.—When in a crystalline or granular compound of felspar and quartz, hornblende is interspersed in place of mica, or at least is abundant, the rock is named Syenite. It is in reality merely a variety of granite, which frequently contains both mica and hornblende. Syenite is frequently porphyritic, like common granite.

(3.) Eurite.—When granite is composed of particles so minute as scarcely to be distinguishable, and the mass resembles compact felspar, it is named Eurite.

(4.) Protogene.—This is a kind of granite, passing into gneiss, or having somewhat of a slaty structure, and in which the mica is substituted by talc, steatite, or chlorite, which often give it a greenish tint, and render it greasy to the touch.

(5.) Euphotide or Diallage Rock.—Felspar of a yellowish or greenish-grey colour, with a lamellar structure, and approaching in tenacity to compact felspar, with interspersed crystalline or compact green or grey diallage. Often breaking equally in all directions, it resembles granite; at other times fissile or laminar, it has more the appearance of gneiss. The general colour varies from light grey to dark grey, green, or brown.

(6.) Gneiss.—In granite and syenite the felspar, quartz, and mica, or hornblende, are intermixed, so that the rock is of a uniformly aggregated structure, not splitting in one direction more readily than in another; but in gneiss, which is composed of the same minerals, there is a distinctly laminated appearance, and the rock forms strata or layers; so that gneiss may be defined laminated and stratified granite. It is in a manner intermediate between granite and mica-slate. Its colours are as variable as those of granite; and the general tint depends chiefly upon that of the felspar, although the mica is generally more abundant than in granite.

(7.) Compact Felspar.—Although felspar of the ordinary lamellar structure, occurs in masses, irregular beds, and veins, it seems scarcely entitled to rank as a distinct rock; but in another form, it exists in vast quantity. In this state, or that of compact felspar, it presents the appearance of a homogeneous mass, of compact texture, opaque, tough, with conchoidal, uneven, or scaly fracture, translucent on the edges; of various colours, white, red, brown, and grey.

(8.) Felspar-Porphyry.—When in a mass of compact felspar, are dispersed crystals, generally of pure felspar, but also of hornblende, mica, or quartz, the rock is named Felspar-Porphyry.

(9.) Clinkstone.—A rock so named on account of the sharp noise which it emits when struck with the hammer; so hard as not to be easily scratched with the knife; its fracture splintery and conchoidal, the lustre glistening, the colours, grey, green, or bluish, often with veins of jasper.

(10.) Claystone.—Compact felspar, softer than usual, with an earthy aspect, conchoidal uneven fracture, and of various colours, yellowish, reddish, purplish, or brown. It is often porphyritic, containing crystals of felspar.

(11.) Trachyte.—A rock composed of earthy, whitish, or greyish felspar, porous, rough, frequently containing crystals of glassy felspar. It is of volcanic origin, and seems to pass into pumice.

(12.) Lava.—Rocks composed of substances emitted by volcanoes, in a fused or fluid state, and when solidified presenting a more or less vesicular appearance, bear the name of Lava, of which there are several varieties.

75. Micaceous Rocks.—The rocks of which mica is the principal ingredient, although extensively distributed, are not numerous.

(1.) Mica-slate.—This rock, which is of a laminar structure, and arranged in strata, is composed of mica and quartz, the former predominating and disposed in scales or plates, the latter interposed in laminæ. The colour of the mica, which varies from black to greyish-white, determines that of the rock. When the quartz predominates, it passes into quartz-rock, and when the scales of mica become extremely small, while the quartz diminishes in quantity, it passes into the next.

(2.) Clay-slate.—Although this rock is named clay-slate, it appears to be mica-slate in a state of extreme division, the scales of mica having gradually become so attenuated as to give it a homogeneous, glistening appearance. It is of various tints of green, grey, yellow, purple, and blue, and often contains iron-pyrites or sulphuret of iron in cubical crystals, as mica-slate frequently contains garnet.

76. Talcose Rocks.—Some of these rocks bear a great resemblance to the last, which is more especially the case with the first in order.

(1.) Chlorite-Slate.—A slaty rock of a light green colour, glistening or shining, rather soft, composed of scales or plates of chlorite, with laminæ of quartz interposed.

(2.) Talc-slate.—Talc and quartz in laminæ; softer than the last, glistening, with an unctuous feel; and of various colours, white, grey, or greenish.

(3.) Serpentine.—The characters of this substance have already been given. It constitutes rocks of irregular form, which are often intermixed with steatite, chlorite, hydrate of magnesia, chromate of iron, asbestus, actinolite, diallage, and hornblende. It is often also intermixed with limestone.

77. Hornblendic Rocks.—Of this series there are only two principal kinds.

(1.) Hornblende-slate.—A rock generally of a distinctly slaty structure, and composed of crystals of hornblende, often intermixed with felspar.

(2.) Actinolite-slate.—When the variety of hornblende distinguished by the name of actinolite, which is generally of a lighter green, and formed of slender, radiating, or variously disposed crystals, with felspar and quartz in laminæ, is the principal ingredient.

78. Augitic Rocks.—Augite so closely resembles hornblende, that these two substances have often been confound-

ed. The former is a principal constituent of a class of rocks supposed to be of igneous formation.

(1.) Greenstone.—Augite and common felspar intermixed, the crystals distinct, sometimes so large as to give the mass a resemblance to syenite or granite.

(2.) Basalt.—An intimate mixture of augite and felspar, of which the crystals are so minute that the rock appears of a homogeneous texture, and of a dark grey or blackish colour.

(3.) Wacke'.—An earthy, apparently homogeneous rock of a yellowish, greenish, or grey colour, usually with small interspersed crystals of augite.

79. Argillaceous Rocks.—Homogeneous soft substances, composed chiefly of aluminous earth, or clay.

(1.) Shale or Slate-Clay.—Argillaceous matter, indurated, with a slaty structure, and dull grey streak. Sulphuret of iron is often intermixed, which on decomposing allows the sulphuric acid to combine with the alumina, and then form alum.

(2.) Bituminous Shale.—Slate-clay with bituminous matter intermixed, giving it a dark brown or blackish colour; its structure slaty, the streak brown and shining.

(3.) Clay.—Unctuous, soft, friable, of a dense homogeneous texture, forming a tenacious paste with water, and of various colours, grey, yellowish, greenish, or reddish.

(4.) Marl.—Clay mixed with lime; soft, friable, not forming a tenacious paste with water; grey, yellow, green, blue, red.

80. Calcareous Rocks.—The numerous modifications presented by carbonate of lime, are highly interesting in a geological, as well as in an economical, point of view. The principal kinds of limestone are the following.

(1.) Crystalline or Primary Limestone.—Of a crystalline texture, varying from large to fine-grained, tough, with an even or conchoidal fracture, translucent on the edges, and admitting of a fine polish. Like all the other limestones, this is readily scratched by the knife, and effervesces with acids. Its colours are various: pure white, grey, blue, green, yellow, or red.

(2.) Compact or Secondary Limestone.—Of a compact texture, with the grain fine, easily frangible, with a large conchoidal smooth fracture. Its colours are grey, yellow, green, blue, red, brown, or black, often clouded, striped, or veined. It frequently contains shells.

(3.) Oolite Limestone.—Composed of grains varying from the smallest size to that of a pea, generally of an elliptical or roundish form. The colours are brown, yellow, white, or grey; the fracture slaty or irregular, the lustre dull.

(4.) Chalk.—Earthy or compact limestone, generally white, and friable, sometimes grey or reddish.

(5.) Dolomite.—Composed of carbonate of lime and magnesia, varying in texture from crystalline to compact; in the former case generally pure white, in the latter yellowish or brown; sometimes earthy and friable. The compact or brown kind is commonly called Magnesian Limestone. All the varieties effervesce feebly with acids.

(6.) Gypsum.—Sulphate of lime. Texture granular or crystalline, very easily frangible, soft, white, grey, red, or brown. It forms beds and irregular masses, and furnishes plaster-of-Paris.

81. Carboniferous Rocks.—The different kinds of coal belong to this division.

(1.) Glance Coal.—With a high or semimetallic lustre, burning without flame or smoke, composed of carbon with silica and alumina.

(2.) Common Coal.—Black, shining, slaty, or laminated; burning with flame and brown smoke, and emitting a bituminous smell. Numerous varieties occur.

(3.) Lignite.—Brown, dull, compact, or laminated, often woody, burning with flame and smoke.

(4.) Peat.—Brown, earthy, or fibrous, chiefly composed of partially decayed vegetables, burning with flame and grey smoke, and emitting a pungent and somewhat fetid odour.

82. Ferriferous Rocks.—Of the different varieties of iron-ore there are few that form rocks, properly so called, although that substance is very abundantly distributed.

(1.) Clay Iron-Ore.—By far the most plentiful of the ores or substances from which iron is obtained. Of an earthy aspect, with even or conchoidal fracture, yellow streak or powder, dull colours, yellowish, brown, reddish, or grey.

(2.) Iron-Pyrites.—Brass-yellow, or greenish-yellow, compact or fibrous, emitting a sulphurous smell when struck; granulated, or even earthy, when impure.

83. Fragmentary Rocks.—Aggregated or Fragmentary Rocks are formed of fragments of other rocks, generally of sufficient size to enable one to distinguish the different kinds. When the fragments are very small, they form sandstones and tufas; when large and rounded, they constitute conglomerates; when large and angular, brecciæ. In these rocks the particles or fragments are usually cemented together by a substance filling up their interstices.

(1.) Sandstone.—Already described among the quartzose rocks. The particles of quartz are sometimes so large that the aggregated structure becomes very distinct. When the cementing substance is quartz, the rock is very hard and durable; when clay or ferruginous matter is in great quantity, it is friable, and easily disintegrated.

(2.) Greywacke′.—Fragments of quartz, felspar, slate, and other substances, generally angular, and firmly cemented by a paste of the same nature. When the grains are very small, it passes into clay-slate or sandstone.

(3.) Volcanic Breccia.—Angular and rounded fragments of volcanic rocks, cemented.

(4.) Conglomerate.—Rounded fragments of quartz and other hard rocks, cemented by clay or sand, with ferruginous matter.

(5.) Trap-Tufa or Conglomerate.—Rounded fragments of greenstone, basalt, and other trap-rocks, cemented by materials of the same description.

84. Organic Remains.—The inspection of these substances will enable the student to distinguish at sight the principal materials which enter into the composition of the globe, and prepare him for the more extended examination of the different rocks. But previous to this, another subject of great importance must occupy his attention. In all the rocks which are disposed in strata or layers, with the exception of some of a more crystalline nature, and occupying a certain relative position, there are found imbedded remains of plants and animals, the study of which therefore constitutes an important branch of geology as well as of zoology. The next chapter, then, will be devoted to a comprehensive view of the different groups composing the Animal and Vegetable Kingdoms, some knowledge of which is necessary to enable the beginner to appreciate the reasonings founded upon their occurrence in the mineral deposits.

Recapitulation.

42. Of what materials does the globe at first sight appear to be composed?—43. What are the simple or elementary substances known? Mention those which are most abundant.—44. Give a short account of oxygen, hydrogen, chlorine, sulphur, phosphorus, carbon, silicium, aluminum, calcium, sodium, potassium, magnesium, iron, and manganese.—45. What are the most abundant simple minerals? —46. Is a knowledge of mineralogy important to the geologist? What is meant by a simple mineral? In what sense is the term Rock used?—47. What is a crystal? What are the principal properties by which minerals may be distinguished from each other? How is the hardness determined? What terms are applied to characters dependent upon light? What are the varieties of texture?—48. Give an account of Quartz.—49. Of Felspar.—50. Mica.—51. Talc.—52.

Chlorite.—53. Green Earth.—54. Hornblende.—55. Actinolite.—56. Asbestus.—57. Serpentine.—58. Steatite.—59. Augite.—60. Hypersthene.—61. Diallage.—62. Schorl.—63. Calcareous spar.—64. Gypsum.—65. Dolomite.—66. Bitumen.—67. Coal.—68. Oxide of Iron.—69. Sulphuret of Iron.—70. Manganese.—71. Garnet.—72. What instruments are useful in examining minerals and rocks? How may the more common rocks be arranged with the view of more easily becoming acquainted with them?—73. What are the principal Quartzose Rocks? Mention the characters of Quartz-Rock, Jasper, Flint, Flinty-slate, Obsidian, Pitchstone, Pumice, Sandstone.—74. What are the rocks of which Felspar is the basis? Give an account of Compact Felspar, Clinkstone, Claystone, Felspar-Porphyry, Granite, Syenite, Gneiss, Protogene, Diallage Rock.—75. What are the Micaceous Rocks? Describe Mica-slate, and Clay-slate.—76. Describe the Talcose Rocks: Chlorite-slate, Talc-slate, Serpentine.—77. What characters distinguish Hornblende-slate and Actinolite-slate? 78. Give an account of the Augitic Rocks: Augite Rock, Greenstone, Basalt, and Wacké.—79. What is the difference between slate-clay and bituminous shale? What are the characters of clay and marl?—80. Describe the Calcareous Rocks: Crystalline Limestone, Compact Limestone, Chalk, Dolomite, and Gypsum.—81. What is the nature of the Carboniferous Rocks?—82. What Ferriferous Rocks are most abundant?—83. Describe some of the Fragmentary Rocks: Sandstone, Greywacké, Volcanic Breccia, Conglomerate, Trap-Tufa.—84. What other substances besides those mentioned enter into the composition of rocks?

CHAPTER IV.

PALÆONTOLOGY.—ARRANGEMENT OF ANIMALS INTO VERTEBRATED, ARTICULATED, MOLLUSCOUS, AND RADIATED.—REMAINS OF VERTEBRATED ANIMALS, OF ARTICULATED ANIMALS, OF MOLLUSCA, OF ZOOPHYTES.—ARRANGEMENT OF PLANTS.

85. PALÆONTOLOGY.—Many deposits of mineral matter, such as beds of clay, shale, sandstone, and limestone, contain imbedded in their substance remains of plants and animals, in various states of preservation, generally, however, the harder and more solid parts alone remaining, and sometimes their existence being indicated merely by the impressions which they have made. These organic remains are extremely diversified, and present themselves under very different circumstances. The consideration of their forms and relations, the changes which they have undergone, and the causes which have produced their immersion in the strata, has obtained the name of PALÆONTOLOGY, a term compounded of three Greek words: παλαιος, ancient, ὢν, a being, and λογος, a discourse. To understand what has to be said respecting these animals and plants, in the subsequent parts of this treatise, it is necessary that the student should acquire some knowledge of the arrangement and nature of the subjects of the animal and vegetable kingdoms.

86. ARRANGEMENT OF ANIMALS.—According to the system now in general use, animals have been arranged into four primary groups:—1. The Vertebrated; 2. The Articulated; 3. The Molluscous; 4. The Radiated.

(1.) VERTEBRATED ANIMALS.—The species belonging to this group agree in having an internal skeleton; a brain, *a*, and spinal marrow, *b*, enclosed within a skull and vertebræ,

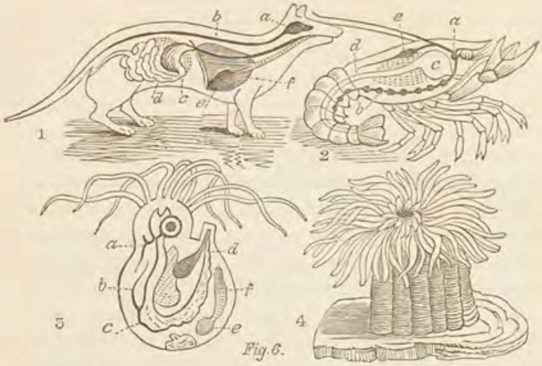


Fig. 6.

and placed above the digestive organs, *c d*; a muscular heart, *e*, composed of two distinct cavities; red blood; organs of sight, hearing, smell, and taste, situated in the head; a symmetrical form of body; never more than four limbs; the sexes always separated.

To this division belong the Mammalia, or animals which suckle their young, Birds, Reptiles, and Fishes.

(2.) Articulated Animals.—In this group, the structure is very different. The body is still symmetrical, but is not supported by an internal skeleton like that of the vertebrated animals. Their skeleton is external, composed of hard plates, enclosing the body as in armour, and formed of a modification of the skin. It is on account of this disposition of the skin into jointed plates or rings that these animals have been named articulated (jointed). Their nervous system is composed of a double chain of ganglia, one of which, *a*, occupies the head, while the other, *b*, runs along the middle line of the body under the digestive canal, *c d*. There is thus no appearance of spinal marrow. The blood is almost always white, and the heart, *e*, is often reduced to the state of a simple longitudinal canal. The organs of sense are less numerous and less perfect than in the vertebrated animals, and sometimes are entirely absent. Lastly, the limbs are generally numerous. Of this kind are Insects, Spiders, Scorpions, Crabs, Centipedes, Barnacles, and Worms.

(3.) MOLLUSCOUS ANIMALS.—In these, there is no skeleton, external or internal, so that the body is soft, whence their name (from *mollis*, soft). But although the skin is soft and contractile, it often secretes an earthy matter, forming hard plates, named shells, which, however, are never disposed so as to form a series of rings or joints. Their nervous system is composed of several scattered masses connected by filaments, *a b*. The blood is white, and the circulating system, *e*, pretty complete. There is never an organ of smell; that of hearing is seen only in one family; and many of these animals are destitute of eyes. Lastly, there are scarcely ever limbs for locomotion. The digestive organs are marked *c d*, the gills, *f*.

To this group belong Slugs, Snails, Oysters, Clams, in short, Shells of all kinds, and Cuttle-fish.

(4.) RADIATED ANIMALS.—In the three preceding groups, the organs of motion and sensation are disposed symmetrically on both sides of the middle line of the body, of which the anterior and posterior surfaces are dissimilar; and there is always a distinct nervous system. But in this division, these organs are placed in a radiating manner around a common centre. The blood is white, as in the mollusca and insects; but if there are organs of circulation, they are very imperfect; and the digestive apparatus is extremely simple, being generally reduced to a single cavity, open only at one end. Some of these animals even appear to be formed of nothing more than a homogeneous pulp, possessed of mobility and sensation. They are named Radiated Animals, on account of the radiating disposition of their organs, and Zoophytes, or animal-plants, because many of them resemble plants.

Of this kind are Sea-anemonies, Corals, Sea-urchins, and Star-fish, as well as the Microscopic Animalcules, and Intestinal Worms.

87. Remains of Vertebrated Animals.—No remains of the human species have hitherto been found elsewhere than in soil, sand, or deposits of recent formation. Very lately, some remains of monkeys have been discovered. Bones and teeth of carnivorous quadrupeds are found in caves, intermixed with those of herbivorous species. A great number of bones of the large quadrupeds, named Pachydermata (thick-skinned), elephants, rhinoceroses, mastodons, hippopotami, tapirs, and palæotheria, have been met with, dispersed even over the colder regions, where such animals could not now find subsistence, or protection from the inclemency of the weather. Bones of ruminating animals, and other herbivorous species, have also been found in the upper deposits; as have those of whales, although these are very uncommon. Remains of birds are of comparatively rare occurrence. Those of reptiles, however, especially of the lizard or crocodile tribe, occur abundantly in some of the upper deposits, and even in others at a great depth. One of these lizards, the Iguanodon, exceeds eighty feet in length, and others, named Ichthyosauri, and Plesiosauri, are of very large size, and furnished with paddles instead of feet, in which respect they differ from any known reptile of the present day. Fishes present themselves in great numbers in many of the strata, not only their bones and teeth being preserved, but frequently their whole bodies, and even their scales and spines.

88. Remains of Articulated Animals.—Comparatively few remains of articulated animals have been met with. Insects, completely preserved, are often seen in amber, and remains of some have been found in rocks, especially of the coleopterous or hard-winged tribes. Crustacea or crabs are not uncommon in certain deposits, especially in chalk and the beds lying over it; and some remains of worms inhabiting tubes have been found in the upper strata.

89. Remains of Mollusca.—Shells of very numerous genera are met with in many deposits; bivalves, or such as are composed of two pieces being more numerous in the

lower, and univalves, or spiral shells, in the upper. Some of those in the latter strata are identical with species at present living. Many limestones appear to be almost entirely composed of shells. The naked mollusca have left fewer traces of their existence, although ink-bags and pens of the cuttle-fish have been found.

90. Remains of Zoophytes.—Radiated animals occur so abundantly in many deposits, that they seem to compose their entire mass. These are of the kind usually denominated Corals or Madrepores. Encrinites, a remarkable family of this order, now almost entirely extinct, are abundant in some of the lower and middle strata. Lastly, Echini, or Sea-urchins of various kinds, are of common occurrence in chalk and some inferior deposits.

In mentioning these circumstances here, the object is only to prepare the reader for the details that will occasionally be presented in treating of the various rocks; and therefore it is that a particular account of the different fossil remains of animals, unintelligible without an extensive knowledge of zoology, has been avoided. We have now to take notice of the remains of vegetables.

91. Arrangement of Plants.—Two great divisions of the vegetable kingdom are indicated by a difference in the internal structure of plants. Some vegetables are exclusively composed of cellules, without any intermixture of those elongated tubes called spiral vessels; while others have in their interior both cellular and vascular tissue. Plants of the former kind are accordingly named Cellular, those of the latter, Vascular.

Cellular Plants are those of which the entire tissue is composed of minute cellules or vesicles. Of this kind are Fungi, Algæ or Sea-weeds, Lichens, Mosses, and Confervæ.

Vascular Plants are those which, together with cellules, contain vascular tissue. Of this kind are all plants that bear flowers, and produce seeds, such as Trees, Shrubs, Grasses, and Herbaceous Plants.

But a more commonly employed division is into Dico-

TYLEDONOUS, MONOCOTYLEDONOUS, and ACOTYLEDONOUS, the distinctions of which are founded upon the structure and mode of germinating of the seed.

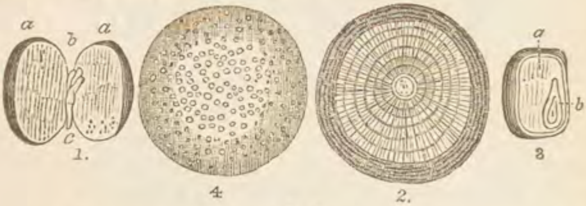


Fig. 7.

(1.) DICOTYLEDONOUS PLANTS.—The seeds composed of two lobes, termed cotyledons, Fig. 7, 1, *a a*, attached to the germen, *b c*, of which one extremity, *c*, descends and forms the root, while the other, *b*, ascends and forms the stem and leaves. The stem, when succulent, composed of a central cylinder of pith, which may ultimately disappear, surrounded by a ring of vessels named the medullary sheath, between which and the cuticle is a layer of cellular tissue with vessels and woody fibres. When woody, the stem, 2, composed of a central column of pith, a medullary sheath, successive layers of woody tissue, a corresponding number of thinner layers of bark, and thin vertical plates of cellular tissue, named medullary rays, radiating from the pith. Plants of this class are also named EXOGENOUS, that is, increasing outwards, because the stems enlarge by means of the annual addition of a woody layer immediately within the bark.

(2.) MONOCOTYLEDONOUS PLANTS.—The seeds, 3, composed of an albuminous mass, having within it or on one side the germen, of which one extremity forms the radicle, the other the stem and leaves, enveloped in a single conical cotyledon, which is ultimately perforated by the first leaf. In the stem, 4, there is no distinction into pith, wood, and bark, it being a cylindrical mass of cellular tissue in which are irregularly distributed bundles of vessels. There are no medullary rays, and the increase takes place towards the centre, the outer parts becoming more condensed, whence these plants are named ENDOGENOUS, or increasing inwards.

(3.) ACOTYLEDONOUS PLANTS.—Plants which do not bear flowers, and thus said to be CRYPTOGAMOUS, in contradistinction to the former two classes, which are PHANEROGAMOUS. There are no true seeds, but minute granular bodies, named SPORULES, capable of becoming distinct plants, and germinating by the addition of cellular tissue. The internal structure is cellular, but in some tribes ducts, or vessels of a particular kind, are interspersed in the cellular tissue. To this class belong Ferns, Mosses, Sea-weeds, Lichens, and Fungi.

92. FOSSIL PLANTS.—The remains or impressions of plants that occur in the rocks that are lowest in the series belong chiefly to the Acotyledonous or Cryptogamous class. Some Algæ and Ferns first make their appearance. In the strata associated with coal are abundance of Ferns, Equiseta, and plants resembling gigantic Lycopodia, and known by the generic names of Lepidodendron, Sigillaria, and Stigmaria, together with some Coniferæ, that is, trees of the pine or fir family. In the strata incumbent on the coal beds are remains of Ferns, Cycadeæ, and Coniferæ; and in the highest or most superficial series of rocks, are found, besides these, fossil plants of the most perfect classes, Monocotyledonous and Dicotyledonous, some of them containing trees similar or analogous to those growing on the surface at the present day.

Fossil plants present themselves in various stages or modes of preservation. Often, in fine shale, or clay, or limestone, there are beautiful and perfect impressions of fronds of ferns, of which the substance has been entirely decomposed. In sandstones, trunks and branches occur, which at first sight seem to retain their structure, but it is found that their form only remains, the interior being composed of sand or clay. Sometimes, however, when the interior is composed chiefly of calcareous or siliceous matter, the structure is so perfectly retained that the microscope enables us to determine with accuracy the family of the plant.

93. General Observations.—Estimating the perfection of animals by the number and development of the organs of sense, and that of plants by the more distinct organization of the organs of fructification, we find that in ascending from the oldest or lowest to the newest or uppermost strata, there is a progressive advance from lower to higher orders. The gigantic forms assumed in the lower strata by plants belonging to families of which the species that now occur on the globe are very diminutive, and the occurrence there of vegetable remains analogous to plants now peculiar to the tropical regions, lead to the inference that at that remote period the temperature of the globe was much higher, and the light more equably diffused than now. It has been conjectured, too, that the constitution of the atmosphere was then different, and that a greater proportion of carbonic acid existed in it, to produce that magnificent vegetation disclosed by the beds connected with coal, which itself is entirely composed of the remains of plants.

In conclusion, it may be well to allude here to certain inferences that may be made from the occurrence of organic remains. If a rock contain exclusively remains of animals known from analogy of structure to be marine, it may be inferred that it has been deposited at the bottom of the sea. If it contain the remains of fresh-water animals or plants, or of terrestrial animals and plants, exclusively, it must have been deposited at the bottom of a fresh-water lake or river. If it contain an intermixture of marine and fresh-water animals and plants, it has probably been formed in an estuary, which has been alternately covered with fresh and salt water.

"Among living families of plants," says Dr. Buckland, in his Bridgewater Treatise, "Sea-weeds, Ferns, Lycopodiaceæ, Equisetaceæ, Cycadeæ, and Coniferæ, bear the nearest relations to the earliest forms of vegetation that have existed upon our planet. The family which has most universally pervaded every stage of vegetation, is that of Coniferæ; increasing in the number and variety of its genera and species, at each successive change in the climate and condition of the surface of the earth. This family forms about one three-hundredth part of the total number of existing vegetables. Another family, which has pervaded all the series of formations, though in small proportions, is that of Palms.

"In the fossil Flora, we have not only the existing fundamental distinctions between Endogenous and Exogenous plants, but we have also agreement in the details of structure, throughout numerous families, which indicates the influence of the same laws, that regulate the development of the living members of the vegetable family. The remains of Fructification, also, found occasionally with the plants of all formations, show still further, that the principles of vegetable reproduction have at all times been the same. The exquisite organizations which are disclosed by the microscope, in that which to the naked eye is but a log of lignite, or lump of coal, not only demonstrate the adaptation of means to ends, but the application, also, of similar means, to effect corresponding ends, throughout the several Creations which have modified the changing forms of vegetable life. Such combinations of contrivances, varying with the varied conditions of the earth, not only prove the existence of a Designer, from the existence of method and design, but from the connexion of parts, and unity of purpose, which pervade the entirety of one vast, and complex, but harmonious whole, show that one and the same mind gave origin and efficacy to them all."

Of such materials, then, as have been briefly described or alluded to in this and the preceding chapters, is the crust of the globe composed. Our next subject of inquiry is the manner in which the masses formed of them present themselves to our view.

Recapitulation.

85. What substances are frequently imbedded in mineral deposits? What name is applied to the branch of science which treats of fossil animals and plants?—86. How may animals be arranged? What are the principal characters of the Vertebrated, Articulated, Molluscous, and Radiated animals? Give the etymology of these terms, and the reasons for their being employed. What animals are the most perfect?—87. Have remains of the human species been found in rocks? What kinds of Vertebrated animals chiefly occur in a fossil state?—88. Are the Articulated animals common in that state?—89. What kinds of Mollusca are prevalent?—90. Are the remains of Radiated animals plentiful?—91. How may plants be primarily arranged? Define Cellular Plants and Vascular Plants. What is the most common physiological arrangement of plants? What are the essential characters of Dicotyledonous, Monocotyledonous, and Acotyledonous plants?—92. Give some account of fossil plants, stating what kinds occur in the lowest, in the carboniferous, and in the upper deposits. In what state of preservation do fossil plants occur?—93. Is there a progressive advance in the perfection of fossil plants from remote to recent periods? Why is it supposed that the temperature of the globe was formerly higher? Is it probable that the constitution of the atmosphere has been different? Mention some inferences that may be made from the occurrence of organic remains in rocks. What plants now living most resemble the fossil species? What are the most universally prevalent families? Are fossil and living plants anatomically similar? What is the inference as to the origin of these substances?

SECTION II.

ARRANGEMENT OF THE COMPONENT PARTS OF THE EARTH.

CHAPTER I.

GENERAL IDEA OF THE DISTRIBUTION AND ARRANGEMENT OF ROCKS: SUMMIT OF BEN-NA-MUC-DUI, AND THE NEIGHBOURING DISTRICT; BEN LEDI AND VALLEY OF THE TEITH; LAMMERMUIR HILLS, VALLEY OF DALKEITH, AND PENTLAND HILLS; YORKSHIRE STRATA; THOSE IN THE VICINITY OF LONDON. REGULAR SUCCESSION OF STRATA, DISTINCTION OF ROCKS INTO STRATIFIED AND UNSTRATIFIED. RELATIVE POSITION OF ROCKS.

94. ROCKS OBSERVED IN DIFFERENT PARTS OF BRITAIN. —Having obtained a general idea of the form of the globe, the distribution of the land and sea, the inequalities of the surface, and the substances which enter into the composition of the earth's crust, together with the nature of the principal masses or rocks, we may now direct our attention to the arrangement and mutual relations of the latter.

Fig. 8.

A person having gained the summit of Ben-na-muc-dui, Fig. 8, *a*, the highest mountain in Scotland, finds its surface composed of fragments of granite, white quartz, disintegrated felspar, and scales of mica. Beneath this superficial layer, and in some places projecting through it, he observes the solid rock, a crystalline compound of the same materials, namely, quartz, felspar, and mica. This coarse-grained, reddish granite, he would find to compose many of the mountains around, and he might suppose it to extend for miles down towards the centre of the earth. By examining the escarpments, of which there are many of great magnificence, he would observe that, although there are sometimes irregular appearances of fissures in the rock, its parts are not disposed so as to form parallel plates, and thus that it is massive or unstratified. Farther to the south, however, he would meet with strata or layers of slaty rocks, *b*, named gneiss and mica-slate, with beds of limestone and clay-slate, leaning as it were against the granite, which therefore probably passes under them, and although rising much above their level in the mountains, is yet geologically speaking inferior to these deposits.

Fig. 9.

Supposing he were now to visit Ben Ledi, *a*, in the Southern Grampians, he would find the surface composed of angular fragments of a glistening slaty substance, which he would readily recognise as mica-slate, together with pieces of white quartz. Descending the mountain and proceeding eastward, he would find in this mica-slate, beds of chlorite-slate and clay-slate as well as limestone, dark-coloured or grey, with numerous white veins, but destitute of organic remains, *b*, succeeded by a rock intermediate between mica-slate and greywacké, *c*, a great mass of conglomerate, *d*, composed of rolled pebbles of quartz, cemented by ferruginous clay and sand, and beyond this sandstone containing much mica, *e*. In the plain, the nature of the superficial covering would be different from that of the summit of Ben-na-muc-dui and Ben Ledi: first a layer of soil, composed of sand, clay, and decayed vegetable matter; then a layer of clay intermixed with pebbles. In some places he would find peat to the depth of several feet; then a fine bluish clay; and lastly, a bed of clay and pebbles.

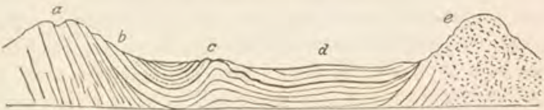


Fig. 10.

On the Lammermuir Hills, to the south of Edinburgh, *a*, he would find the superficial layers to be of soil, gravel, or peat; the subjacent rock composed of Greywacké in inclined strata, varying from coarse-grained to fine-grained, and occasionally becoming slaty. Proceeding northward, he would pass in succession beds of red conglomerate and sandstone, *b*, then a deposit of limestone, and lastly numerous beds of sandstone of various colours and textures, shale, clay, and coal, *c d*, in some places horizontal, in others variously inclined. Towards the Pentland Hills, he would observe the strata again cropping out, and on ascending the nearest eminence would find it to be composed of an unstratified mass of that kind of igneous rock named compact felspar. Or arriving at Arthur's Seat, he would find a mass of rock rising abruptly out of the plain, and resting upon sandstone; its lower part composed of porphyritic greenstone disposed in columns, above which a great mass of trap-tufa, and lastly at the summit greenstone. Salisbury Craigs, he would perceive to be formed of crystalline greenstone, lying beneath beds of sandstone, and covering strata of the same nature.

In Yorkshire, by examining the cliffs along the coast, he would discover a succession of regularly stratified rocks:

first chalk, beneath the soil, then green sand and clay, oolitic limestone, blue clays and limestones, clays and sandstones of a red colour, a series of sandstones and shales, with layers of coal, lastly limestone and clay-slate.

In the vicinity of London, there are found, in like manner, under the soil and gravel, in nearly horizontal strata, layers of clay at the top, beds of sand and clay farther down, and last of all chalk; these substances and their superposition being disclosed by the sinking of wells.

95. Succession of Strata.—Now this chalk, which forms as it were the bottom of the London basin, but which rises on either side to the surface, has been traced northward all the way to Scarborough and Whitby in Yorkshire, where, beneath it, are strata of clay and limestone, forming several series, below which are sandstones and coal, similar to those observed in the plain near Edinburgh, which rest upon limestone and conglomerates, reposing upon greywacké. These conglomerates are somewhat similar to that in the valley of the Forth and Teith, which rests on a kind of greywacké, beneath which is a series of slaty rocks. Lastly, in Aberdeenshire, these slaty rocks are found resting on granite.

96. Stratified and unstratified Rocks.—Excepting the last, all these rocks are disposed in beds or strata, of great extent and comparatively little thickness. The granite, and the rocks similar or analagous to those of the Pentland Hills and Arthur's Seat, differ in not being disposed in layers, or, in other words, in not being stratified. Such unstratified rocks occur abundantly in many parts of Scotland, and in the northern and western portions of England, sometimes forming ranges of hills, and sometimes appearing as isolated masses. There is thus a natural division of rocks into stratified and unstratified. The latter sometimes lie over the stratified rocks, and are also found beneath them. The stratified rocks, in the examples adduced, are observed to have a kind of regular succession; gneiss being lowest, then mica-slate, chlorite-slate, primary

limestone, clay-slate, greywacké, sandstone and conglomerate, limestone, sandstone with coal, red sandstone, blue clays and limestones, oolitic limestone, clay and green sand, and above all chalk and clay.

Any one of all these rocks, however, may occur at the surface. Granite, that on which all the others rest, forms even the highest point of Britain, mica-slate is seen everywhere in the southern Grampians, greywacké on the Lammermuirs, coal and sandstone in the valley of Dalkeith, chalk at Scarborough, and clay in London.

97. General Idea of the Arrangement of Rocks.—By multiplying observations of this nature, it has been found that rocks, in their arrangement, observe a certain order of superposition, and that the interruptions of continuity in the strata caused by the interference of unstratified masses, together with the various inclinations, fractures, and dislocations of the stratified rocks, if not perfectly accounted for, can yet be in some measure understood.

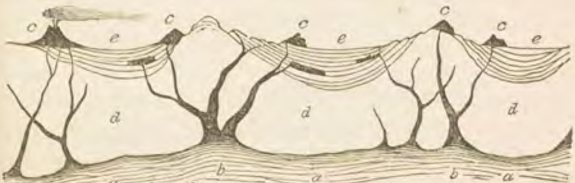


Fig. 11.

An ideal section of a portion of the earth's crust will serve, along with what has been said above, to afford some idea of the manner in which rocks are disposed. The interior of the globe is represented by *a a a*, possibly in a state of fluidity and incandescence; its consolidated surface indicated by the dark line forming the lower boundary of the Granite, *d d d*, which has its upper outline sinuous, rising here and there into eminences projecting beyond the stratified rocks, *e e e*. As if these stratified rocks had been at one time continuous, they are seen to have a curved arrangement in the basins formed between the granitic ridges. Streams of melted matter from the interior have traversed the granite in great fissures, *b c*, *b c*, *b c*, and produced deposits at the surface, as well as in the midst of the stratified rocks, *c c c c c*.

It must not, however, be understood that the different layers are always disposed in the regular curved manner in which they are here represented; for in very many cases they present themselves to the observer in such apparent confusion, some inclining one way, some another, that he might at first be apt to despair of comprehending their arrangement.

But before proceeding to the exposition of this most interesting subject, it becomes necessary to present a statement of various circumstances relative to mineral deposits, and to explain the terms employed in describing their structure and relations.

Recapitulation.

94. Of what rock is Ben-na-muc-dui composed? With what slaty rocks is the granite there connected? Describe the succession of rocks from Ben Ledi eastward. What are the rocks of the Lammermuir Hills, the Plain of Dalkeith, the Pentland Hills, and Arthur's Seat? What rocks occur in Yorkshire, and about London?—96. Distinguish between stratified and unstratified rocks. Do rocks observe any regularity in their succession? How may a rock geologically the lowest become in parts the highest?—97. Give a comprehensive account of the disposition of the rocks forming the earth's crust?

CHAPTER II.

GENERAL IDEA OF THE STRUCTURE OF ROCKS. COMPOSITION OF ROCKS. TEXTURE OF SIMPLE ROCKS, OF AGGREGATED ROCKS, OF FRAGMENTARY ROCKS. FORM OF ROCKS. DISTINGUISHING CHARACTERS. INSTRUMENTS USED IN EXAMINING ROCKS.

98. General idea of the Structure of Rocks.—Looking upon the masses of mineral matter which present themselves to our view at the earth's surface, we presently perceive that they may be examined with reference to their texture, or the mode of arrangement of the particles or crystals or fragments of minerals of which they are composed, or with reference to their disposition in masses in relation to each other. Thus, on inspecting a rock exposed in a quarry, for example, we may find, if it be sandstone, 1st, that it is composed of particles of quartz, among which are interspersed finer grains of argillaceous matter; 2dly, that it has a granular composition; 3rdly, that its particles are disposed in thin laminæ; 4thly, that these laminæ compose beds or layers of various sizes, separated from each other by parallel seams. If we examine a mass or mountain of granite, we find, 1st, that irregular crystals of felspar, quartz, and mica, enter into its composition; 2dly, that it has a crystalline texture; 3dly, that its structure is either compact, that is, without any appearance of fissures or laminæ, or somewhat prismatic, that is, divided into fragments bounded by planes; and 4thly, that viewed in the mass it has no determinate form. Again, examining a deposit of mica-slate, we observe, 1st, that the minerals of which it is composed are mica and quartz; 2dly, that it has a laminar or scaly texture; 3dly, that its laminæ are disposed so as to

form plates; and, 4thly, that these plates form larger layers, separated by distinct seams, so as to constitute beds, which are besides intersected by straight clefts having a determinate direction. Thus the structure of rocks resolves itself into four divisions: the mineralogical structure, or COMPOSITION; the intimate structure, or TEXTURE; the structure in mass, or STRUCTURE; and the external structure, configuration, or FORM.

99. COMPOSITION OF ROCKS.—Of the mineralogical structure of rocks it is unnecessary to speak in detail. As the term is employed here, it has reference merely to the simple minerals of which they are composed. Thus, what is the composition of Granite? Quartz, felspar, mica. Of Gneiss? Quartz, felspar, mica. Of Greenstone? Augite and felspar, or hornblende and felspar. The mineralogical structure of a rock is discovered on close inspection, sometimes without difficulty when the crystals or fragments are large, but often requiring the aid of a lens, and presupposing a knowledge of the forms, colours, and other qualities of the simple minerals that usually enter into the composition of rocks. § 45—69.

100. TEXTURE OF SIMPLE ROCKS.—The intimate texture of rocks, or the mode of aggregation of the mineral substances of which they are composed, exhibits considerable variety. Viewed in this respect, rocks may be SIMPLE or COMPOUND, that is, composed of a single mineral species, or of several species. The texture of simple or homogeneous rocks may be referred to nine different kinds.

(1.) COMPACT TEXTURE.—When the particles or crystals are so minute as not to be distinguishable by the naked eye, as in some kinds of Felspar and Limestone, on that account called Compact.

(2.) EARTHY TEXTURE.—When the particles are minute, and, having little cohesion, readily crumble; as in some kinds of Chalk.

(3.) GRANULAR TEXTURE.—When the particles or crystals are distinguishable, and of a rounded form; as in Oolite.

(4.) Crystalline Texture.—When they are easily distinguishable, confusedly aggregated, and present the appearance of imperfect crystals; as in Primary Limestone.

(5.) Scaly Texture.—When the particles are disposed in the form of small scales; as in some varieties of Clay-slate.

(6.) Lamellar Texture.—When the rock is composed of very thin plates; as in some kinds of Pitchstone.

(7.) Laminar or Slaty Texture.—When it is composed of thin parallel plates or laminæ; as in Clay-slate.

(8.) Fibrous Texture.—Composed of very elongated slender crystals; as in Fibrous Gypsum.

(9.) Radiated Texture.—When the fibres present a radiated or divergent arrangement; as in Actinolite slate.

101. Texture of Aggregated Compound Rocks.—Rocks composed of two or more simple minerals, are divided into two kinds, some being fragmentary, or having their particles or fragments united by a cement; others aggregated, or having their parts coherent without the intervention of a cement. The latter rocks present many of the above defined kinds of texture, as well as several others.

(1.) Compact Texture.—When the particles are so minute as to give the rock a dense, homogeneous appearance; as in some kinds of Granite and Greenstone.

(2.) Earthy Texture; in Lava.

(3.) Granular Texture; in Clay and Marl.

(4.) Crystalline Texture, also called granular or granitic, by many geologists; in Granite and Hornblende Rock.

(5.) Slaty Texture; in Gneiss, Mica-slate, and Chlorite-slate. In the compound Rocks this texture is crystalline, but with the component minerals more extended in one direction than in another, and thus arranged so as to form distinct laminæ.

(6.) Porphyritic Texture.—When in a basis, either crystalline or compact, distinct crystals are interspersed; as in Porphyry of various kinds, Porphyritic Granite, Syenite, and Greenstone. Fig. 15.

(7.) Amygdaloidal Texture.—When in a basis, generally compact, sometimes crystalline or earthy, are interspersed roundish or oval bodies, composed of one or more mineral substances; as in Amygdaloidal Claystone or Greenstone.

(8.) Cavernous Texture.—Numerous small cavities, roundish, oval, or of various forms, in a compact or granular rock; as in Lava.

102. Texture of Fragmentary Rocks.—When the minerals, or fragments of minerals, of which a rock is composed, are agglutinated by clay, or other finely divided matter, the mass is said to be fragmentary. Only two or three varieties occur.

(1.) Brecciated Texture.—Angular fragments, cemented together, constitute Breccia.

(2.) Conglomerated Texture.—Rounded fragments of quartz, granite, flint, or other substances cemented, form conglomerate.

103. Structure of Rocks.—Viewed with reference to the arrangement of their parts, on a larger scale than their texture, rocks may be distinguished as follows.

(1.) Massive Structure.—When a rock presents no internal division into plates, or prisms, or balls; but is of a uniform texture over a great extent.

(2.) Prismatic or Columnar Structure.—When a mass of rock is internally divided by fissures into prisms of various sizes or forms. Granite often exhibits this structure, which is more regularly displayed in Basalt, Greenstone, and Porphyry. The prisms or columns vary from a diameter of a few inches to eight or nine feet, and in length from one to three hundred feet or more. They vary in form, sometimes having only three sides, sometimes so many as twelve, but generally four, five, or six. It is obvious that this kind of structure is quite distinct from those contained in the last paragraph; the compact or crystalline, for example, which may be included in the prismatic; that is, a rock divided into prismatic portions, may have those portions crystalline, or compact.

(3.) Tabular Structure.—When a rock is composed of parallel plates, separated by regular seams.

(4.) Globular Structure.—Globular masses of large size imbedded in a substance of the same nature.

104. Form of Rocks.—Dr. MacCulloch, in his Classification, enumerates the following different forms of rocks:

Fig. 12.

(1.) Irregular Masses.—Rocks of no determinate form, and of any size; as Granite, Greenstone, Porphyry. Fig. 12, *a*.

(2.) Table-layers.—This name may be given to extended plates of rock, not divided into parallel laminæ. Dr. MacCulloch proposes calling them Pseudo-strata. Mr. Bakewell remarks on what he calls the stratiform structure, that many masses of rock, not really stratified, occur divided into parallel planes, by seams or divisions which resemble those in regular strata; such planes have not been superimposed in succession, but are the result of a crystalline arrangement of the mass. Fig. 12, *c*.

(3.) Strata.—Some geologists make a distinction between a Stratum and a Bed, meaning by the latter what Dr. MacCulloch has named pseudo-stratum; but in this treatise Stratum and Bed are synonymous. Strata are masses having a much greater extension in two of their dimensions than in the third, and generally occupying large spaces. In its simplest or most perfect form, the stratum may be considered as a great bed or plate, of which the upper and lower planes are straight and parallel. But many modifications are observed; for the planes may be inclined to each other, so that the stratum if prolonged would terminate in an edge; or the stratum may be thicker at one part than another; or it may be variously bent, or undulated, or fractured. While some strata are horizontal, others are perpendicular, and all intermediate degrees of inclination are met with. Strata of sandstone and clay are generally allowed to have been deposited from the turbid waters of the sea, lakes, or rivers, their laminæ being arranged over each other in a regular manner. Others again, as of mica-slate, are supposed to have resulted from chemical precipitation. A stratum may vary in thickness from a few yards to a thousand feet or more. Dr. MacCulloch mentions an instance, in the mountain of Kea-cloch in Ross-shire, where an uninterrupted series of horizontal red sandstone is nearly 4000 feet in depth; and another in Argyleshire, where the chlorite-slate, having a considerable inclination, is nearly 20 miles in lateral thickness. Strata are separated from each other by SEAMS, or parallel planes, and sometimes by JOINTS or fissures forming some angle with the planes. Fig. 12, *b*.

(4.) NODULES OR GLOBULAR MASSES.—By these terms are designated rocks of irregular form, varying from a foot to a mile or more, and imbedded either in a stratified or a massive rock. Fig. 13, *a*.

Fig. 13.

(5.) VEINS.—Supposing in a rock of any kind a rent, straight or tortuous, simple or branched, to be filled with mineral matter, the result would be a vein. The size of veins varies from a mere thread to a hundred yards or more, and their positions vary through every possible angle. They are presumed in every case to be connected with some irregular mass, as no example of an independent or isolated vein has yet been discovered. Fig. 13, *b*.

105. DISTINGUISHING CHARACTERS OF ROCKS.—In distinguishing and describing rocks, we have to attend to the following circumstances.

(1.) FRACTURE.—This term is employed to designate the appearance of a fresh surface exposed by the blow of a hammer or any other forcible separation of parts. It may be EVEN, or forming a plane of greater or less extent; UNEVEN, when formed of variously inclined planes of small extent; CONCHOIDAL, when one of the separated surfaces is concave, and the other convex; SPLINTERY, when the surface presents the appearance of thin-edged scales; HACKLEY, when covered with very sharp protruding points.

(2.) HARDNESS.—This character does not require so precise a determination as in the case of simple minerals. The extremes are the hardness of quartz on the one hand, and soft chalk on the other.

(3.) LUSTRE.—According to Dr. MacCulloch, the highest degree of lustre that occurs in rocks is the PLUMBAGINOUS, or that of graphite or black lead, which is seen in some clay-slates. The other extreme is that of chalk, which is DULL, or almost destitute of lustre. The principal intermediate kinds are the SILKY, RESINOUS, VITREOUS, FLINTY, and WAXY.

(4.) FRANGIBILITY.—The degree of facility with which a rock yields to the hammer is named its frangibility. Easily frangible, very or remarkably easily, or frangible with difficulty, or with great difficulty, and such readily intelligible, although rather vague terms, are those employed to denote this character.

(5.) ACTION OF ACID.—Some varieties of limestone are conveniently distinguished by the greater or less facility with which carbonic acid is extricated from them by means of diluted nitrous or muriatic acid.

(6.) Specific Gravity.—This character, obtained in the usual manner, by weighing a fragment in air, and again in water, commonly enters into the description of rocks. Pure water at the temperature of 60°, being taken as the standard, a mineral of which an equal bulk is double the weight of water, is said to have a specific gravity of 2; or two and a half times the weight of water, of 2.5; and so on.

(7.) Colour.—Although generally an empirical, and frequently a fallacious character of rocks, colour is yet of great use in enabling the student to distinguish not only rocks themselves, but also the minerals which enter into their composition. Some rocks, as marble and serpentine, own their chief value, in an economical point of view, to their colours. Werner's Nomenclature of Colours, by Syme, may be taken as a standard for comparison; but very precise distinctions are not so necessary in rocks as in simple minerals. Pure or vivid colours seldom present themselves, and the most common tints are modifications of grey, red, or brown. It has been found that most rocks owe their colours to the presence of iron in different conditions.

106. Instruments useful in examining Rocks.—The instruments necessary to the geologist are not numerous. The most important is the Hammer, of which two different kinds will be found useful; the first, an oblong hammer with flat extremities or faces, weighing about three pounds, and an ash handle about two feet and a half in length; the other, a very small flat-faced hammer, half a pound in weight, with a handle of about ten inches. The large hammer is used for breaking up a rock into chips or splinters, while the other is used for chipping or dressing. To these instruments may be added an iron Wedge and a Chisel.

Another necessary instrument is a Compass, to show the direction of strata, or the bearing of one place upon another. The inclination of strata is shown by the Clinometer, which is merely a quadrant adapted to this particular use. These two instruments are usually combined, and along with them is generally placed a tube for levelling.

If to these are added a little nitrous or muriatic ACID in a small glass well secured, a well-tempered strong KNIFE, and a canvas BAG lined with leather, the young geologist may consider himself well equipped for the field.

107. ARRANGEMENT OF ROCKS INTO GROUPS. — With these preparatory explanations we are now in some measure qualified to proceed. Rocks, as has already been observed, are either simple or compound, formed of a single mineral species, or composed of two or more species. But as they present themselves in nature, simple rocks do not form a class distinct from compound rocks; for the former may occur in immediate contact with the latter, or a rock may be simple in one part, and compound in another. Some rocks are stratified, or disposed into laminæ and strata; while others are massive or irregularly fissured, or at most, present only the semblance of strata. Hence a division of rocks into two great classes, STRATIFIED and UNSTRATIFIED.

It will farther be adverted to that one or more simple minerals constitute a ROCK; that one or several rocks united by certain common characters, constitute a FORMATION, or connected series; and that several formations constitute a SYSTEM of Rocks. Thus particles of quartz and argillaceous matter form sandstone; this sandstone in strata, together with strata of slate-clay, bituminous shale, ironstone and coal, constitute the Coal Formation; while the Coal Formation, Millstone Grit, Mountain Limestone, and old Red Sandstone, taken collectively, form, according to many authors, the Carboniferous System. These remarks apply solely to the stratified rocks, which are supposed or understood to have been deposited in a sedimentary or crystalline form from water.

The unstratified rocks, on the contrary, cannot be thus grouped into systems on the principle of a mutual relationship; for while a particular formation of stratified rocks always reposes upon a certain other formation, and is surmounted by a third; or at least never changes its position with reference to those other formations; the members of the unstratified class may present themselves in any position both with reference to each other, and with reference to the stratified rocks. Nor can the unstratified rocks be arranged into groups upon the principle of an affinity in mineralogical composition; for they all pass into each other in an imperceptible manner.

108. Relative Extent of Stratified and Unstratified Rocks.—The stratified rocks reposing upon a basis of granite, which is referred to the unstratified class, are universally distributed over the globe, forming a much greater extent at the surface than the unstratified rocks, which generally appear towards the central parts of the elevated ridges, or mountain-chains, the valleys and plains being occupied by the stratified rocks. The unstratified rocks are interspersed among or laid over the stratified rocks, not in unconnected and independent masses, but, as has been shown in some cases, and as is believed in all, connected with veins or seams intersecting the strata, and proceeding from the internal parts of the earth, so that although a mass of this nature may lie over the higher strata and appear at the surface as a mountain, its origin is from beneath the lowest stratum, and even the granite on which that stratum reposes.

109. Order of Description of Rocks.—Considering granite as the basis of the stratified rocks, we may, with propriety, commence our description of the materials of which the crust of the globe is composed with it; but although the other unstratified rocks belong to the same class, their basis or origin being inaccessible to observation, and they being variously interspersed among the stratified rocks, it will be found more convenient to make their description follow that of the stratified series.

Most English geologists, in describing the strata, begin at the surface, and proceed downwards; while most Continental geologists take the opposite method. On this subject, some remarks by Mr. Bakewell are so accordant with the views of the author of this treatise, that they may with propriety be here introduced. "In describing the different classes of rock, we may either commence with the lowest or most ancient, or with the uppermost or most recent; but I am persuaded that the student will find it most convenient to begin with the lowest, and proceed in an ascending series to the uppermost. The rocks called primary have distinctly marked mineral characters, and contain few, if any, organic remains. As the student proceeds, he may trace the first indication of organic existence, and in ascending to the upper rocks he will observe the gradual increase of genera and species that have left their remains in the different beds; in some cases indicating great changes in the condition of parts of the globe, as from sea to land, or from salt water to fresh, or from deep to shallow seas. If the student begin with the more recent or uppermost strata, he will find them difficult to recognise by fixed mineral characters, and he will be confused by the variety of organic species presented to his notice, but from which he can derive little instruction, until he be able to compare them with the fossil remains in the lower strata."

110. Classification adopted.—The rocks which present themselves to observation at the surface of the globe, may be arranged into four classes or groups, dependent chiefly upon their relative position. I. Granitic Rocks, or those forming the basis or foundation of the rest; II. Stratified Rocks, divided, according to the order of their deposition, into four groups: 1. Primary; 2. Secondary; 3. Tertiary; 4. Alluvial. III. Overlying or Interjected Rocks, so named, because they appear lying over, or interspersed among, the stratified rocks. IV. Volcanic Rocks, of the same nature as the last, but produced by volcanoes at present or recently in action.

The Granitic, Overlying, and Volcanic Rocks, are all unstratified. The overlying rocks are probably connected with deposits situated beneath the fundamental, having apparently been ejected in a melted state, through fissures in the strata.

This arrangement is conceived to be that best adapted for description, and, being unconnected with theoretical views, ever varying as knowledge increases, is employed merely to afford a general idea of the nature and arrangement of the various deposits exposed at the earth's surface.

Recapitulation.

98. What circumstances must be attended to in examining rocks?—99. Give some examples of the mineralogical composition of rocks.—100. What is meant by the texture of rocks? Define the principal kinds of texture in simple rocks.—101. What textures are observed in compound rocks?—103. What is meant by structure? Define the principal kinds of structure.—104. What are the principal varieties of form or configuration in rocks? Distinguish between strata and pseudo-strata. Give a particular account of strata.—105. What other characters are used in distinguishing rocks?—106. What instruments are necessary to the geologist?—107. Is the arrangement of rocks into simple and compound useful in geology? What is the difference between stratified and unstratified rocks? What gradations are employed in arranging rocks? Do these gradations apply to the unstratified series?—108. What rocks are most extended at the surface? What is the disposition of the unstratified rocks?—109. Whether is it most convenient to commence with the lowest or with the highest rocks?—110. What classification is it proposed to follow in this treatise?

CHAPTER III.

OF THE GRANITIC ROCKS.

POSITION AND EXTENT OF GRANITE; ITS COMPOSITION, TEXTURE, AND VARIETIES; ITS STRUCTURE, CONNECTION, AND ECONOMICAL USES.

111. Position and Extent of Granite.—The foundation on which repose the lowest or oldest stratified rocks, is generally admitted to be Granite, which, although not accessible to observation in plains and the lower parts of valleys, is yet exposed in mountain-ranges, to such an extent as to enable us to study its characters and relations. Although this rock forms the most elevated portion of the great European elevated or mountain land, rising in Mont Blanc to the height of nearly sixteen thousand feet above the sea, it does not form the highest summits of the Andes, nor, as is believed, those of the Himmalayan mountains, which are ten thousand feet higher than any in Europe; and in Canada, the eastern parts of the United States of America, and other parts of the world, occurs at the surface at no great elevation. The same circumstance is observed in Scotland, where the granitic range of the Aberdeenshire Grampians forms the highest land in Britain, while the same granitic rock is observed on the coast. In England, granite occurs in Cornwall, Devonshire, North Wales, Anglesea, the Malvern Hills, Charnwood Forest, in Cumberland and Westmoreland. In Scotland, it is seen in Galloway, Argyleshire, Forfarshire, Aberdeenshire, Sutherland, and other counties.

112. Composition and Texture of Granite.—The rock to which the name of Granite is given, probably on

Fig. 14.

Fig. 15.

account of its granular appearance, is essentially composed of Felspar, Quartz, and Mica, or of the two former minerals and Hornblende. These substances are confusedly aggregated in crystals of imperfect form, varying in size and colour. The parts sometimes exceed two inches in their dimensions, while at other times they are reduced to scarcely distinguishable granules; and often in a very limited space great varieties of texture are observed. Occasionally patches, or veins of finer texture, are interspersed through a mass of coarser materials, and in one variety the particles have arranged themselves into spherical concretions. The Felspar of granite is subject to a greater diversity of colour than the other ingredients, and as it is usually the most abundant material, the general tint of the rock is derived from it. It may be dark-red, light-red, or flesh-colour, reddish-white, pure white, grey, yellow, greenish, or greyish-black. The quartz, although usually white, may be grey of various tints, brown, or almost black. The Mica, in plates or scales, may be white, silvery, brown, or black. The hornblende is always black or very dark green. Granite, properly so called by most geologists, who exclude hornblende as a constituent, is composed of felspar, quartz, and mica. But several modifications have received distinctive names. Thus,

Porphyritic Granite.—Granite composed of felspar, quartz, and mica, but having distinct additional crystals of felspar of larger size interspersed, Fig. 15. A remarkable light-coloured variety of this kind, in which the white crystals of felspar are often several inches in length, and very conspicuous, is found in Cornwall; and others occur in Aberdeenshire.

One of the ingredients may be wanting, or substitutions may take place of one mineral for another, or various minerals may be occasionally added. Thus,

Graphic Granite, so named, because when polished it presents some appearance of written characters, is a compound of felspar and quartz, with little or no mica, so disposed as to produce an imperfect prismatic or laminar structure; or it may be described as formed by small prisms or plates of quartz dispersed in felspar. Granite of this kind very seldom forms extended masses.

Pegmatite is a granular mixture of quartz and felspar. It is often met with in granite veins, and passes into Graphic Granite, from which some geologists do not distinguish it.

Eurite or Whitestone is a variety in which felspar is the predominant ingredient, the quartz, and especially the mica, being very rare; or in which all the ingredients are blended into a finely granular mass of a white colour. Crystals of quartz are sometimes dispersed through the mass, rendering it porphyritic.

Schorl Rock or Schorly Granite.—When crystals of schorl are added to the usual ingredients of granite; or when quartz and schorl only occur, the felspar and mica having disappeared.

Protogene or Talcose Granite.—A mixture of felspar, quartz, and talc or chlorite. It occurs abundantly in the Alps of Savoy, and is found in Cornwall, where, on decomposing, it yields the china-clay or porcelain-earth which is annually exported in great quantities.

Syenite or Hornblendic Granite.—When hornblende is substituted for mica. But very often both mica and hornblende occur together in granite, and the hornblendic variety gradually passes into the common in the same mass. Syenite, which receives its name from the ancient quarries of Syene, in Egypt, varies in colour and texture; the felspar sometimes predominating, and sometimes the hornblende.

It is often like common granite, porphyritic, that is, contains distinct crystals of felspar.

Many other varieties might be enumerated, were all the combinations of minerals observed in granite separately distinguished. Very frequently Garnet, Zircon, Beryl, Topaz, Tourmaline, Actinolite, and other simple minerals, are found imbedded in it.

113. Structure of Granite.—Masses of this rock are often continuous over a wide space, preserving a uniform character, and forming rounded hills scantily clothed with vegetation. The surface of the rock is usually much disintegrated, and frequently exhibits heaps of tabular or prismatic fragments, of which the edges and corners have been rounded by the action of the weather. Frequently no particular arrangement can be observed in granitic masses, but sometimes they are seen to form irregular beds, or to be separated by fissures or joints; and these beds are divided by

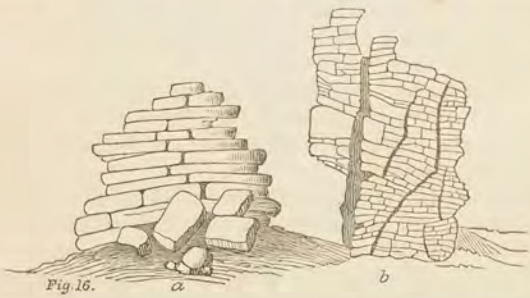


Fig. 16.

cracks into smaller prismatic parts. In the upper part of Aberdeenshire I have observed that the granitic mountains are very remarkable for their extreme sterility and the desolate aspect which they present. The summits are rounded, sometimes nearly flat, to a great extent, and entirely covered by disintegrating blocks and stones, together with gravel and sand. Some of them present protuberances, consisting of granite much decomposed, forming tabular masses, intersected perpendicularly by fissures, and evidently portions of the mass of the mountain, which have either originally protruded beyond the surface, or have resisted disintegration. Most of the mountains exhibit perpendicular precipices near the summit, which generally assume the circular form, constituting the hollows named corries, and having a lake at their base. The rock near the surface, wherever it is exposed, has split into tabular masses, generally pretty regular, and exhibiting the appearance of strata, intersected by rectangular fissures. The true nature of these tables, however, is readily understood on examining the precipices, where they are best seen, and where, notwithstanding, the perpendicular fissures more resemble the seams of strata. There is no tendency in any part to the concentric or globular arrangement, nor do the masses in decomposing ever present that appearance. Fig. 16, *a*, represents the general appearance of the protuberances on the summits of these mountains, and Fig. 16, *b*, has been taken from a columnar mass at the upper part of the corry of Lochnagar.

As viewed from the summit of Mont Blanc, Saussure describes the masses of the central Alps as composed of vertical plates, most of which range from north-east to south-west. These vertical beds, in so far as could be determined, are composed of the same substances at their summits as at their bases, and preserve the same nature through their whole extent. From this he infers that the beds of granite were originally horizontal, and were subsequently elevated by some convulsion of nature. Other geologists, however, consider these beds of granitoid rock as belonging to the gneiss formation, or to a series of laminar rocks passing into talc-slate on the one hand, and into protogene on the other.

114. Connection of Granite.—Frequently in sections where granite is seen in contact with other rocks, it forms veins which shoot up into them. This phenomenon has been

observed by Sir Basil Hall at the Cape of Good Hope, Fig. 17, *a*, where granite veins intrude themselves into the superincumbent clay-slate, and by Dr. MacCulloch at Cape Wrath, Fig. 17, *b*, the northern extremity of Scotland, where

Fig 17. *a* *b*

they traverse gneiss. The granite of such veins is usually of finer texture than the principal mass; but in those large veins, less tortuous in their course, which are named dykes, the ingredients are often of very large size. In some veins of this kind, in the gneiss islands of the Hebrides, I have seen plates of mica more than eight inches in breadth, and crystals of felspar half a foot in length. Sometimes veins of quartz, usually white, but sometimes brown or grey, occur in granite, where they seem to have been formed by infiltration into fissures. Granite may be in contact with any of the stratified rocks, all of which, even the highest, have been found reposing directly upon it. The superincumbent rock is usually much altered in appearance and texture towards the line of junction, and this is also frequently the case with the granite itself. While granite sends veins into the superincumbent rocks, it is itself traversed from beneath by veins of Porphyry, Greenstone, Basalt, and other rocks of the same nature.

115. Economical uses of Granite.—Tinstone, oxide of iron, auriferous iron-pyrites, copper-pyrites, galena or sulphuret of lead, oxide of chrome, oxide of uranium, and molybdena, are found in granite, as well as sometimes gold, silver, zinc, and other substances. Tin, however, is the principal metal obtained from granite, which is not so pro-

ductive of ores as many other rocks. Granite is employed in the construction of dwelling-houses, public buildings, bridges, and piers, for which some varieties are well adapted, being not only durable but superior to most rocks in appearance Many granites, however, decompose rapidly, their felspar becoming converted into a kind of clay. The best known granites in Britain for building are those of Aberdeen and Peterhead. Granite is also employed in making roads, and for paving streets, for both which purposes it is well adapted. "Most of the Egyptian obelisks," says M. Rozet, "were constructed of the beautiful syenite of the cataract of the Nile; many immense statues of men and animals, which decorate that celebrated country, and which are seen here and there buried in the sands, were made of the same stone." The Kaolins or porcelain clays come from the decomposition of granite, and the varieties that readily decompose yield sands that may be employed in the manufacture of mortar. Granite districts are usually sterile, or at least less productive than most others; but they often yield good pasturage, and are well adapted for the growth of pines.

116. General Remarks.—From the position and general characters of granite, together with the circumstance of its traversing the rocks above it in the form of veins, it has been inferred, not only that it has been originally fluid, but that, since its consolidation, it has been partially fused, so as to form those protruding veins. Being itself traversed by veins of other rocks of a similar nature, or igneous origin, the source of these rocks must occur beneath it, although they may rest upon it in masses, or even upon the highest of the superincumbent strata. In mineralogical composition and characters, these rocks also approximate or pass into granite, so that they might be referred to the same class, were it not more convenient to treat of them separately, after the series of stratified rocks. In the regular series, Gneiss is the stratified rock that succeeds granite, and the grada-

tion to it is direct, gneiss being mineralogically the same, but distinctly stratified, and more or less laminated. Of this rock, and the series of which it forms the basis, we have next to speak.

Recapitulation.

111. What rock constitutes the foundation of the stratified deposits? Does Granite appear at great heights? Is it the highest as well as the lowest rock? What elevated district in Britain is formed by it? In what parts of England and Scotland does it occur?—112. Of what minerals is Granite composed? Describe its principal varieties: Graphic Granite, Porphyritic Granite, Pegmatite, Whitestone, Syenite, &c.—113. Is granite often of uniform character over a large space? What is the usual appearance of its surface? and of its interior? What characters does it present in Aberdeenshire? How did it appear to Saussure from the summit of Mont Blanc?—114. What connections has granite with other rocks? Are the veins which it sends into them of a different texture?—115. What metallic substances occur in granite? For what economical purposes is it employed? Of what substance have the Egyptian monuments been formed? How is porcelain earth formed?—116. What inference has been made as to the nature of granite? Is it ever traversed by other rocks? What rocks resemble it in character? Which of the stratified rocks succeeds it in the regular series?

CHAPTER IV.

OF THE PRIMARY ROCKS.

ARRANGEMENT OF THE STRATIFIED ROCKS INTO PRIMARY, SECONDARY, AND TERTIARY. RELATIONS OF THE PRIMARY ROCKS. GNEISS, ITS COMPOSITION, VARIETIES, MINERALS, VEINS, RELATIONS, AND DISTRIBUTION. MICA-SLATE, CHLORITE-SLATE, TALC-SLATE, HORNBLENDE-SLATE, ACTINOLITE-SLATE, CLAY-SLATE. QUARTZ-ROCK, PRIMARY LIMESTONE, DOLOMITE, SERPENTINE, DIALLAGE ROCK. CHARACTER OF THE SCENERY OF PRIMARY DISTRICTS.

117. Division of Stratified Rocks.—Having obtained some general idea of the nature of granite, that rock which appears to form the universal basis of the stratified series, and which, on account of its supposed formation at a great depth, and subjected to a vast pressure, has been designated as Plutonic and Hypogenous (*ὑπο*, under, *γινόμαι*, to be formed), we now enter upon those rocks which, being supposed to have been deposited from water, are disposed in layers or beds, and are therefore named STRATIFIED. Of these stratified rocks, the lowest series, characterized by a crystalline texture, and never containing remains of plants or animals, are named Primary, Fig. 18. This term has no reference to the priority of their formation, but is used to express the order of their occurrence, they being the FIRST after granite. These lower or primary formations, being found to differ from those lying above them in containing no organic remains, in being highly crystalline, in presenting no pebbles or rolled stones, sand, flags, or angular fragments, although yet divided into strata, like the upper

rocks, are by some supposed to have been deposited in a sedimentary form, but afterwards altered by the action of heat, and have therefore by Mr. Lyell been termed METAMORPHIC (μετα, a preposition denoting change, μορφη, form).

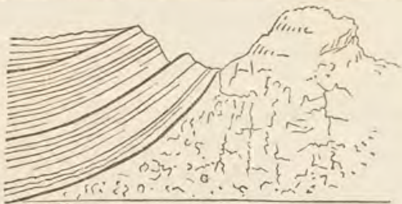


Fig. 18.

A series of stratified rocks, containing organic remains, extends from these primary strata to the surface, and is divided into two subordinate groups, the SECONDARY, Fig. 18, S, and the TERTIARY, Fig. 18, T. These will form the subjects of two succeeding chapters, while the present will be devoted to the PRIMARY.

118. PRELIMINARY REMARKS.—Previous to entering on our subject, it is necessary to present a few explanations having reference to it. The Primary Rocks may be distinguished, 1st, by their inferior position, when other members of the series are present; but as a secondary rock may be found in contact with granite, and resting upon it, this character is not of itself distinctive; 2dly, by their comparatively inclined position, which, however, is not general, for a primary rock may often be nearly horizontal, and a secondary rock highly inclined; 3dly, by their crystalline aspect, which, however, is not absolutely peculiar, as several secondary rocks present the same appearance; 4thly, by the absence of rolled fragments or sand; and, 5thly, by that of organic remains. Many difficulties must occur to the student, but these he may surmount by patience and minute inquiry. In some text-books and lectures, matters are represented so regularly and methodically, that after he has received his instructions, and betaken himself to the hills to apply his

knowledge to nature, he finds every thing so different from what he had anticipated, that he can hardly recognise a single substance. Gneiss, mica-slate, chlorite-slate, hornblende-slate, actinolite-slate, and serpentine, are peculiar to this series, and therefore cannot be mistaken; but quartz-rock sometimes resembles the sandstones of the secondary series, and clay-slate has occasionally the aspect of shale or slate-clay. Some secondary limestones also are as crystalline as the primary, some of which again are compact or even earthy; while jasper and flinty slate are common to both classes. The connections of these rocks must therefore be examined before their nature can be ascertained.

119. Species of Primary Rocks.—Although Gneiss frequently occupies the lowest place in the series, another member may present itself in that position, and the arrangement of the primary rocks does not show that regularity which we observe in the secondary. However, we may take as the most common order:—1. Gneiss, 2. Mica-slate, 3. Chlorite-slate, 4. Talc-slate, 5. Hornblende-slate, 6. Actinolite slate, 7. Clay-slate; to which are added Limestone, Serpentine, Diallage Rock, and Quartz-Rock. The accompanying diagram is intended merely to facilitate the recollection of their names. Mr. Bakewell remarks that Granite, Gneiss, and Mica-slate might with propriety be regarded as belonging to one formation, they being composed of the same materials varying in different proportions, passing into and alternating with each other in various situations. But Hornblende-slate passes into and alternates with gneiss and syenitic granite, as well as with clay-slate, and therefore has an equal claim to be included in the same family.

Fig. 19

120. Gneiss.—Being composed of felspar, quartz, and mica, or hornblende, arranged in parallel laminæ, this rock might be called stratified granite. The size and colour of the component minerals differ as in that rock, although the crystals are never so large, and gneiss exhibits as many varieties as granite, although they have not been distinguished by particular names. Three principal kinds, however, may be pointed out. 1. Sometimes the laminæ are so indistinct, although the scales of mica show some uniformity in their direction, that it is impossible in a small space to distinguish the rock from granite; but when viewed on the large scale, this variety, which is named Granitic Gneiss, is seen to be disposed in strata. 2. In Slaty Gneiss, the texture is usually minute, and the scales of mica or crystals of hornblende form small laminæ, rendering the rock easily fissile. This variety, by losing the mica or hornblende, passes into quartz-rock, beds or layers of which sometimes alternate with it. On the other hand, by the disappearance of the felspar, it passes into mica-slate. 3. Sometimes the ingredients form plates of considerable thickness, and the laminæ of quartz and felspar, which are the largest, being variously coloured, give rise to much diversity of aspect. This kind is named Laminar Gneiss. The granitic variety sometimes contains large crystals of felspar, and thus becomes porphyritic.

In an extended series of gneiss rocks, such as those which occur in the outer Hebrides, or on the coast of Aberdeenshire, the student who has not been made aware of the great diversity of aspect and composition which this rock presents, is likely to be much perplexed by it. In one place, it may closely resemble granite, in another syenite; beds of it, considered individually, may be taken for mica-slate, hornblende-slate, quartz-rock, compact felspar, eurite, or talc-slate. From such a series, in fact, specimens may be taken representing all the primary rocks.

Gneiss contains garnet, actinolite, epidote, calcareous spar, tourmaline, zircon, hematite, molybdena, and several other minerals. Strata or beds of limestone, hornblende-slate, and other rocks of the primary series, alternate with, or are imbedded in it. Veins of granite, porphyry, green-stone, and other rocks of igneous origin, occur in gneiss, which, as Professor Jameson remarks, is one of the most metalliferous of the series, the great iron-mines in Norway, Sweden, and Lapland, and the most valuable mines in Saxony, Bohemia, and Salzburg, being situated in it. The lead veins of Strontian in Argyleshire are in this rock.

In Britain, it forms extensive tracks in the middle and northern divisions of Scotland, and in its islands. In many parts of the globe it occurs very abundantly, as in Brazil, the United States of North America, Sweden, Norway, Saxony, Bohemia, the Hartz, Southern Alps, and Pyrenees. It is often found immediately succeeding granite, and placed beneath other primary strata, but it may also succeed these, or alternate with them. The dimensions of its strata are often very great, but frequently also the layers are very thin, especially where hornblende-slate is abundant. The strata are often contorted in a very remarkable degree, and frequently are intersected by granite veins so as to render it difficult to say whether the rock be granite or gneiss.

121. Mica-Slate.—Supposing one of the constituent minerals of gneiss to have disappeared, namely, its felspar, there would remain the materials of which mica-slate is composed, that rock being a compound of mica and quartz, arranged in parallel laminæ, the mica sometimes predominating, and sometimes the quartz. This rock passes into gneiss by the addition of felspar, into quartz-rock by the diminution of its mica, into chlorite-slate, by the substitution of chlorite, and into clay-slate by the comminution of the particles or scales of mica, and the disappearance of its quartz. It forms various other transitions, and although often lying upon gneiss, is uncertain as to its position, for it may occur as beds in that rock, or in connection with any other of the series, and it is often associated with, and graduated into quartz-rock. Several varieties of this rock are

enumerated by authors, but the principal are the following: —1. LAMINAR MICA-SLATE, formed of mica in continuous laminæ, alternating in pretty regular layers with quartz also in plates, the mica usually predominant, and varying in colour from brownish-black to greenish-grey. 2. GRANULAR LAMINATED, when the plates of mica are formed of scales, and those of quartz of granules or crystals, the latter often predominant, so as in the cross-fracture to present the appearance of quartz-rock. 3. PORPHYRITIC MICA-SLATE, of either of the former kinds, containing crystals of hornblende, felspar, or garnet. Many modifications are produced by differences in the proportions, forms, and colours of the ingredients, as well as by the laminæ being thin, thick, straight, undulated, or contorted. The quartz is generally white, the mica grey, and some varieties become brown, others yellow, on being exposed to the weather.

Various minerals are found intermixed in mica-slate, as garnet, tourmaline, schorl, emerald, cyanite, actinolite, epidote, beryl, pycnite, prehnite, oxide of iron, and iron-pyrites. Its strata are traversed by veins of granite and quartz, as well as igneous rocks of the overlying series. The metallic minerals which it contains, are iron and copper pyrites, red iron-ore, galena, blende, gold, and silver. Beds or layers of limestone, hornblende-slate, chlorite-slate, and quartz-rock, are often observed associated with it. Its strata are often very thin, sometimes of great thickness, and are frequently much undulated or contorted. But in cases where the stratum, viewed as a whole, may be straight, the subordinate laminæ are often singularly contorted.

Mica-slate scarcely occurs in England, but is very abundant in the Highlands of Scotland, forming, for instance, many of the mountains of the Southern Grampians. It abounds in many parts of the Continent of Europe, as well as in Asia, Africa, and America. Its economical uses are unimportant, it being ill adapted either for building or roofing.

122. CHLORITE-SLATE.—This rock, which is composed

of chlorite in foliated laminæ or scales, and quartz, greatly resembles mica-slate in appearance, as well as the disposition of its strata and plates. It is also usually associated with mica-slate, into which it graduates, but it may occur also in gneiss or clay-slate. Its strata may be of great thickness, or very thin, its laminæ straight, undulated, or contorted. Chlorite-slate being, as its name implies (χλωρὸς, green), of a greenish colour, is, in this respect, easily distinguishable from mica-slate, although mixed varieties occur, which might be named chloritic mica-slate. It is also softer and more tender, usually of a finer texture, and has a little of the greasy or saponaceous feel characteristic of talc, to which it appears to be allied. Chlorite-slate may be simply foliated or laminar, granular and foliated, and occasionally contains felspar, hornblende, actinolite, mica, tourmaline, and pyrites. It is abundant in the Southern Grampians, associated with mica-slate and clay-slate.

123. TALC-SLATE.—This rock is of much less frequent occurrence, and more limited extent, than chlorite-slate, sometimes forming thin beds in gneiss, in connection with hornblende or actinolite-slate, and sometimes passing into chlorite-slate, or mica-slate. It is generally associated with steatite, asbestus, actinolite, and serpentine; and is essentially composed of talc, a very soft, unctuous-feeling, generally light-green substance, either single, or combined with chlorite, serpentine, quartz, or felspar. The minerals found imbedded in it are asbestus, actinolite, cyanite, chromate of iron, and pyrites.

124. HORNBLENDE-SLATE.—Rarely independent, or forming extensive tracts, but usually associated with gneiss in thin strata, and often graduated into it, this rock is essentially composed of grains or crystals of hornblende, intermixed with felspar. It may also be found in connection with mica-slate, and even clay-slate, and passes into actinolite-slate. The minerals connected with it are chlorite, mica, garnet, and pyrites. The colour of hornblende being very dark-green or black, these are the predominant colours

of hornblende-slate, unless when the felspar exists in large proportion, when it may impart various tints of grey, white, red, or green. Two principal varieties occur: 1st, HORNBLENDE-ROCK, or Primitive greenstone of many authors, a crystalline compound of hornblende and felspar, not laminar or fissile, but massive, although generally disposed in strata; 2dly, HORNBLENDE-SLATE, composed of the same materials, but having a distinct slaty structure. Numerous varieties are produced by the size of the crystals, their colour, the tenuity of the laminæ, and the intermixture of other minerals, especially mica, chlorite, or actinolite.

Hornblende-slate, containing quartz or mica, passes into gneiss; becoming very fine in the grain, it seems to graduate into clay-slate; and by being intermixed with chlorite, into the slate of that name. In Scotland, it occurs abundantly in the Grampians, and in many of the Hebrides. On the continent, it is extensively distributed in all the primary districts, and often contains the same metallic ores as gneiss.

125. ACTINOLITE-SLATE.—Less abundant than Hornblende, but similar in its relations, and apparently graduating into it, this rock, which is composed of actinolite and felspar, is easily recognised by its light-green colour, and the elongated form or fibrous appearance of its principal constituent mineral. It is often associated with chlorite-slate, into which it passes by interchange of substances. It is comparatively rare, and perhaps does not require to be separated from hornblende-slate. Varieties are formed by its being composed of actinolite alone, or combined with felspar or hornblende, chlorite, talc, or mica.

126. CLAY-SLATE.—When it occurs in beds in mica-slate, or chlorite-slate, this rock often appears to be of the same nature, or to be produced by the extreme attenuation of the scales of mica or chlorite, so that in a series of specimens, some will be found precisely intermediate; and it is in connection with such rocks that it presents itself in the most characteristic form, the texture being finely laminated,

and often in some degree undulated. But it also occurs in extensive tracts, forming mountains, and even whole districts, in which case the strata are often of great thickness. The laminar arrangement of its beds renders it capable of being split into thin plates for roofing. Its colours are greenish-grey, blue, purple, red, or yellow; its transverse fracture irregular, that in the planes of its laminæ, glossy or silky; its texture homogeneous or minutely scaly, its streak grey, and its feel somewhat greasy. It is found to consist of silica and alumina, with oxide of iron, potash, and magnesia. Many varieties are enumerated, but of these some belong to the greywacké series, which Dr. MacCulloch has very improperly referred to this rock. The principal varieties of primary clay-slate are, 1st, That of a greenish or yellowish-grey colour, and glistening or shining lustre, that connects this rock with mica-slate and chlorite-slate. 2dly, The more compact and less glistening kind, employed as roofing-slate,—not, however, always characterized by dark colours, being as frequently light greenish or greyish as dark blue or purple. 3dly, The amorphous, or imperfectly fissile kinds. There is no end of slight gradations, however, as the colour, texture, and lustre vary, as well as the composition, the rock being either pure or combined with mica, chlorite, talc, hornblende, and quartz. Clay-slate also contains calcareous spar, garnet, epidote, cyanite, topaz, oxide of iron, and iron-pyrites, as well as some other minerals. Sometimes it has a fibrous aspect, or is dull and earthy, or black and so soft as to mark paper, or so hard as to be employed as a whetstone. Many slates of the secondary series so closely resemble varieties of this that they cannot be distinguished in specimens.

Clay-slate is distinctly stratified, and its slaty cleavage is generally parallel with the planes of the strata, as in Fig.

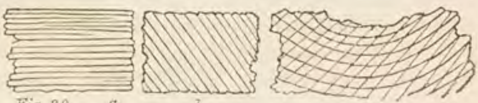


Fig. 20. a b c

20, *a*; but sometimes the fissile tendency lies in an oblique direction, *b*; and in some cases where the strata are curved, the cleavage is still parallel, *c*. It is very widely distributed, being found in many parts of Europe and America; and contains ores of tin, lead, cobalt, silver, gold, copper, and iron. In Scotland, it is plentiful in the Grampians, in connection with mica-slate.

127. Quartz-Rock.—The mineral called Quartz occurs abundantly in the primary series, not only forming a constituent of gneiss and mica-slate, and occasionally intermixed with the other rocks, but traversing them in veins or interposed in laminæ or beds. It also appears as an independent formation, and is stratified like the rest, the separation of its beds being commonly very distinct. Although the strata are sometimes bent, they never present the contortions so common in gneiss and mica-slate. It occupies no precise place, but alternates with all the primary deposits. When connected with gneiss it frequently contains felspar, and when associated with mica-slate presents scales of mica, so that it passes into both these rocks. In alternating with mica-slate, the strata sometimes graduate into each other, but are frequently very distinctly defined. Sometimes Quartz-Rock is simple in regard to its mineralogical composition, being composed entirely of quartz, pure and glassy, or opaque and white, opaque, granular, or crystalline, in various degrees, and the varieties of this kind may be white, bluish-grey, yellow, brown, or red. More frequently it is composed of quartz, with felspar, mica, or clay-slate, and is variously laminated, sometimes finely granular or scaly, and sometimes presenting a kind of fragmentary texture. Few minerals occur imbedded in Quartz-Rock, the principal being hornblende, garnet, oxide of iron, titanite, iron-pyrites, and occasionally galena, copper-pyrites, and blende. In many parts of Scotland, as in Jura, Isla, Shetland, Sutherland, and Inverness-shire, it occurs abundantly, as is also the case in primary districts on the Continent.

128. Primary Limestone.—This rock presents itself under many different aspects, and occurs in every member of the series, so that no particular position can be ascribed to it. The strata present the usual appearances, and may be very thin, or of great thickness, sometimes in mere laminæ intermixed with other rocks, or in irregular masses or nodules. When interstratified with mica-slate, it often contains so much mica as scarcely to be distinguishable from that rock. The strata are frequently bent, or even contorted, but present no remarkable variations of structure besides the laminar. The texture varies from crystalline of every degree to compact, and the mineral composition is simple, although the rock is often much modified by the occurrence of various minerals. The simple kind, or that composed exclusively of crystals of carbonate of lime, may be pure white, grey, bluish-grey, greenish, reddish, or yellowish. It may be crystalline, with very large, middle-sized, or small crystals, or compact and splintery. In the kinds composed of two ingredients, mica, clay-slate, hornblende, sahlite, talc, serpentine, garnet, quartz, felspar, tremolite, and actinolite occur, modifying the aspect of the rock so as often to produce highly ornamental varieties. Sometimes these ingredients are found together, and some limestones have a fragmentary structure, being composed of pieces of limestone agglutinated, or of fragments of quartz, clay-slate, or other primary rocks imbedded in limestone. Owing to this intermixture of substances, the varied tints of the carbonate of lime itself, and the frequent intersection of the strata by veins, often very minutely ramified, and generally composed of pure white limestone, a vast variety of colouring is produced. Very numerous simple minerals occur in this kind of limestone: hornblende, actinolite, asbestus, talc, chlorite, mica, quartz, sahlite, augite, tremolite, serpentine, steatite, garnet, stilbite, emerald, olivine, pyrites, titanite, and others.

In Scotland, primary limestone occurs abundantly in the Grampians, the Hebrides, and other parts,—some of the varieties, as those of Glentilt and Tiree, being used as ornamental stones. The term MARBLE is applied to every limestone finely coloured and capable of receiving a high polish, or of being worked into statuary, the pure white crystalline kinds being those employed for the latter purpose. A description of all the varieties of marbles employed in ancient and modern times, would form a large treatise.

DOLOMITE, or a variety of limestone, having in its composition a large proportion of magnesia, although it occurs in great masses in the Alps, Appenines, Carinthia, and other parts of the world, is yet not generally ranked by geologists as a distinct primary rock. It presents itself also in the secondary series, under the name of Magnesian Limestone.

129. SERPENTINE.—The only rock that remains to be described as a component of the primary series, is Serpentine, which is seldom very decidedly stratified, but differs from the unstratified rocks in not presenting branches or veins intersecting the strata with which it is in contact. Its masses vary in extent from a few feet to several miles, and have been observed in gneiss, hornblende-rock, clay-slate and limestone. When in contact with mica-slate or clay-slate, it is changed at the junction with these rocks into talc or potstone; and when in contact with limestone, the two substances are usually much intermixed. Although it presents a great variety of colours, it is easily distinguished, being of a compact, homogeneous aspect, with a splintery or conchoidal fracture, dull, and somewhat greasy. Its more common colours are dark-green, greenish-grey, or yellowish; but it is often variegated and spotted with red. When opaque, it is named Common Serpentine; when translucent, noble or precious serpentine. The minerals which occur imbedded in it are asbestus, amianthus, diallage, steatite, hornblende, actinolite, calcareous spar, chromate of iron, and many others.

Serpentine occurs rather abundantly in Scotland, and in Cornwall, where, as Dr. Boase remarks, "it is proved to be a compound of diallage and felspar, or perhaps rather of compact felspar, by its frequent transition into euphotide. This rock exhibits a great many varieties; some of which are hard, whilst others are so soft as to yield to the nail. This difference appears to depend on the felspar base, which undergoes several modifications, between a crystalline, compact, and granular state, as seen in the precious, common, steatitic, and oleaceous serpentines. The accessary mineral, diallage, also imparts characters to the serpentine, according to which, it is intimately combined with the base, or is disposed in distinct forms." Serpentine and Diallage Rock thus seem to differ from each other only in texture.

130. Diallage Rock.—Euphotide or Diallage Rock, is composed of felspar and diallage, both very crystalline, and generally distinct, in the form of crystals of various sizes, aggregated together in the manner of granite. Sometimes, the crystals becoming very small, it assumes a slaty texture; and sometimes the felspar entirely disappears. It is frequently intersected by thin veins or laminæ of talc, chlorite, or mica. The colours of the diallage are pale greyish-green, light green, grey, brown, purple, or black; and those of the felspar, white, grey, greenish, or purplish. It passes into talc-slate and chlorite-slate, on the one hand, and into serpentine on the other. The strata vary in thickness, from a few inches to many yards, and are associated with gneiss, mica-slate, clay-slate, or serpentine. The minerals which it contains are chiefly talc, chlorite, asbestus, actinolite, and steatite. It occurs abundantly in Cornwall, and in the Shetland Islands, as well as in Norway, Germany, Switzerland, and Italy. It is esteemed as an ornamental stone, being cut and polished like serpentine, with which it is sometimes intermixed.

131. Character of the Scenery of Primary Districts.—The nature of the surface produced by these various rocks, presents numerous varieties. Granitic mountains are often rounded, and more or less elongated, or of a massy form, and connected into groups, having a central portion from which ramifications extend in all directions,

gradually declining towards the plains. The hollows or passes in the main-ridge are deep, the valleys usually commence with an abrupt hollow or corry, are extremely numerous, and join each other at every degree of inclination. In the elevated regions they are narrow, with steep sides, but in mountains of mean height they are wider with gentle slopes. The slopes and even the summits are frequently covered with granite blocks of all sizes, heaped upon each other, sometimes rounded by decomposition, but often fresh and angular, or shooting into elongated points. GRANITIC GNEISS constitutes the central part of the great chain of the Alps, in which the mountains present abrupt precipices and ridges rising into points so slender that they are called Needles; the valleys are narrow, and all commence with a very wide amphitheatre, having the sides highly inclined; the secondary valleys are still narrower, and are often merely deep fissures. All the mountains, whatever be their form or height, compose masses unconnected with each other, all having a central part from which all the rest diverge, gradually declining in height the farther they proceed, and giving off inferior ramifications, which lose themselves in the valleys and plains, or abut against those of other masses. Each central part is surrounded by a number of large amphitheatres, forming the commencement of the valleys that run between the different branches. In the Vosges, where the mountains are much lower, they present rounded outlines, few precipices, and no serrated ridges; but these mountains always form masses, each having a central part from which all the rest diverge. When gneiss has little elevation, it presents groups of hills having similar characters.

The MICA-SLATE formation, having the strata much undulated, the surface of the ground presents rounded and wavy outlines, with few elevated projections, but often platforms of great extent. Mountains of this rock are commonly disposed in groups of which the central part is occupied by gneiss or granite. The summits rise above each other as we approach the centre of the group, and it is seldom that two neighbouring summits attain the same height. The declivities are cut by numerous ravines, and often disposed in the form of terraces.

TALC-SLATE mountains are not of great height, and present platforms declining gently towards the valleys, of which the slopes are sometimes covered with transported blocks. These mountains are especially remarkable for their large cracked and serrated masses, of most fantastic form, and so inclined as to threaten destruction to the traveller.

The above account is condensed from M. Rozet's Traité Elémentaire; but it will be seen that he considers the Central Alps as gneiss, while several other geologists admit them to be granite. In Scotland, as I have observed, the GRANITIC mountains are characterized by rounded summits, covered with decomposed fragments, through which protrude here and there fissured masses of the rock. The valleys are of moderate width, precipitous at their commencement, with semi-circular hollows, but subsequently with gentle slopes, covered with detritus, and usually furrowed deeply by the streams. The GNEISS mountains are much more rugged, often precipitous, but seldom presenting continuous escarpments of great extent. With us, gneiss is among the most indestructible of the primary rocks, and the mountains formed by it in Scotland are singularly bare, being destitute of alluvial covering, and but scantily clothed with vegetation in patches. Those of MICA-SLATE, which are clothed with a more abundant and more verdant vegetation, yet often present very rugged slopes, and serrated outlines, which are still more remarkable in the chloritic mica-slates, as in Glencroe. The QUARTZ-ROCK hills are very bare, and sometimes exceedingly abrupt, but often less precipitous than those of mica-slate. The granite districts have the poorest soils, and their vegetation is heathy, but in the lower parts often covered with fir woods; those of gneiss are sometimes remarkable for the accumulation of peat in favourable places, and their vegetation is chiefly of heath and carices. Grass and mosses, with alder, oak, birch, and other deciduous trees, characterize the micaceous hills, which produce the alpine plants in greater profusion.

132. CONCLUDING REMARKS.—Having thus enumerated and briefly described the primary strata, we may now offer some general observations respecting them. It was at one time supposed that these rocks followed each other in a regular unvarying order; but this idea has been found incorrect, "principally," as Dr. Boase remarks, "through the labours of Dr. MacCulloch, who taught us that these slates are arranged in Scotland in every possible sequence; and his statement has since been confirmed by observations made in other countries. Indeed, when we consider how few minerals enter into the composition of the primary slates, and the infinite but similar varieties of modes in which these are united, and the perpetual fluctuation or transition of these minerals into each other, it is not surprising that they are associated together in series of endless permutations."

The primary strata present themselves in all degrees of inclination, but are very seldom horizontal. They are traversed by veins of granite, which are generally of a smaller grain than the main body, but sometimes, especially when of great size, of much larger crystals. When slaty rocks are in contact with granite veins, they are frequently much harder, more crystalline, and less slaty. Sometimes the veins are intimately united with the rocks which they traverse, but generally they are separated by a seam or joint. Fragments of gneiss and other rocks are often found detached in granite veins, and fragments of granite in like manner occur in the rocks traversed by it. Granite veins have been sometimes traced to the mass of granite, when they appeared to be in perfect union with it, but sometimes to pass through it as well as through the other rocks. These granite veins do not often pass beyond the primary strata, which are also traversed by veins, generally of large size, and then called DYKES, of greenstone, porphyry, and other rocks belonging to the trap or overlying family. The nature of these bodies, and the phenomena which they present, will be elsewhere described.

RECAPITULATION.

117. Why is granite called plutonic or hypogene? What rocks succeed granite? In what respect do the primary differ from the secondary rocks? Why have they been called Metamorphic?—118. How may the primary rocks be distinguished? What species are peculiar to the series? What kinds are common to it and the secondary?—119. Are the primary rocks regularly superimposed upon each other?—120. Give an account of the composition of Gneiss, its three principal varieties, the minerals contained in it, the veins by which it is intersected, and the countries in which it occurs.—121. What is the composition of Mica-slate? Its principal varieties, and the minerals contained in it?—122. Describe Chlorite-slate?—123. What are the characters of Talc-slate?—124. What are the nature and varieties of Hornblende-slate?—125. Describe Actinolite-slate.—126. What are the characters, connections, and varieties of Clay-slate?—127. Give a general account of Quartz-rock. What are its composition, imbedded minerals, and distribution.—128. Has Primary Limestone any particular position with reference to the other rocks? What are its texture, composition, colours, imbedded minerals, and distribution? What is the nature of Dolomite?—129. Give an account of Serpentine, its transitions, varieties, and distribution.—130. Describe Diallage Rock.—131. What peculiarities of surface and vegetation belong to the different rocks of the primary class?—132. Why do the primary rocks so readily pass into each other? What appearances do granite veins present in traversing these rocks? Are they penetrated by other veins?

CHAPTER V.

OF THE SECONDARY ROCKS.

CLASSIFICATION OF THE SECONDARY STRATA. PHENOMENA OF STRATIFICATION. ARRANGEMENT INTO LOWER, MIDDLE, AND UPPER SECONDARY. LOWER SECONDARY ROCKS: CLAY-SLATE OR GREYWACKÉ, AND SILURIAN SYSTEMS.

133. Classification of the Secondary Strata.—The great series of the Secondary Strata includes all the deposits intervening between the non-fossiliferous stratified rocks, and the upper surface of the Chalk or Cretaceous System. These deposits are variously grouped and sub-divided by geologists, some instituting a Transition Class for the lower part of the secondary series, others considering the non-fossiliferous stratified rocks and some of the lower fossiliferous rocks as together constituting the Primary series. Let the accompanying diagram represent the series of strata from granite to the surface. We have, 1. The Fundamental Rock, Granite and its varieties; 2. The Primary or non-fossiliferous stratified Rocks; 3. The Secondary Rocks, or the fossiliferous strata, intervening between the primary rocks and the upper limit of the chalk; 4. The Tertiary Rocks, or those surmounting the chalk; 5. The Alluvial. But these strata might be differently grouped.

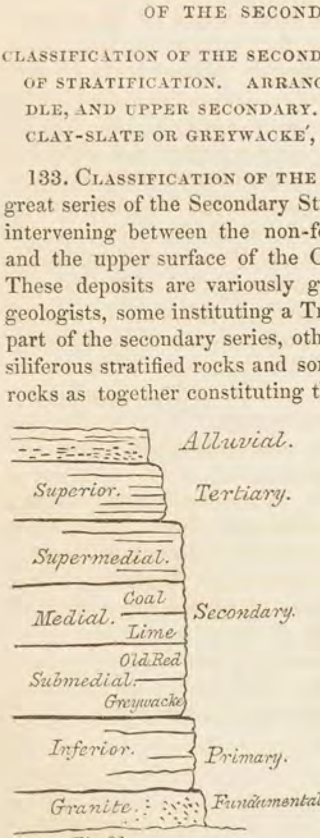


Fig. 21

Thus, the Primary and Fundamental Rocks might be named the INFERIOR or Primitive; the next or Greywacké series might be denominated SUBMEDIAL; the Mountain Limestone and Coal Systems might be considered as MEDIAL; the strata above coal, including chalk, would be SUPERMEDIAL; while the Tertiary and Alluvial might aptly be named the SUPERIOR.

Various other arrangements have been employed. Thus, M. De la Beche divides the crust of the earth into two series, the Stratified and Unstratified. The former he arranges into ten groups:—1. The Modern Group; 2. The Diluvial; 3. The Supercretaceous; 4. The Cretaceous; 5. The Oolitic; 6. The New Red Sandstone; 7. The Carboniferous; 8. The Greywacké; 9. The Inferior Fossiliferous; 10. The Inferior Non-fossiliferous stratified Series. In the Traité Elementaire of M. Rozet, one of the most recent works on this subject, the arrangement is as follows:—1. The first period comprises all the formations dependent upon causes at present in action; all the products of the phenomena which are now taking place at the earth's surface. 2. The second, all the old great deposits of transported matters, or diluvium, which contains abundant remains of large terrestrial mammalia of species not now living. 3. The third, all the stratified deposits comprised between the diluvial system and the Chalk-Formation, perfectly recognisable in all countries of the earth. 4. The fourth period contains the Chalk-Formation, and all those which follow in the descending series down to the great Coal-Formation, on which the strata of the groups of this period are generally placed in discordant stratification. 5. In the fifth period we place the Coal-Formation, and all those which are inferior to it until we come to the crystalline stratified rocks. 6. Our sixth period comprises all the stratified crystalline rocks; the talc-slates, mica-slates, and gneiss, in which no organic remains have hitherto been found.

The arrangement adopted in this treatise nearly corresponds with the above: The Primary series being the 6th of M. Rozet's arrangement; the Secondary including his 5th and 4th; the Tertiary being his 3rd; and the Alluvial being his 2d and 1st. Before proceeding to give an account of these strata, some circumstances having reference to them may be adverted to.

134. PHENOMENA OF STRATIFICATION.—Strata may be horizontal, as is represented by Fig. 22, *a a*; but this very rarely happens, they being generally more or less inclined. The inclination from the horizontal position is called the DIP. Thus at *b b*, the strata incline or dip at an angle of about 45°. The direction or STRIKE of the strata is indicated by a horizontal line at right angles to the dip. When strata protrude above the surface, or appear uncovered, they are said to CROP OUT. They are said to be CONFORMABLE, when their planes are parallel, whatever their dip may be, as in *a a*; UNCONFORMABLE, when a set of strata is so connected with another, that the planes of stratification of the one series have a different direction from those of the other series.

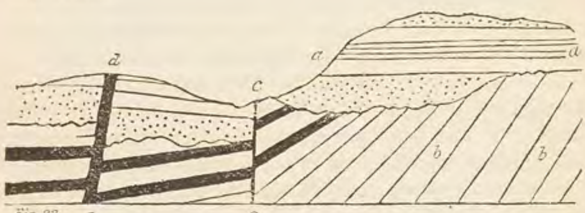


Fig. 22

Thus, the strata, *a a*, being horizontal, are not conformable to the strata, *b b*, on which they lie, these latter being much inclined. When the strata are dislocated, so that on one side of a fracture or line of accidental separation, *c c*, they no longer correspond with those on the other, although they had evidently at one time been continuous, there is produced what is called a FAULT. A dyke, *d d*, is a wall of rock interposed between the two sides of a dislocation, and generally composed of some igneous rock, such as granite, greenstone, or porphyry.

When several strata of the same kind of rock alternate with strata of another rock, occurring as it were occasionally or irregularly; or when strata of different kinds pass into each other, but all contain similar organic remains, the strata are considered as of nearly contemporaneous origin, and collectively constitute what is called a FORMATION.

135. ARRANGEMENT ADOPTED.—The Secondary Strata intervening between the Primary and the upper surface of the Chalk-Formation, may be divided into three series: the Lower, Middle, and Upper. The lower series includes two systems, the Greywacké System, and the Silurian System; the middle series is composed of the Carboniferous System, including the Coal-Formation; and the upper series contains three systems, the Saliferous or New Red Sandstone, the Oolitic, and the Cretaceous or Chalk. Each of these systems is composed of a series of strata, often very different from each other in chemical and mineralogical characters, but agreeing, either by mutual transition, or by a community of organic remains, so as to constitute a whole distinct from the other systems.

Fig. 23.

OF THE LOWER SECONDARY ROCKS.

SUBMEDIAL OR TRANSITION.

136. GENERAL REMARKS.—The Primary Rocks described in the preceding chapter often form masses or

mountain-ranges, rising to a great elevation, and uncovered by other rocks. Or, they may be covered by rocks of the secondary series, or merely by beds of clay and gravel, or by lava and other volcanic products. But frequently, they are succeeded by rocks bearing a close resemblance to some of them, although differing in being often fragmentary, and in containing organic remains. These rocks, named by some Transitional, on account of their forming the gradation from the primary non-fossiliferous, to those abundantly supplied with remains of animals and plants, occur abundantly in Scotland, England, and Wales, where they compose the highest ranges, exclusive of the Grampians. They are divided into two series or systems, one named the Gray-wacké System, the other the Silurian System.

Clay-slate and Greywacke' System.

137. Extent and Relations.—Independent of the strata of clay-slate immediately connected with mica-slate and other primary rocks, a more extensive series of the same nature occurs, which is generally associated with greywacké and other rocks of a less crystalline texture than the primary. "Few mountainous districts," says Professor Phillips, "are wholly devoid of argillaceous primary rocks; but these deposits are not at all to be compared in extent with the older mica-slate and gneiss formations. The gneiss and mica-slate of the Alps, Pyrenees, and mountain borders of Bohemia, are not entirely unaccompanied by such argillaceous deposits, any more than the Scandinavian and Highland chains, and the north-western primary tract of Ireland; but the principal masses of the clay-slate system lie apart in the Hartz and Ardennes, in Brittany and Cornwall, the Welsh and the Cumbrian mountains, and the ranges of Lammermuir and Donegal; yet under all these slate tracts lies the fundamental granite, and similar veins pass from it into the argillaceous covering. In some parts, as in Cumberland (Skiddaw), and in the Isle of Anglesea, slight traces of

the older stratified rocks appear below the clay-slate; but the general fact appears to be, that the deposition of the two systems was influenced by different physical conditions related to different geographical centres." In Britain, it is in Cumberland and North Wales that this system of rocks presents itself in the highest development, and the series observed in these districts have been named by Mr. Sedgwick, the CUMBRIAN, which is the lower group, and the CAMBRIAN (or Welsh), which is the upper of the clay-slate series.

138. CUMBRIAN GROUP.—This series, of which the thickness is stated to be upwards of 3000 feet, is arranged into three divisions: 1. HORNBLENDIC CLAY-SLATE, a rock not composed of hornblende and felspar, like the primary hornblende-slate, but of clay-slate, in which are interspersed crystals of hornblende and actinolite. 2. CHIASTOLITE-SLATE, or rather clay-slate, dark coloured, and generally soft, containing crystals of the mineral called Chiastolite; and, 3. CLAY-SLATE, of a dark colour, laminated texture, and, like the other rocks of this series, destitute of organic remains.

139. CAMBRIAN GROUP.—This series is also divided into three subordinate groups, which, in Cumberland, have a thickness of upwards of £3000 feet: 1. SNOWDON ROCKS, of various colours and textures, varying from fragmentary to the finest roofing-slate; 2. BALA LIMESTONE, a dark-coloured slaty limestone, in Westmoreland 100 feet thick, and both there and in Wales containing organic remains; 3. PLINLIMMON ROCKS, greywacké of various qualities, sometimes fine and slaty. In Cumberland, its thickness is estimated at 3000 feet or more. This Plinlimmon Rock corresponds with the Greywacké Range of the Lammermuir, extending from St. Abb's Head, on the east Coast of Scotland, to the Mull of Galloway. In the latter district, the author of this Treatise has found it presenting the following appearances.

140. GREYWACKE' SERIES OF THE LAMMERMUIR RANGE.—The central and most elevated portion of this district is

composed of greywacké, greywacké-slate, clay-slate, and slate-clay, passing into each other, or alternating, distinctly stratified, often laminar, and frequently presenting plates of extreme tenuity. The general direction of the strata is from south-west to north-east. They are usually much inclined, sometimes vertical, and not unfrequently horizontal, but present every degree of inclination. The composition of the greywacké presents considerable variety.

Sometimes it is a very closely aggregated fragmentary rock, composed of white crystalline quartz, brown and red jasper, black Lydian stone, grey or bluish flinty-slate, and pieces of dark-coloured shale impacted in a fine-grained greyish basis. The fissures are filled with indurated argillaceous matter, and dark-green unctuous earthy chlorite. Particles of mica and felspar are sometimes seen in the mass, of which the aggregation is often less perfect when it approaches in character to a conglomerate.

More frequently, when the rock is large-grained, it is of a bluish-grey colour, mottled with white, more crystalline, but still evidently fragmentary. The basis is small-grained, grey, with large fragments of compact or slaty rocks of the same colour, or sometimes of dark shale, interspersed. The impacted substances are white and grey quartz, with very few fragments of a different colour, sometimes small crystals of calcareous spar, and a few particles of mica. Veins of quartz and calcareous spar often intersect this variety.

From this it passes into a rock, presenting at first sight, on its recently exposed surfaces, the appearance of a greenstone, but still composed of the same ingredients. The layers are usually thin, varying from a foot or more to a few inches.

Less aggregated, or more decomposed and earthy, the rock assumes a dull red colour, presenting the appearance of a sandstone, but very readily distinguishable by its other characters. The fissures often present a ferruginous clayey matter, and the rock is less tenacious.

Next, it becomes very fine-grained, with numberless glistening points, and very readily splits into plates an inch or less in thickness, the interior of which is not laminar, but yields an uneven or conchoidal fracture in whatever direction it is broken. This variety is the common greywacké-slate.

The laminæ becoming smaller, and the texture finer, with a lamellar disposition, the greywacké passes into clay-slate, which is glistening with minute points, but does not present the glossy surfaces of the primitive clay-slates, which seem to form a passage from the micaceous and chloritic slates. The greywacké clay-slates are always easily distinguishable from the primitive, although their colour may be nearly the same. They are never so hard, their laminæ are less coherent, and they decompose more readily.

Becoming still finer, and assuming a black or grey tint, without lustre, the slates pass into shales resembling those of the coal-formation, from which they often cannot be distinguished in hand specimens. Having the same carbonaceous aspect with shining surfaces, they become glossy alum-shale, as in the ravines of Hartfell and White Coom.

All these varieties, but especially the slates and shales, have a tendency to break into rhomboidal fragments, of which the acute angle is about 65°. Quartz, calcareous spar, heavy spar, chlorite, iron-pyrites, and galena, are found in veins and nodules.

In form the hills approximate in a considerable degree to many of the granitic masses of Aberdeenshire, but they never present the precipices and corries which characterize the more elevated of the latter. The whole district with its rounded, smooth-sloped mountains, connected in elongated heaps, its long, narrow, straight, or slightly tortuous valleys, its argillaceous and pebbly soil, its clear and rapid streams, and its grassy vegetation, with the absence of natural wood, and the scarcity of artificial, forms a strong contrast to the mountainous districts of the middle and northern divisions of Scotland, in which peaked, serrated and ridgy mountains, with crags and corries, rugged and winding valleys, slopes covered with debris and patched with heath and brake, brown or limpid streams fringed with alder and birch, rivers and lakes with cataracts and islands, dark forests of pines, and thickets of briars, with other remarkable features, characterize a primary region.

141. MINERALS AND ORGANIC REMAINS.—No organic remains have been found in the lower or Cumbrian series of slates, but in the limestone interposed between them occur some corals and shells. Organic remains are more numerous in the Bala Limestone, and consist also of shells and corals. With these lower secondary rocks are associated, in veins, dykes and irregular masses, granite, syenite, porphyry, and greenstone of various kinds. Mineral veins, containing ores of lead, silver, copper, iron, zinc, manganese, cobalt, antimony, and bismuth, also occur, and are especially abundant in the slate district of Cornwall, which some consider as belonging to the Cambrian or Greywacké system. According to Dr. Boase, the slaty rocks of Cornwall "may be divided into two series, the porphyritic and the calcareous; the former including those rocks which occur next the granite, and contain porphyries and other granitic rocks in the form of regular beds or elvan-courses, and which abound in veins of tin and copper ores; the latter comprising those rocks which are more or less remote from the granite, contain no ELVANS, but abound much more in greenstone, especially its obscure varieties, and in dark-coloured limestones, sparingly metalliferous containing no tin, but productive of lead and antimony, and, lastly, possessing occasionally organic remains. The rock in contact with granite has been called argillaceous schist or clay-slate, greywacké, or killas. Dr. Boase considers it different from clay-slate or greywacké, and divides it into two kinds, CORNUBIANITE and PROTEOLITE. The first of these, most abundant in the western part of Cornwall, is dark blue or purple, uniform, striped, or patched, hard and laminated. The Proteolite is of a lighter colour, soft, arenaceous, slaty. They appear to be chiefly composed of compact felspar, with quartz, mica, and schorl, and contain beds of that substance and of quartz. All the

rocks of this series have a basis of compact felspar, united with hornblende, actinolite, or chlorite, and pass gradually into each other. The slaty rocks which immediately surround the granite of Cornwall are thus Cornubianite, Proteolite, Greenstone or Hornblende-rock, Actinolite-rock, and Chlorite-rock. These rocks appear analogous in position and structure to the primary rocks of the north of Scotland. Another class of rocks, the magnesian, may be subdivided into Diallage-rock, Serpentine, and Talc-slate. Together with these, is Quartz-rock in beds. Granitic rocks often occur in these slates as large beds or dykes, locally called ELVAN-COURSES. On comparing them with the primary rocks of Ireland, Scotland, and other countries, Dr. Boase concludes that they belong to the primary series, and not to the transition or lower part of the secondary series. Other geologists, however, are of opinion that the Killas of Cornwall is a variety of clay-slate or greywacké analogous to the Plinlimmon Rocks and those of the Lammermuir.

Silurian System.

142. Silurian Rocks.—The upper part of the lower series of secondary rocks has been named by Mr. Murchison the Silurian system, from its being highly developed in that part of Wales formerly inhabited by the Silures, namely the counties of Hereford, Radnor, Brecon, Caermarthen, and Pembroke. He divides it into two portions, the Lower and the Upper.

The Lower Silurian Rocks are: 1. Llandeilo Flags, 1200 feet thick, hard, dark-coloured slaty, sandstones, frequently calcareous, sometimes slightly micaceous, containing Mollusca and Trilobites, a kind of crustaceous animal. 2. Caradoc Sandstone, red, purple, green, and white, micaceous, sometimes quartzose grits, and limestones, 2500 feet thick, containing Corals and Mollusca.

The Upper Silurian Rocks are: 1. Wenlock Lime-

STONE and SHALE, 1800 feet thick; the former a crystalline grey or blue limestone, abounding in corals, encrinites, marine Mollusca and Crustaceous animals of the Trilobite family; the latter a dark-coloured shale, with nodules of earthy limestone, and containing Mollusca and Trilobites. 2. The LUDLOW ROCKS, 2000 feet thick, composed of three groups: The LOWER LUDLOW ROCK, or Mudstone, sandy, dark-coloured shales and flags, with concretions of earthy limestone, and containing marine Mollusca, Corals, and Fishes; the AYMESTRY LIMESTONE, grey or bluish argillaceous limestone, full of remains of shells and corals; the UPPER LUDLOW ROCK, thin, grey, slightly micaceous sandstones and shales, containing shells and trilobites. "The most remarkable fossils," says Mr. Lyell, "are the scales, icthyodorulites, jaws, teeth, and coprolites of fish, of the upper Silurian Rock. As they are the oldest remains of vertebrated animals yet known to geologists, it is worthy of notice that they belong to fish of a high or very perfect organization. In these shales many zoophytes are found enveloped in an erect position, having evidently become fossil on the spots where they grew at the bottom of the sea." He further states that the Silurian strata extend over a wide area, and closely resemble those of England, and is of opinion that the limestones of Lake Michigan, and other regions bordering the great Canadian lakes, belong to the same series.

143. GENERAL REMARKS.—The lower part of the first or lower series of the Secondary Rocks differs little from those belonging to the primary series; but, as we ascend, the strata become less crystalline, and present organic remains, which in many of the upper limestone beds are very abundant. The Greywacké System is penetrated by granite veins, like the primary series, but it does not appear that those veins frequently traverse any of the rocks above it. The precise limitation of the Primary Rocks is scarcely yet determined, for the Cornish and Cumbrian Rocks may be claimed for

either series, and it appears that the crystalline stratified rocks have been subjected to a less strict examination than the secondary.

During the deposition of the primary crystalline rocks, it would seem that the primitive ocean underwent little agitation; but the fragmentary and sandy deposits of the lower secondary series indicate considerable disturbance. The great inclination of the strata in both, probably caused by internal action giving rise to the protrusion of granite and other igneous rocks, appears to show that great convulsions had taken place consequently to the deposition of these rocks. Mr. Lyell, however, states that the Silurian strata throughout a large portion of the south of Sweden are perfectly horizontal, and cannot have been disturbed unless "by such gradual movements as those by which large areas in Sweden and Greenland are now slowly and insensibly rising above or sinking below their former level." This he considers as agreeing with the idea that while at all periods some parts of the earth's crust have been violently convulsed, other spaces have never once been visited by this kind of movement.

Recapitulation.

133. What is meant by Secondary Rocks? Is there any difference of opinion as to the grouping of these deposits? Mention some examples.—134. Are the strata often horizontal? What are the dip and strike of strata? When are strata conformable? What is meant by a fault or dyke? How are the Secondary Rocks disposed?—135. Why were the lowest called Transition? Into what systems are they divided?—136. Are the Greywacké and Clay-slate rocks of great extent?—138. What are the three divisions of the Cumbrian group?—139. Into how many parts is the Cam-

brian group divided?—140. Give a general account of the central portion of the Lammermuir range. What is the character of the scenery there?—141. Do any organic remains occur in the Greywacké or Slate? Are they productive of metallic ores? Are the rocks of Cornwall primary or secondary?—142. What name is given to the upper part of this section of the secondary Rocks? How is the Silurian system divided? What are the lower Silurian Rocks? Give a brief account of the Upper. What are the most remarkable fossils in these rocks? Are the Silurian strata widely extended?—143. Is there any difference in the texture of the lower and upper strata of these lower secondary rocks? Do the primary rocks exhibit indications of disturbance in the ocean in which they were deposited? What may be inferred from the fragmentary structure of many of the lower secondary strata? Are the latter always highly inclined?

CHAPTER VI.

MIDDLE SECONDARY ROCKS.

POSITION AND EXTENT OF OLD RED SANDSTONE SYSTEM, MOUNTAIN LIMESTONE SYSTEM, CARBONIFEROUS SYSTEM. ARRANGEMENT OF THE STRATA. FAULTS. MINERALS AND PETRIFICATIONS. NATURE AND ORIGIN OF COAL. ECONOMICAL USES. GENERAL REMARKS.

144. Position and Extent.—The primary and lower secondary or transition rocks having, by convulsions arising from within the earth's crust, been broken up and displaced, so as to present an irregular surface, and degrees of inclination of their masses of strata seldom preserving much uni-

formity over a great extent, the series of deposits which immediately succeed those last described in the order of superposition, does not often occur in conformable stratification. In Herefordshire, however, where the Upper Silurian sandstones and shales gradually pass into the shales and sandstones of the Carboniferous system so as to render their separation there in a great measure arbitrary, the two series are parallel. The strata of the Carboniferous System have been found resting on Greywacké, Clay-slate, Gneiss, and even Granite, and, as in other cases, members of the series may be wanting, or but partially developed. The secondary rocks do not continuously cover the continents and large islands, but are separated into local groups, and in Britain, the Carboniferous System is found here and there in patches, one of which occupies a great portion of the low grounds intervening between the Grampians and the Lammermuir range in Scotland, another, the Newcastle coal-field extends inwards from the east coast of the northern division of England, that of Sheffield in the central part, and in South Wales is another of great extent, while less extensive patches are dispersed over the middle and northern districts. It occurs in the same manner irregularly distributed in Ireland, and is found in various parts of Europe, America, and Australia. The strata of which the Carboniferous system is composed are Sandstones, Shales, Limestones, Ironstone, and Coal. This series, varying from a few to several thousand feet in thickness, in different localities, and seldom presenting itself complete in any, is divided into three subordinate series or formations: The Old Red

Fig. 24.

Sandstone-Formation, the Carboniferous Limestone or Mountain Limestone Formation, and the Coal-Formation. Others with perhaps more propriety, divide the series of inferior secondary deposits into three systems: The Old Red Sandstone System, the Calciferous or Mountain Limestone System, and the Carboniferous or Coal System.

Old Red Sandstone System.

145. Old Red Sandstone.—As seen along the slopes and valleys of the eastern parts of the counties of Ross and Sutherland, or as flanking the Grampian Range from Dunottar to Dumbarton, this rock presents itself as an aggregate of pebbles of all sizes, from the diameter of two feet downwards, cemented by argillaceous or ferruginous matter. The pebbles are very frequently of quartz, that substance having better resisted the attrition to which it has been subjected, but frequently also of granite, gneiss, clay-slate, jasper, greywacké, flinty-slate, in short, all the materials of which the preceding primary and transition deposits have been formed. In other cases, it is a sandstone of various colours, dull red, greenish grey, light grey, or even white or brown, and of which the grains, generally coarse, but sometimes fine, are composed of the ingredients mentioned above. When the particles are fine, the argillaceous predominant, and scales of mica interspersed, it becomes slaty, and sometimes contains remains of fishes. On the borders of the Silurian System in Wales, it assumes a different character, being composed of arenaceous, calcareous, and argillaceous strata, which Mr. Murchison, who estimates their thickness at 10,000 feet, divides into three parts:—1. The lower, slaty, micaceous, red and green sandstones, with shells of several genera; 2. The middle, red and green concretionary limestones, with spotted clayey marls, and beds of sandstone, containing various marine fishes; 3. The upper, red, quartzose conglomerate, lying on sandstone in thick beds, without organic remains.

Carboniferous System.

146. Mountain or Carboniferous Limestone.—This formation, which in England lies over the Old Red Sandstone, and under the Coal-Formation, and in Scotland alternates with the lower part of the latter, is composed of beds of compact or often crystalline limestone, of various colours, bluish-grey, light grey, brown, or even black, and containing numerous Corals, Encrinites, some Echini, and abundance of univalve and bivalve shells, many of which belong to genera still existing, together with species of two extinct genera, Spirifer and Productus. Orthoceratites and other Cephalopodous Mollusca also occur, but no terrestrial animals or plants, the fossils of both this and the Red Sandstone Formation being marine. Professor Phillips states, that in Derbyshire and the South of Yorkshire, the Mountain Limestone is composed of three terms: 1. The Upper: Millstone Grit, a coarse sandstone, with shales, and bad coal. 2. Middle Term: a mass of bituminous shale, in which locally black limestone bands and nodules of ironstone occur. 3. Lower: a great mass of calcareous rocks, almost entirely free from arenaceous and argillaceous admixture. To this type, he states, all the Mountain Limestone of the south of England, as well as of Ireland, Belgium, Dusseldorf and Silesia, are to be referred. In the north of England, according to the same authority, these three terms are compounded and otherwise varied. The upper group is composed of three millstone grit rocks, alternating with shales, laminated sandstones, coal seams, schist beds, and five or more limestone rocks, each from 10 to 80 feet thick. The lower group consists of limestone alternating with shale and sandstone, with some coal.

As this limestone receives a good polish, it is often used as marble, some of the varieties, especially those containing numerous organic remains, being of great beauty. It is also important, as containing veins of lead, zinc, and other metallic ores, almost all the lead obtained from the English mines being found in it. Caves of vast extent frequently occur in it, both on the continent, and in England. Mr. Bakewell supposes that they have been formed by the agency of water percolating through natural fissures, and in the lapse of ages excavating the softer or more broken parts of the rock.

147. Coal-Formation.—In an economical point of view this is the most important of all the series of deposits, and in a geological it is of great interest on account of the multiplicity of organic remains which it contains, and the various phenomena which it presents. It never occupies a very elevated situation, but is generally found in hollows or valleys at the foot of mountain ranges, and its strata are frequently curved, and variously fractured. In consequence of their bending, they rise to the surface in some part of their course, a circumstance which renders coal more easily discovered and worked than it would otherwise be. In the north of England, the strata of sandstone, shale, ironstone, and coal, of which it is composed, are 3000 feet thick, and in Derbyshire 2500. But the quantity of coal found in this great mass of rock bears a very small proportion to it, the thickest bed of English coal being from 30 to 40 feet, and the aggregate thickness of all the beds in a coal district not often exceeding from 40 to 60 feet. The strata of the coal-formation are usually disposed so as to form a basin or trough, and in the different coal-fields which occur in England, Germany, and other countries, they are not uniformly arranged, but each coal district has its peculiar series, varying in thickness and disposition. In a section of the Moira Coal Mine in Leicestershire, given by Mr. Bakewell, "there are about 130 distinct strata, comprising ten beds of coal, and twenty seams of ironstone and strata containing ironstone. The main-coal is from 13 to 14 feet in thickness, containing twenty seams of coal of different qualities." The characters of the different strata in coal basins vary, and are not reducible to a formula applicable to all; but the

following may answer as a general statement. The strata are,

1. SANDSTONE, OR FREESTONE, of various colours, red, white, grey, yellow, brown, or variegated, and composed of grains of quartz intermixed with clay; sometimes felspar, flinty-slate, and other matters, especially scales of mica, enter into its composition. It varies from hard and compact, to soft or friable, and occurs in beds presenting little or no appearance of laminæ, or in laminated strata, in which the plates or leaves are separated by scales of mica or carbonaceous matter. Sometimes the sandstone is so indurated as to resemble quartz-rock, and when much intermixed with clay it passes into slate-clay or shale.

2. SHALE: indurated clay, laminated, bluish, dark grey, or black. When much intermixed with carbonaceous matter, and impregnated with bitumen, it is usually named BITUMINOUS SHALE. When highly impregnated with silica, it passes into FLINTY-SLATE.

3. IRONSTONE, forming thin beds, or disposed in globular or depressed masses, and alternating with layers of shale. It is of a brown or grey colour, and principally composed of iron combined with oxygen, carbonic acid and water, usually with a little alumina, silica, and lime.

4. CLAY of various colours and qualities.

5. COAL.—This substance is a compound of charcoal, bitumen, and earthy matter, the latter varying from two to twenty per cent., the bitumen from twenty to forty, and the charcoal from forty to eighty. It presents numerous varieties, distinguished by various qualities, some highly bituminous and burning with flame and much smoke, others, as cannel coal, containing a large proportion of gases, and burning with much flame and little smoke, while others burn with little of either. Anthracite, or glance-coal, also, which is nearly pure carbon, often with semi-metallic lustre, very hard, and difficult to ignite, sometimes occurs in small quantities, in coal strata.

6. LIMESTONE.—Beds of limestone often occur in the

midst of the series of strata containing coal, and are generally of the same nature as the mountain limestone already described.

148. Arrangement of the Strata.—Coal-deposits, or, as they are usually called, Coal-fields, generally occupying hollows or plains intervening between two ranges of high ground, have their strata arranged somewhat in conformity with the surface of the subjacent deposits, and thus in a section present the appearance of curved and parallel layers, often, however, variously disarranged by fissures which are when large filled with some hard rock of the kind usually named trap. Frequently when extended over a large district they present a series of undulations, and when no other deposit lies over them, the eminences thus formed have been as it were abraded and their parts dispersed, which is more especially the case with elevated portions of strata caused by dykes or fissures. The explanation of this phenomenon usually given has reference to diluvial currents that have swept over the surface of the land; but Mr. Bakewell accounts for it by supposing the strata to have been still in a soft and yielding state when the forces by which they were dislocated acted upon them, and thus to have been submitted to the violent action of water when, having been suddenly broken and forced upwards, they were still beneath the surface of the ocean. The accompanying figure represents a section of a portion of carboniferous strata, the parts of which that have been elevated above the general surface have disappeared.

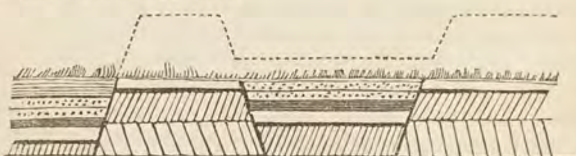


Fig. 25.

149. Faults.—The strata of the coal-formation are very frequently intersected by fissures, causing disturbances in

the strata, so that the same bed, being broken across, may be found at different levels, and thus a bed of coal, suddenly terminating, may be found continuous with a bed of sandstone or shale. The cracks vary in their direction, inclination, extent, and width, their faces being sometimes in apposition, sometimes separated a few inches or feet, or many yards, and filled either with loose matter, or with solid rocks of the trap or igneous kind. These veins thus formed are, when large, named dykes. Sometimes these fissures are so numerous that the deposit seems as if composed of masses separated from each other by laminæ of clay, brecciæ, basalt, or porphyry; and as these interposed plates are generally impermeable to water, they are of advantage to the miners, as they prevent the water of one part of a coal-field from inundating another portion. In the vicinity of these trap dykes, the strata are frequently altered in texture, coal being converted into charcoal, shale into siliceous slate, and sandstone indurated.

150. Minerals and Petrifications.—Metalliferous veins sometimes pass from the carboniferous limestone into the coal-formation; but the most important ore that occurs in it, is that commonly called clay ironstone, which frequently yields more than thirty per cent. of iron. Remains of animals are not of very common occurrence in the sandstones and shales of the coal-formation; but there have been found in them fishes, trilobites, and shells of several genera, such as Nautilus, Orthoceras, Spirifer, and Productus. The fishes are of a peculiar kind, allied to the Saurian Reptiles, or Lizard family. Some of these fossils are of marine origin, others belong to fresh water. The vegetable remains, which are extremely abundant, belong chiefly to the Cryptogamous or Cellular Class, such as Ferns and Sigillariæ, Lepidodendra considered by some analogous to our Lycopodia, Calamites supposed to be allied to our Equiseta, Coniferæ, and Stigmariæ, the latter apparently extinct. These plants, usually of gigantic dimensions, occur in the state of impressions, or having their trunks filled with sand

or mud, the carbonized bark remaining. In two great trunks found in Craigleith Quarry, near Edinburgh, the interior of which remained entire, although petrified, the original structure of the cells is well seen in thin slices subjected to the microscope.

151. Nature and Origin of Coal.—At the present day there can be little difference of opinion respecting the nature of the deposits of coal that belong to this formation. In the three varieties of coal found in the Newcastle deposit, Mr. Hutton states, that "even in samples taken indiscriminately, more or less of vegetable texture could always be discovered, thus affording the fullest evidence, if any such were wanting, of the vegetable origin of coal. Each of these three kinds of coal, besides the fine distinct reticulation of the original vegetable texture, exhibits other cells, which are filled with a light wine yellow-coloured matter, apparently of a bituminous nature, and which is so volatile as to be entirely expelled by heat, before any change is effected in the other constituents of the coal. The number and appearance of these cells vary with each variety of coal. In caking coal, the cells are comparatively few, and are highly elongated. In the finest portions of this coal, where the crystalline structure, as indicated by the rhomboidal form of its fragments, is most developed, the cells are completely obliterated. The slate-coal contains two kinds of cells, both of which are filled with yellow bituminous matter. One kind is that already noticed in caking coal; while the other kind of cells constitutes groups of smaller cells, of an elongated circular figure. In those varieties which go under the name of Cannel, Parrot, and Splint Coal, the crystalline structure, so conspicuous in fine caking coal, is wholly wanting; the first kind of cells are rarely seen, and the whole surface displays an almost uniform series of the second class of cells, filled with bituminous matter, and separated from each other by thin fibrous divisions."

152. Economical uses.—It is unnecessary to advert to the uses of coal, which, in domestic consumption, in the ma-

nufacture of gas, in navigation, and in most of the arts, is so extensively employed in this and some other countries. "The vast extent and importance of our iron-works," says Mr. Bakewell, "are well known; but their establishment is of recent date. Formerly our furnaces were on a diminutive scale, and wood or charcoal was the only fuel employed; but in the present cultivated state of the country, wood could not be procured in requisite quantity. The application of coal or coke to the smelting of iron, is among the most useful of modern improvements; but it is only some kinds of coal that are proper for the purpose. Inattention to this circumstance has frequently led landed proprietors to great unprofitable expense. Finding ironstone and coal in abundance upon their estates, they have constructed furnaces and other works at a considerable cost, and have discovered, too late, that the coal, however suitable for domestic or other uses, was unfit to make iron of a marketable quality. To make good iron from the best ironstone, it is necessary that the coal should be as free as possible from every substance with which sulphur is combined. It should possess the property of forming a hard coke or cinder; and if it have the quality of cementing or caking, it is the more valuable, as the small coal can then be used for the purpose of coking."

153. General Remarks.—Igneous or trap rocks, chiefly greenstone and basalt, are of frequent occurrence in the Carboniferous series, and in the coal-fields of Scotland and the north of England are abundantly dispersed among the strata, in the form of dykes, imbedded and overlying masses. It appears that, subsequently to the deposition of this series of strata, great convulsions had taken place, by which disruptions, dislocations, and subsidences, had been produced in them. Previously to the commencement of its deposition, it is supposed that portions of the globe had been elevated from the waters, and that the currents of the sea had produced in their vicinity the great deposits of old red conglomerate. When the agitation subsided, the finer sedimentary

deposits succeeded. Beds of limestone, formed of corals and shells, or chemically deposited, were strewn along the bottom of the seas; and in basins, bays, or estuaries, were deposited the upper beds of shale and sand, alternating with the vast masses of land or marsh plants now converted into coal. Brongniart has supposed that to produce such a mass of vegetation the atmosphere contained more carbonic acid gas than it does, and that by the vegetation the earth was prepared for a higher order of animals.

It being impossible, in a treatise so condensed as this, to give an account of the organic remains so profusely distributed in the Carboniferous and other systems, it may be well here to represent a few of the more remarkable forms already alluded to.

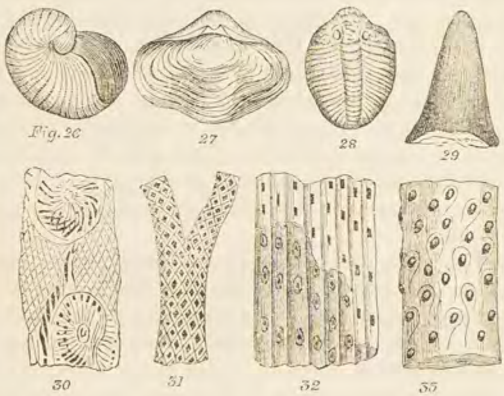


Fig. 26 represents a univalve shell, or molluscous animal having a shell resembling that of the nautilus, and distinguished by the name of Bellerophon costatus, which abounds in the Mountain Limestone. Fig. 27 shows a bivalve shell, named Spirifera glabra, which occurs in the same deposit. Fig. 28 is a rude representation of a Trilobite, an animal of the Crustaceous kind. Fig. 29 is a tooth of Megalichthys

Hibberti, a fish of which remains are found in the Coal-Formation. Fig. 30 represents a fragment of an impression of Ulodendron Allanii on sandstone from Craigleith Quarry, near Edinburgh. Fig. 31 shows the appearance of a portion of the dichotomous branch of Lepidodendron Sternbergii, from the Coal-formation in Bohemia. Fig. 32 is a fragment of the bark of a species of Sigillaria. And Fig. 33 represents a portion of a species of the genus Stigmaria, both from the Coal-Formation.

Recapitulation.

144. Are the carboniferous strata usually conformable to the lower secondary rocks? Are they very extensively distributed in Britain? Into what subordinate series is the carboniferous system divided?—145. What are the extent, composition, and colour of the Old Red Sandstone? In what respect does it differ in Wales?—146. Give a general account of the Mountain Limestone. To what economical uses is it applied?—147. Is the Coal-Formation of great extent? What proportion does the coal bear to the other strata? How are the strata usually arranged? Of what are they composed?—148. How does Mr. Bakewell account for the disappearance of the upraised portions?—149. What is the nature of faults and dykes? What alterations do the strata undergo in the vicinity of trap dykes?—150. What minerals occur in the Coal-Formation? Are there many organic remains? Of what nature are they?—151. Give an account of the nature and origin of coal.—152. What are its economical uses? What other substance is of great importance?—153. Are igneous rocks of frequent occurrence in the Coal-Formation? How do they present themselves? Give an account of the manner in which the Carboniferous strata are supposed to have been formed.

CHAPTER VII.

UPPER SECONDARY ROCKS.

SALIFEROUS, OOLITIC, AND CRETACEOUS SYSTEMS.

SALIFEROUS OR NEW RED SANDSTONE SYSTEM: ITS SUB-DIVISIONS, LOWER AND UPPER NEW RED SANDSTONES, ROCK-SALT AND GYPSUM, ORGANIC REMAINS. OOLITIC SYSTEM; ITS STRATA. LIAS, LOWER OOLITE, MIDDLE OOLITE, UPPER OOLITE, AND WEALD CLAY. CRETACEOUS SYSTEM, OR CHALK. GENERAL REMARKS.

154. UPPER SECONDARY ROCKS.—The deposits which succeed the Coal-Formation consist of beds of sandstone, marl, clay, limestone, and shale, exhibiting considerable variety of texture and composition, and containing a great profusion of organic remains. They are divided into three series or systems: the Saliferous or new Red Sandstone system, the Oolitic, and the Cretaceous. The accompanying diagram will afford a general idea of their arrangement.

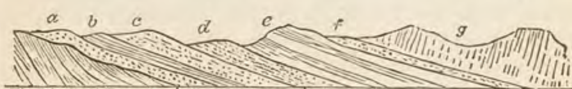


Fig. 34. Coal Formn. | New Red Sandst. | Lias and Oolite | Chalk

The Carboniferous strata are represented as lowest; the Saliferous strata, lying unconformably, *a*, *b*, *c*; the Oolitic system, or Lias and Oolite, *d*, *e*; and the Cretaceous system, *f*, *g*.

SALIFEROUS OR NEW RED SANDSTONE SYSTEM.

155. NATURE AND SUBDIVISION OF THE SALIFEROUS SYSTEM.—Beds of compact limestone, containing shells,

separated by deposits of sandstone, clay, and marl, of a red colour, or variegated, and containing vast quantities of salt and gypsum, constitute the saliferous system. In England the strata of this series extend from the mouth of the Tees to Nottingham, then expand so as to cover a great portion of the midland counties, and stretch along the coal basin of South Wales. In Scotland and Ireland the New Red Sandstone occupies much less space. On the Continent of Europe it occurs in patches and large masses over a vast surface, generally occupying low districts in which are dispersed hills and ranges of igneous or older stratified rocks. This series of deposits has been divided into two groups: 1. The Lower New Red Sandstone, *a*; 2. The Upper New Red Sandstone, *c*. The former is composed of the Lower New Red Sandstone properly so called, and the Magnesian Limestone; the latter of the Variegated Sandstone, the Shell Limestone or Muschelkalk, and the Saliferous Sandstones and Marls. Of these the Muschelkalk is wanting in England, but occurs in France and Germany.

156. LOWER NEW RED SANDSTONE.—The strata of this system are generally unconformable to those of the Carboniferous series. Its lowest beds are composed of sandstones, sometimes in the state of conglomerates. The sandstone is fine-grained or coarse, quartzose, often much intermixed with decomposed felspar, sometimes micaceous, and passing into shale. Its colours are red or yellow, it being generally impregnated with oxide of iron. The MAGNESIAN LIMESTONE is sometimes represented by a conglomerate composed of pebbles of older rocks cemented by a limestone containing magnesia. In the north-east of England it is a yellowish limestone, compact and of a dull earthy appearance, or crystalline, and lying upon red marl and gypsum. In the district of Mansfeld in Thuringia, this limestone, named Zechstein, is in the lower part of the deposit compact, of a blackish or ash-grey colour, and contains veins of calcareous spar. In the upper part it represents beds of cellular limestone, magnesian limestone or dolomite, and fetid limestone

with gypsum. It rests upon marly and bituminous slates, sometimes containing copper, sometimes iron-pyrites, together with gypsum and rock-salt.

157. Upper New Red Sandstone.—In England, the Shell Limestone or Muschelkalk being wanting, the Upper Red or Variegated Sandstone passes into the Red Marl, which lies above it, without exhibiting any very distinct line of separation. The Red Sandstone is of various characters, being coarsely granular and friable, or fine-grained, siliceous, and hard, red, brown, yellowish, grey, or spotted and striped with red, green, and grey. It sometimes contains crystals of felspar, and is often intermixed with fragments of the neighbouring rocks. On the Continent the lowest series or Red Sandstone of the Vosges, is quartzose, generally of a brick-red colour, and passes into conglomerate. It is largely developed in Lorraine and Alsace, where it forms a belt around the primary masses of the Vosges, and contains iron, manganese, and galena. Over this are variegated sandstones and marls, containing numerous masses of salt and small deposits of lignite or brown-coal.

The variegated Red Sandstone or Red Marl, is a sandstone with an argillaceous cement, often containing beds of red or variegated marl, and subordinate beds of reddish oolite and dolomite, with clays containing gypsum and salt.

The Muschelkalk or Shell Limestone, is compact, of a smoke-grey colour, and in certain localities contains a great variety of fossils. It is distinguished from the Magnesian Limestone by its never presenting the shells of the genus Productus, which occur in that deposit, and from the Lias by its wanting the Ammonites and Grypheæ which characterize the latter.

The variegated marls, or keuper, are red, greenish-grey, and bluish, and contain subordinate beds of sandstone and dolomite, deposits of brown-coal, masses of gypsum and salt. These marls are covered with a white quartz sandstone, which connect them with the Lias.

158. Rock-Salt and Gypsum.—Although salt and gypsum are not peculiar to the Red Sandstone System, they are more abundant in it than in any other series. The gypsum, which occurs in the marl beds, is fibrous or foliated and massive, and sometimes anhydrous, or destitute of water in its composition. It is in the Upper New Red Sandstone strata that the principal deposits of rock-salt occur. According to Mr. Bakewell, the rock-salt of Cheshire is found in the red marl above the red sandstone, its upper bed being twenty-six yards thick, and separated by a stratum of argillaceous stone ten yards thick, from the lower bed of salt, which has been sunk into forty yards. In another part of that county, three beds of rock-salt have been found, the uppermost four feet, the next twelve feet, the lowest not cut through, although it has been sunk into twenty-five yards. Numerous brine springs, containing more than 25 per cent. of salt, rise in that county. In Worcestershire, the salt is nowhere worked, but is procured by evaporating the water, which is nearly saturated with it. Salt springs rise in some of the coal strata in the neighbourhood of these deposits, and in North America, where rock-salt has not yet been discovered, there are brine springs in the strata above and below the coal in the districts west of the Alleghanies. In France, Switzerland, and Spain, there are also salt springs, and in the latter country, in the District of Cardona, are vast deposits of rock-salt, one of which forms a mountain 663 feet in height, and 1220 feet in breadth at the base. According to M. Brongniart, the most extensive deposits of rock-salt in Europe are in Hungary and Poland. It is also found in the elevated deserts of Caramania in Asia, in Great Tartary, Thibet, and Hindostan. The island of Ormus in the Persian Gulf is said to be composed of Rock-salt. In short, this substance is very extensively distributed. The best kinds consist of muriate of soda or chloride of sodium nearly in a pure state, and has scarcely any water of crystallization. It is usually transparent and whitish, but often tinged red, and sometimes purple or blue. It is supposed

to have been formed by the gradual evaporation of the lakes and pools of salt water, that remained when the ocean retired from the land.

159. Organic Remains.—In the lower new Red Sandstone, fossils are of extremely rare occurrence. Several species of fishes have been found in this part of the series, and in the Magnesian Limestone. The remains of Saurian (Lizard) reptiles have been found in the Zechstein in Germany, and in the analogous dolomitic conglomerate near Bristol. It is in this series that animals of that order first make their appearance.

In the Magnesian Limestone a few Saurian Reptiles, several Fishes, a considerable number of Mollusca, and two or three Corals, have been found; and the fossils of this rock, as well as of the Zechstein, are analogous to those of the Carboniferous series. In a grey quartzose Sandstone, at the village of Hessberg in Saxony, footsteps of a five-toed animal, supposed to be allied to the Marsupialia, have been found by Professor Kaup, and in the New Red Sandstone of Dumfriesshire impressions of the same nature, probably made by Tortoises, have been described by Dr. Duncan. In the shell limestone of the Continent, Encrinites, Crustacea, Mollusca of various genera, and several Sauria, have been met with. The shells of this system are of marine origin, as are most of the other organic remains; and the reptiles and few land plants that occur are chiefly confined to particular districts.

Oolitic System.

160. Strata of the Oolitic System.—In Scotland and Ireland there are but slight appearances of this series of rocks, which in England, on the contrary, is highly developed. "From the prominent parts of the Yorkshire coast, between Redcar and Filey," as stated by Professor Phillips, "it holds an uninterrupted course, with varying breadth, through Yorkshire, Lincolnshire, Northamptonshire, Oxfordshire, Gloucestershire, Somersetshire, and

Dorsetshire, to the southern coast between Exmouth and the Isle of Purbeck, almost every where forming a rather high table-land and dry surface, sloping regularly to the east, and dividing the eastern and western drainage of the island." On the Continent of Europe, also, it is widely extended, and presents characters similar to those exhibited by it in England. This system, which receives its name from the texture of some of its principal members, which are composed of granules resembling the eggs or roe of fishes (ὠόν, an egg, λίθος, stone—oolithic, or oolitic) is formed of strata of limestone intermixed with others of clay in various stages of induration. The formations or series of strata of which it is composed are five: the Lias, Lower Oolite, Middle Oolite, Upper Oolite, and Weald Clay.

161. THE LIAS-FORMATION.—The lower part of the oolitic system is composed of a great mass of dark grey or bluish argillaceous limestone, arranged in thin strata, and connected with beds of clay, of which the lower rest upon, and pass into the New Red Marl. The term LIAS is thought by Mr. Bakewell to have arisen from the "provincial pronunciation of the word 'layers,' as the strata of lias limestone are generally very regular and flat, and can easily be raised in slabs from the quarry." In England this formation generally consists of, 1. LOWER LIAS-CLAYS, passing into red marl; 2. LIAS-LIMESTONE; 3. The MIDDLE LIAS-SHALE; 4. Arenaceous and calcareous layers, or MARL-STONE, with nodules of ironstone; 5. The UPPER LIAS-SHALE. The clays are sometimes soft and friable, but not unfrequently more or less indurated and fissile, forming shales, which being often impregnated with bitumen and iron-pyrites, undergo a slow combustion on being laid in

heaps with faggots and ignited. The sulphur in the pyrites being thus set free, combines partly with the oxygen of the atmosphere, and partly with the alumina of the shale, forming alum or sulphate of alumina; and on this account these clays are named alum-shale. They also frequently contain some proportion of muriate of soda and sulphate of magnesia and soda, and thus sometimes give rise to mineral springs, as at Cheltenham and Gloucester. The limestones are characterized by their earthy texture, large conchoidal fracture, and dark grey or dull bluish-grey colour. Sometimes, however, their colour is yellowish, or even white. This limestone is composed of from eighty to ninety per cent. of carbonate of lime, with bitumen, alumina, and iron, the latter when present in large quantity forming, when the stone is burned, a lime that has the property of setting under water.

162. MINERALS AND FOSSILS OF THE LIAS.—Besides the iron-pyrites already mentioned, there occur in the lias-clays gypsum and calcareous spar. Veins of galena and carbonate of copper, with celestine and heavy spar, are found in the upper parts; and in some districts on the Continent, coal or lignite occurs in sufficient quantity to be worked. In England, fragments of wood and remains of several species of Zamiæ and Coniferæ have been found in the lias; and in remains of animals it is remarkably rich. In consequence of the numerous shells of the genus Gryphæa which it contains, it has sometimes been named the GRYPHITE LIMESTONE. Ammonites, Nautilites, and Belemnites, are also abundant in it, as well as numerous other shells of various genera. Teeth and other remains of fishes also occur, and among them Ichthyodorulites, or large spines, supposed to have formed part of the dorsal fin. But the most remarkable organic remains of the lias are those of reptiles of large size and singular formation, they having been furnished with paddles somewhat similar to those of the cetacea. "Some of the most remarkable of these reptiles," says Professor Buckland, "have been arranged under the

genus Ichthyosaurus, or Fish Lizard, in consequence of the partial resemblance of their vertebræ to those of fishes. If we examine these creatures with a view to their capabilities of locomotion, and the means of offence and defence, which their extraordinary structure afforded to them, we shall find combinations of form and mechanical contrivances, which are now dispersed through various classes and orders of existing animals, but are no longer united in the same genus. Thus, in the same individual, the snout of a Porpoise is combined with the teeth of a Crocodile, the head of a Lizard with the vertebræ of a Fish, and the sternum of an Ornithorhynchus with the paddles of a Whale. The general outline of an Ichthyosaurus must have most nearly resembled the modern Porpoise and Grampus. It had four broad feet, or paddles, and terminated behind in a long and powerful tail. Some of the largest of those reptiles must have exceeded thirty feet in length."

The Ichthyosaurus communis, represented by the accompanying figure, had a head resembling that of a Dolphin, but in essential characters approaching to that of a Lizard; its teeth similar to those of a Crocodile; its eyes of enormous size, and having a series of thin bony plates or sclerotic bones; its vertebræ hollow at each end, as in fishes; its ribs slender, its sternum or breast-bone of a strong and complex structure, its extremities converted into fins. It was an inhabitant of the sea, and fed on fishes as well as animals of its own nature.

Another genus of these Saurian reptiles, named Plesiosaurus, "united to the head of a Lizard the teeth of a Crocodile; a neck of enormous length, resembling the body of a serpent; a trunk and tail having the proportions of an ordinary quadruped, the ribs of a Chameleon, and the paddles of a Whale. The Plesiosauri appear to have lived in shallow

seas and estuaries, and to have breathed air like the Ichthyosauri, and our modern Cetacea." The head of PLESIOSAURUS DOLICHODEIRUS approaches to that of a Lizard, its teeth resemble those of a Crocodile, its neck is of extraordinary length, having about thirty-three vertebræ, the dorsal vertebræ with flat articulating surfaces, the ribs, composed of two pieces, and uniting with those of the opposite side by means of an intermediate bone, and their extremities converted into paddles.

163. LOWER OOLITE.—Above the lias reposes a series of strata of oolitic limestone, clays, and marls, which may be subdivided into four groups, that immediately succeeding the lias being named the Lower Oolite. This series varies in different parts of England, as well as on the Continent; but may here be described as composed of—1. The LOWER or CHELTENHAM OOLITE, consisting of beds of sandstone, sand, and oolite; 2. FULLER'S EARTH, or beds of clay of an unctuous quality; 3. STONESFIELD SLATE, slaty Calcareous Limestone; 4. GREAT OOLITE: oolitic limestone, intermixed with comminuted shells, the upper and lower beds coarser, and called rag-stones; 5. FOREST MARBLE: a coarse laminated shelly oolite, interposed between beds of clay, sand, and grit; 6. CORN-BRASH: a thin bed, composed of hard limestone, generally in detached masses, externally brown, but in the interior of a bluish or grey colour, and remarkable for the great variety of its fossils.

164. MIDDLE OOLITE.—The Middle Oolitic Formation is separated from the lower series by a great deposit of clay,

and consists of coralline and shelly oolitic limestone, calcareous sandstone, and clays. The following are its subdivisions:—

1. OXFORD CLAY, or Clunch Clay, of a dark blue colour, some of the beds bituminous, and abounding in septaria, or masses having internal dissepiments; in its lower part are beds of limestone called KELLOWAY ROCK, often composed of irregular nodules, and sometimes full of shells, among which predominate Ammonites and large Gryphea; 2. CALCAREOUS GRIT or Sandstone; 3. CORAL RAG and Oolite; 4. CALCAREOUS SANDSTONE.

These strata pass into each other, and vary in thickness and composition. The Coral Rag is so named from its containing abundant remains of corals of various kinds; and the Calcareous Sandstones consist of comminuted shells in oolitic limestone. Sometimes the grains are as large as peas, so that this variety has received the name of PISOLITE.

165. UPPER OOLITE.—As between the lower and middle oolites we find interposed a great argillaceous bed named the Oxford Clay, so between the middle and upper limestones of this series intervenes a deposit of a similar nature named KIMMERIDGE CLAY. The series of which the upper oolite consists are the following:—

(1.) The KIMMERIDGE CLAY, of a blue or yellowish-grey colour, more or less slaty or passing into shale, sometimes so impregnated with bitumen as to be used for fuel, and containing remains of saurian reptiles and shells.

(2.) PORTLAND SAND, an intermixture of siliceous and calcareous sand, containing green particles.

(3.) PORTLAND OOLITE, a calcareo-siliceous, more or less oolitic freestone, of a yellowish-white colour, containing nodules of flint in its upper part.

166. MINERALS AND FOSSILS OF THE OOLITIC FORMATIONS.—The Oolitic or Jura Limestone series contains a vast number of fossils of various classes. Remains of an animal considered by many as of the marsupial order and of the opossum kind, have been found in the Stonesfield slate

near Oxford. Reptiles of the saurian or lizard kind, to which are given the names of Ichthyosaurus, Megalosaurus, Plesiosaurus, Teleosaurus, together with Crocodiles, Gavials, and Pterodactyli or winged lizards, are plentiful. Coprolites or petrified fœces of these animals are also found in the midst of their remains. Fishes, Crustacea, very numerous Mollusca, Radiaria, and Zoophytes, the enumeration of which would occupy a large space, also occur. Remains of wood, jet, coal, and cryptogamic plants, as well as Cycadeæ, Zamiæ, and some other genera, are found in various strata, but these remains are not abundant. Calcareous spar, selenite, quartz, and some ores of iron, occur in these formations, the latter sometimes in sufficient quantity to be worked.

167. Economical Uses.—Oolitic iron-ore is worked in various parts of the continent. Lignite, an imperfect kind of coal, has been also sometimes obtained from the lower oolite series. Some of the sandstones are used for building, as are the oolites, which, however, are not generally very durable, and therefore are less adapted for public buildings. Lithographic Limestone belongs to this series, and is obtained in Bavaria and in the Jura range. Some of the strata afford limestone which on being burned yields a lime capable of setting under water; and the calcareous clays are useful as manure or for mixing with the soil. Fuller's earth is employed as a detergent, some of the calcareous strata are so fissile as to be used for roofing slates, and several kinds of marble are obtained from this series.

168. Wealden Formation. — The deposits hitherto spoken of are of marine origin, but in the upper portion of the oolitic system we find organic remains which have been deposited in fresh water. The strata of this formation have by some been referred to the oolitic series, while others have associated them with the chalk which lies immediately above them. They form a series of sandstones and clays, with layers and nodules of limestone.

The lowest part is named Purbeck Limestone, and is composed of fresh-water shells united by a calcareous cement. It is slaty, argillaceous, of a brownish colour, alternates with slaty marl, and sometimes contains beds of compact limestone.

Above this series is the HASTINGS SAND, composed of yellowish grains of sand, very loosely coherent, alternating with beds of clay and conglomerate, containing fragments of bones and scales of fishes. This sand is generally siliceous, of a yellowish or reddish colour, seldom blue, and contains strata of clay, marl, fuller's earth, and ironstone, which presents itself in nodules, and is sometimes worked. The shells and remains of vertebrate animals which occur in this part of the series are of fluviatile origin.

The upper portion of this formation, the WEALD CLAY, is composed of beds of clay, sandstone, calcareous sandstone, conglomerate, limestone, and ironstone. The Weald Clay, which is the principal member of this series, is of a bluish or brownish colour, tenacious, somewhat indurated, and slaty. The limestone is often concretionary, and usually contains fresh-water shells of the genus Paludina. In the whole mass there occur scales of mica, iron-pyrites, crystals of selenite, and traces of lignite.

169. ORGANIC REMAINS OF THE WEALDEN.—As is indicated by the organic remains which it presents, the Wealden Formation is of fresh-water origin. Many of the shells which are found in it are of genera which occur at the present day in rivers, marshes, or lakes, such as Neritina, Paludina, Cyclas, and Unio. Among them, however, are some of marine origin; but the presence of these is not sufficient to deteriorate the evidence afforded by the rest. Fishes of a peculiar character, somewhat resembling the perch, but covered with large rhomboidal, thick, and hard scales, also occur in it; as well as Reptiles of various genera, including Tortoises, Crocodiles, and other Saurians, of which the most remarkable is the IGUANODON, an herbivorous reptile, upwards of seventy feet in length, and having the teeth worn flat as if by the action of bruising or grinding

its food. Some bones of the order of Wading Birds have also been found in it, and are the first of this class that present themselves in the ascending series of strata in Britain. As yet, however, no bones of Mammalia have been observed in the Wealden deposits, of which the vegetable remains are Ferns, Cycadeæ, Coniferæ, and others of lacustrine or terrestrial origin. Between the Purbeck beds, or lower division of the Wealden, and the Portland stone, or upper part of the oolite, there occurs in the Isle of Portland, and elsewhere in Dorsetshire, a layer of dark-coloured matter, from twelve to eighteen inches thick, containing numerous silicified trunks of coniferæ and cycadeæ, of which the roots and a small portion of the trunks are frequently found in their natural position. This "dirt-bed," as it is named by the workmen, is therefore supposed to be the remains of a bed of soil, surmounting the oolite, in which grew a forest, ultimately submerged, and covered with a fresh-water deposit.

Cretaceous System.

170. Extent of the Cretaceous System. — On the Wealden or upper part of the oolitic system, rests the Chalk or Cretaceous System, which derives its name from the remarkable and well-known earthy limestone, generally of a whitish colour, which forms its principal mass. In England, it may be traced from Yorkshire, through the counties of Lincoln, Norfolk, Suffolk, Hertford, Bedford, Buckingham, and Wilts, to Dorsetshire, and from thence through the Isle of Purbeck, and the Isle of Wight. In Scotland, however, it nowhere occurs, and in Ireland is confined to the north-eastern part, where it assumes a peculiar character. In France, it extends from Calais round Paris to the mouth of the Seine. It also occurs in various parts of Germany, Denmark, and Russia. In America, although chalk properly so called is scarcely known, strata like those usually associated with it occur abundantly along the eastern side of the

United States. Great differences in the strata of the Cretaceous system are observed in different localities. In the South of England the series is composed of the followiug members:—1. The Lower Green Sand, of which the upper part is ferruginous; 2. The Gault or Folkstone Marl; 3. The Upper Green Sand and Chalk Marl; 4. The Lower Chalk; and, 5. The Upper Chalk, containing flints. In a more general sense, the Cretaceous system is divided into the Green Sand and the Chalk Formations.

171. Green Sand Formation.—This deposit, which has received its name from the particles of green earth intermixed with it, varies much in its aspect and texture, being sometimes a loose siliceous sand, sometimes a siliceous sandstone cemented by calcareous matter. Its entire thickness amounts to about six hundred feet, and it is divided into the Lower and Upper Green Sands, between which intervene a bed of grey or blue marl, named Gault.

The Lower Green Sand is generally ferruginous in its upper part, so that from the quantity of oxide of iron dispersed through it, it has also been named the Iron Sand.

The Gault or Folkstone Marl, as it is variously named, presents the appearance of ordinary clay or marl of a grey or blue colour.

The Upper Green Sand is similar to the lower, but with less ferruginous matter, and gradually passes into a chalky marl, intermixed with green earth, which may be considered as the lowest bed of the Chalk Formation. It is remarkable for the nodules of siliceous stone which it contains, varying from a whitish chert or hornstone to flint and calcedony.

172. Chalk Formation.—The earthy limestone known by the name of chalk consists of carbonate of lime. Although generally soft and friable, it is sometimes so hard as to be employed for building; and although usually white or yellowish-white, its colour varies to red or brown. It seldom presents a laminated structure, or even the appearance

of strata, although its deposition from water is rendered apparent by the parallel layers of flint nodules which generally occupy its upper part. These nodules or irregular masses of siliceous matter vary in colour from black or brown, yellow, and grey, to white, and frequently contain organic remains, such as Echini, shells, and other marine bodies. They are supposed to have been formed by the aggregation of the siliceous particles originally deposited along with the chalk. Sometimes also the flint occurs in flattened pieces, forming beds of great extent. Three principal beds occur in this formation:—The Chalk Marl, or lowest, containing green particles; The Middle Chalk, of a greyish colour intermixed with sand, and containing whitish chert; and the Upper Chalk, of a white colour, and containing nodules of flint.

173. Fossils of the Cretaceous System.—All the beds of this series contain organic remains, too numerous to be in any degree described here. In the chalk very few vegetable remains have been met with, and these chiefly supposed to be Fuci. It contains Corals, Sponges, Radiated animals, and multitudes of bivalve and univalve Shells of numerous genera, with a few Cirrhipeda, some Crustacea, numerous teeth, palates, and scales of Fishes, and some remains of Saurian Reptiles, none of which are identical with species found alive at the present day. With the exception of some ferns and remains of dicotyledonous plants, the organic bodies found in the chalk formation are of marine origin. In the Green Sand series, remains of Ferns, Cycadeæ, and Fuci, are met with. Its organic remains of the animal kingdom are generally similar to those of the chalk.

174. Uses in the Arts.—The clays of the Green Sand series are employed in the manufacture of bricks and pottery, and the sandstones are sometimes used for building. In some parts of the Continent lignite is worked for fuel. The siliceous nodules which are so abundant in the upper or white chalk, furnish, on being split and chipped, the

flints used for gun-locks. Chalk itself is used for many purposes, being employed as a crayon, a limestone, and when sufficiently hard, as a building stone. The marls and soft chalks are also used by farmers as manure.

Having thus given a brief account of the series of upper secondary Rocks, including the Saliferous, Oolitic, and Cretaceous systems, some general remarks may be offered, having reference to their stratification and the igneous rocks by which they are traversed.

175. General Remarks on the Upper Secondary Rocks.—The irregular surface formed by the dislocation of the carboniferous strata was partially covered by the New Red Sandstone deposits, which appear to have been formed in a comparatively short time. This epoch has been characterized on the Continent by a great predominance of igneous rocks, chiefly of Red Porphyry; but in Britain this is less apparent, and the disturbances which it presents are very unimportant. The different members of the Oolitic System being conformable, and containing marine organic remains, have been deposited at the bottom of the sea or of estuaries, and have been subjected to an elevating force, which in various parts has alternately ceased its action. The Chalk Formation seems to have been deposited in a sea of considerable depth, and this substance is supposed to have been derived from the decomposition of corals and shells, the particles of which have been scattered by the currents. Trap-rocks of various kinds intersect all these deposits; but in England none are found in connection with those of the Cretaceous system. In Ireland, however, the chalk is traversed and covered by Basalt and Greenstone. Even Granite, it is alleged, has been found on the Continent overlying chalk.

176. Surface of the Secondary Deposits.—The character of the scenery which these deposits present is various. According to M. Rozet, the Greywacké mountains of the Ardennes are usually terminated by platforms of large extent, and present highly inclined flanks, with narrow val-

leys. In Britain the hills of this series are rounded, and present no bold features. The Coal-Formation sometimes occupies spaces of great extent, having the form of oblong basins, contained between mountains composed of older rocks. When occupying open spaces of great extent it presents an undulated surface. The New Red Sandstone Formation presents elevated platforms, intersected by deep and narrow valleys, on the flanks of which the strata are seen to correspond. The Lias usually occupies wide valleys or plains, but often also constitutes mountain-masses, presenting large inclined platforms, terminated by an escarpment in which the inferior deposits may be seen. The Oolitic series presents long slopes and rounded or gently undulated surfaces; and the Chalk formation has its eminences flat or rounded.

RECAPITULATION.

154. What are the upper Secondary Rocks?—155. Into what groups is the new Red Sandstone system divided?—156. Describe the Lower New Red Sandstone, and the Magnesian Limestone.—157. What is the nature of the Upper New Red Sandstone? and of the Red Marl, and Shell Limestone?—158. What minerals occur abundantly in this formation? Where is rock-salt found in greatest quantity? How are brine springs formed?—159. What organic remains are found in the New Red Sandstone? What vertebrate animals first make their appearance in it? Are the fossils of this series analogous to those of the Coal-Formation?—160. From what circumstances does the Oolitic System derive its name? Of what formations is it composed? How is alum obtained?—161. What are the characters of the Lias Limestone?—162. What minerals occur in the Lias? What are the most remarkable of its fossils? Give some account of the Ichthyosaurus. What are the principal characters of Plesiosaurus?—163. What formation lies over the

Lias? Mention the six members of which it is composed.—164. Give a short account of the Middle Oolite.—165. Of what series is the Upper Oolite composed?—166. Have the remains of any mammiferous animals been found in the Oolitic formations? Are reptiles abundant in them? What other animals occur there?—167. To what economical uses are the members of this series applied?—168. What is the uppermost series of the Oolitic System named? What is the nature of Purbeck Limestone? What sand lies over it? Describe the Weald Clay.—169. Are the organic remains that occur in it of marine origin? Of what nature is the Iguanodon?—170. What is meant by the Cretaceous system? Into how many parts is it divided?—171. Describe the Green Sand.—172. What are the principal characters of the Chalk Formation? How are flints disposed in it?—173. Mention some of its fossils.—174. Is it applied to any economical uses?—175. What igneous rocks characterize the New Red Sandstone? Whence has the chalk been derived?—176. What varieties are exhibited by the surface of the Secondary Deposits?

CHAPTER VIII.

OF THE TERTIARY ROCKS.

RELATIONS AND NATURE OF THE TERTIARY ROCKS.—TERTIARY DEPOSITS IN THE NEIGHBOURHOOD OF PARIS.—TERTIARY DEPOSITS IN ENGLAND.—ORGANIC REMAINS.—IGNEOUS ROCKS.—GENERAL REMARKS.

177. Relations of the Tertiary Strata.—Having obtained a general idea of the series of strata intervening between Granite and the upper limit of those stratified rocks

in which no organic remains have been found, and again between that limit and the upper boundary of the Chalk Formation, we now enter upon the consideration of an order of deposits in which we begin to perceive a more evident relation to the presently existing system of nature than has hitherto been seen. The gradual elevation of the strata from the depths of the ocean, in which they were deposited, has been apparent, continually reducing the limits of the newer formations, which have, as it were, receded within each other, until the Chalk, the uppermost of the series, occupies the least extent, and is margined by the Upper Oolite, which in its turn is girdled by the other Oolites and the Lias. From the Carboniferous series to the Chalk, the strata have been in a general sense conformable ; and considering the deposit just mentioned as the basis of those which are now to engage our attention, we find that they too are for the most part conformed to it. But there is no decided alternation of the chalk with the tertiary strata, and almost everywhere the organic remains of the two series are entirely different. For this reason, the series of secondary rocks is understood to end with the Chalk, and those which succeed form a distinct class, named the TERTIARY, being the third in order, as we proceed upwards. These strata usually occupy basins or hollows on the surface of the chalk formation.

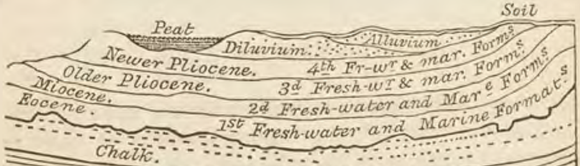


Fig. 38

178. NATURE OF THE TERTIARY STRATA.—Indications of an alternation of fresh-water and marine formations have occasionally appeared in the secondary series, without, however, being decided or extensive ; but in the new series alter-

nations of this kind are abundantly evident. To produce the tertiary strata, there must therefore have been alternate depositions from the sea and from fresh water, such as may be supposed to have taken place in a basin or estuary, at one time filled with fresh water, and at another overwhelmed by the ocean. The strata thus formed consist of sand, mud, and limestone, containing myriads of organic remains of all classes. These deposits had long been overlooked, or only submitted to a very superficial inspection, until those which occur in the neighbourhood of Paris, forming the most complete series hitherto observed, were minutely examined by Cuvier and Brongniart, who, in 1811, published the results of their labours in a work entitled, An Essay on the Mineralogical Geography of the Neighbourhood of Paris. As the Paris basin affords a better specimen of the tertiary series than that of London, we may first direct our attention to it. But these strata are not confined to the two localities mentioned, being, on the contrary, found in some degree of development in most parts of the globe, always, however, in spaces of limited extent.

179. ARRANGEMENT OF THE TERTIARY STRATA.—As will be seen from Fig. 38, the strata of the Tertiary Series have by some geologists been arranged under four formations, each containing a marine and a fresh-water deposit. The abundance and variety of organic remains that occur in the tertiary strata have suggested the idea, that the relative ages of strata may be determined by the species of shells which they contain. M. Deshayes, on this principle, institutes two divisions among the fossiliferous rocks, referring to the first those of which the shells are different from those of the present day, and to the second those in which species identical with living shells occur. To the first division belong the Secondary, to the second the Tertiary Rocks. On this basis Mr. Lyell has founded an arrangement of the latter series. M. Deshayes having been requested, says that geologist, to draw up, "in a tabular form, lists of all the shells known to him to occur, both in some tertiary forma-

tion and in a living state, for the express purpose of ascertaining the proportional number of fossil species identical with the recent which characterized the successive groups; this table was published by me in 1833. The number of tertiary fossil shells examined by M. Deshayes was about 3000; and the recent species with which they had been compared, about 5000. The result at which that naturalist arrived was, that in the oldest tertiary deposits, such as those found near London and Paris, there were about 3½ per cent. of species of fossil shells identical with recent species; in the next, or middle tertiary period, to which certain strata on the Loire and Gironde, in France, belonged, about 17 per cent.; and in the deposits of a third, or newer era, embracing those of the sub-Appenine hills, from 35 to 50 per cent. In formations still more modern, some of which I have particularly studied in Sicily, where they attain a vast thickness and elevation above the sea, the number of species identical with those now living was from 90 to 95 per cent. For the sake of clearness and brevity, I propose to give short technical names to these four groups, or the periods to which they respectively belong. I called the first or oldest of them EOCENE, the second MIOCENE, the third OLDER PLIOCENE, and the last or fourth NEWER PLIOCENE. The first of the above terms, Eocene, is derived from ηως, eos, drawn, and καινος, cainos, recent, because the fossil shells of this period contain an extremely small proportion of living species, which may be looked upon as indicating the dawn of the recent or existing state of the testaceous fauna. The other terms, Miocene and Pliocene, are comparative; the first meaning less recent (from μειον, meion, less, and καινος, cainos, recent), and the other more recent (from πλειον, more, and καινος, cainos, recent); they express the more or less near approach which the deposits of these eras, when contrasted with each other, make to the existing creation, at least so far as the Mollusca are concerned." Very different opinions, however, are entertained as to the proportion of shells in these strata; and in the remaining part of this chapter I shall follow Daubuisson, who institutes purely geognostical subdivisions, arranging the tertiary strata into Lower and Upper.

TERTIARY DEPOSITS IN THE NEIGHBOURHOOD OF PARIS.

180. Lower Tertiary Formation.—In the neighbourhood of Paris, the lower tertiary formation is composed of two distinct stages: the Plastic Clay and Coarse Limestone.

(1.) The Plastic Clay, which rests on chalk, is a nearly pure, highly unctuous, tenacious, infusible clay, often of a dark grey colour, or veined with red and yellow, and employed in the manufacture of pottery and bricks. It contains lignites and numerous vegetable remains; pyrites, resinous nodules, crystals of selenite, and siliceous or calcareous fragments, together with fresh-water and marine shells, which are found intermixed in the uppermost layers. This, stage is usually subdivided into two members. The upper, known by the name of Fausses Glaises, is sandy, of a dark colour, often carbonaceous, and separated from the other by a small bed of fine grey sand. The lower bed is of pure clay, seldom containing minerals or remains of organized bodies. The carbonized vegetables of the upper bed, or fausses glaises, are sometimes so abundant as to form layers of lignite.

(2.) The Coarse Limestone, or Calcaire grossier, which is composed of limestones characterized by a prodigious quantity of marine shells, alternating with clayey marls and calcareous marls, succeeds the plastic clay. The limestones of the lower bed are often sandy, and are sometimes separated from the plastic clay by a stratum of sand. They abound in shells, and are of a coarse texture, interspersed with grains of a deep green colour, resembling those of the green sand. The shells are remarkably well preserved, many of them still retaining their pearly lustre. They belong to the genera Nummulites, Lucina, Bucardium, Crassatella, Turritella, and

Cerithium, a species of the latter, Cerithium giganteum, being characteristic of this deposit. The next bed is composed of strata of yellowish limestone, of varying solidity, full of shells, and rarely containing grains of chlorite. There is seen in it a layer of a greenish colour, having in its lower part brown impressions of stems and leaves of terrestrial plants, mingled with marine shells. The upper bed of the Calcaire grossier commences with the most solid layers, which are worked for building; but as we ascend, we find the strata becoming thinner, and alternating with argillaceous and calcareous marls. The rock then passes into a hard, compact limestone, in thin beds, sometimes homogeneous, like lithographic limestone, and sometimes full of shells. Hornstone and sandy quartz frequently occur among these hard limestones; but at other times the upper layers are many, and contain crystals of gypsum.

181. UPPER TERTIARY FORMATION OF PARIS —The succession of deposits which belong to the Upper Tertiary Formation in the neighbourhood of Paris, is subdivided into at least four geognostical stages: the Siliceous Limestone, entirely of fresh-water origin; the Gypseous Deposit, of which the lower part is of fresh-water origin, while the upper is marine; the Marine Sands and Sandstones; and, lastly, the Fresh-water Millstones and Marls. To these may be added the marine faluns of Touraine and the Loire.

(1.) The SILICEOUS LIMESTONE is composed of alternations of fine-grained white limestone, and yellowish-white, compact, hard limestone, intimately mixed with a large proportion of siliceous matter. The latter variety is often cavernous, and contains fresh-water shells. The siliceous limestone rests upon the Calcaire grossier, but is principally developed where the latter is thinnest, so that the thickness of the two is in inverse ratio. It presents alternating layers of clay and marl, and contains flints, menilites, plates of gypsum, shells, and sometimes bones of mammalia.

(2.) The GYPSEOUS DEPOSIT consists of alternate layers of gypsum and argillaceous or calcareous marl. There are two very distinct beds; the Gypseous Deposit, properly so called, characterized by its gypsum and the remains of land animals; and the Upper Deposit, exclusively composed of marls and containing marine shells. The gypseous deposit is itself divided into two masses. The lower is composed of numerous alternations of marls, and thin layers of granular or crystalline gypsum. The marls are either calcareous and solid, or argillaceous and laminated. The former often contain large yellow lenticular crystals of selenite, and the latter sometimes present siliceous tubercles, known by the name of menilite. This first gypseous mass contains skeletons of fishes. The upper division of the gypsum is of great thickness, and contains but few beds of marl. The gypsum is sometimes finely granular, sometimes composed of small lenticular crystals cohering confusedly. The first layers often present siliceous infiltrations, sometimes concentrated into masses, sometimes in small alternating layers, so that in the quarries are seen blocks having successive bands of opaque yellowish-white flint, and gypsum. The intermediate beds are the largest. The gypsum is in them in some measure massive, and often divided into large irregular prisms. Lastly, the higher beds are thin, and penetrated by marls, with which they alternate. The marls at length separate, and then calcareous and argillaceous alternations form a mass of greater or less thickness above the gypsum. The upper mass or bed of the gypsum contains a vast quantity of bones of quadrupeds, remains of birds, crocodiles, land and fresh-water tortoises, and several genera of fishes. The mammalia, which have been rendered so celebrated by the researches of Cuvier, are especially characteristic of it. Above the white marls containing fresh-water shells, are coloured marls destitute of shells, which lead to a bed of a yellowish laminated marl, belonging to the upper division of the gypsum. Its lower part contains nodules of sulphate of strontian, and above a thin bed of bivalve marine shells. It serves as a limit between the fresh-water marls and the marine marls ; for all the shells that are found above it are marine. These marls are sometimes green and clayey, sometimes yellowish, or whitish and calcareous. In the latter are found beds of oysters, cohering in the same manner as we see them in our own seas, and consequently in the position in which they have lived. The uppermost part is composed of a mass of clayey sand, without shells.

(3.) THE UPPER SANDS AND SANDSTONES, characterized by marine shells, are of great extent. In the lower part of this series are very frequently found finely micaceous sands of a yellowish or reddish colour, which afterwards pass into a white and very pure sand, used for the manufacture of glass. After this sand come the sandstones of the upper part of the series, which are sometimes very hard, sometimes sandy and granular. The upper part of these beds of sandstone is sometimes impregnated with limestone, especially when they are covered by the upper fresh-water limestone. The beds are very thick and irregularly stratified ; the lower sandy strata frequently mixed with hydroxide of iron, clay, and mica, and containing some rolled shells. The upper part, sometimes in the state of pure, friable, reddish sandstone, sometimes argillaceous and reddish, or calcareo-siliceous, contains numerous marine shells, of the genera Cerithium, Melania, Pectunculus, Cytherea, and others. These marine sands and sandstones vary little in their characters. The latter often appear in the form of enormous blocks, with rounded and tubercular surfaces, and sometimes present cavities filled with sand, in which are found groups of rhombohedral crystals of the same nature.

(4.) THE UPPER MILLSTONES AND MARLS.—The upper stage is composed of millstones and clayey ferruginous sands, alternating with greenish, reddish, or whitish marls. The reddish cavernous millstones are the most common, but the whitish or bluish varieties are the most esteemed. They contain no organic bodies, and present themselves in very irregular blocks. Above them is frequently nothing but soil or alluvium ; but sometimes there are marls and limestones, containing fresh-water shells and other remains of organic bodies not of marine origin, as well as flints and buhr-stones or millstones of a more compact texture than those of the lower part. The upper fresh-water limestone, characterized by Lymneæ, Helices, and fossil seeds of Chara, is white or greyish-white, sometimes friable like marl or chalk, sometimes compact and solid.

TERTIARY DEPOSITS IN ENGLAND.

182. Extent of Tertiary deposits in Britain.—In Scotland and Ireland no deposits strictly analogous to those above described have been met with; nor do any occur in Wales. The portions of England in which they are observed are the eastern part of Norfolk, the valley of the Thames, and the southern parts of Dorsetshire and Hampshire; but in that space they are not continuous, and the principal deposits are confined to the London and Hampshire basins. A complete series of the English strata, however, does not occur in any particular locality, so that to present a continuous view of them, those of different places must be brought together. It is also difficult to determine the identity of a tertiary bed in one country with that of another; for in all the localities great differences exist, and the stratum which in one contains marine shells, may in another present fresh-water remains.

183. Arrangement of English Tertiary Strata.—The marine tertiary deposits of the south of England may be arranged under three heads; the Lower, Middle, and Upper.

(1.) The Lower, or Plastic Clays and Sands.—Mr. Webster describes this series, as examined at Alum Bay in the Isle of Wight, as succeeding chalk, nearly in a vertical position. Next to the chalk is a bed of calcareous marl. Strata of sand, of green, red, and yellow colours, and sixty feet in thickness, follow; then a dark blue clay, two hundred feet thick, containing green sand and septaria, or balls of imperfect ironstone, intersected by calcareous spar; sands of various colours, upwards of three hundred feet thick; pipe-clays, and sands exhibiting a variety of bright colours, and nearly five hundred and fifty feet in thickness. In the London basin, the plastic clays and sands are generally similar, but less distinctly marked and variable in thickness. Lignites, some marine shells, and rolled flints, occur in these deposits.

(2.) The Middle, or London Clay, which is most highly developed in the valley of the Thames, where it varies from one hundred to seven hundred feet in thickness, is a mass of clay of a dull blue or blackish-brown colour, sometimes considerably indurated, so as to have a laminated structure. It rests on thin beds of green sand and clay belonging to the inferior deposit, and its uppermost bed is more sandy, and of a reddish-brown colour. Some beds of limestone, septaria, and shells occur in it, as well as branches of trees perforated by a boring molluscous animal named Teredo navalis, remains of turtles and crocodiles, teeth of elephants, and numerous species of bivalve and univalve shells.

(3.) The Upper, or Crag Formation.—This is not superincumbent on the preceding, but occurs detached in Norfolk, Suffolk, and Essex, and is composed of beds of sand and gravel, containing shells. At Brammerton, near Norwich, it is, according to Mr. Bakewell, forty-five feet thick, and consists of a bed of sand and clay with shells, resting on chalk, and fifteen feet thick, four feet of coarse white sand, fifteen of yellow and red sand, a foot and a half of pebbles and shells, two beds, each of the same thickness, one of white sand and shells, the other of ferruginous sand, four feet of loamy earth, and two of vegetable soil. The shells are marine, those in the lower part unlike the species at present alive, but a large proportion of those of the upper identical with species living in the neighbouring sea. This Crag is supposed by some to be merely a portion of the bed and shore of the present German Ocean elevated.

184. General Remarks.—It is unnecessary for our pre-

sent purpose to treat more particularly of the Tertiary deposits, which, although widely extended, are not continuous over vast spaces, like the secondary strata, but present themselves in basins of limited extent. In these different basins, there is generally little accordance in the strata, so that it becomes impossible to determine from their mineralogical characters the analogous or contemporaneous deposits. The numerical proportions of the marine shells have, however, as already mentioned, been considered as indicating this relationship, and have given rise to the distinction of the Tertiary strata into EOCENE, or those containing few species identical with those of our present seas; MIOCENE, or those of intermediate nature; and PLIOCENE, or those containing a very large proportion. Many genera of shells disappear with the chalk formation, and with the tertiary strata a new order of things appears to have commenced, the series of organic beings being continuous with that at present in existence, although many species have become extinct. Between the tertiary and alluvial strata there seems, in fact, to be no marked distinction.

185. FOSSILS OF THE TERTIARY SERIES.—The shells, whether of marine or fresh-water origin, that occur so abundantly in the Tertiary deposits, are generally found in a high state of preservation. All the genera, and many of the species, are the same as those at present living; and the latter are more numerous in proportion to the comparative newness of the strata. All the classes of animals have representatives in these deposits: there being found in them Corals, Mollusca, Crustacea, Reptiles, Fishes, and Birds. Many extinct tribes of Quadrupeds, as Palæotheria, Ano-

plotheria, Mastodons, and Lophiodons, are discovered in them, together with numerous species belonging to genera still in existence, as Elephas, Hippopotamus, Rhinoceros, Equus, Cervus, Lupus, Canis, Ursus, Felis, &c. The accompanying figures represent the Palæotherium magnum, and Anoplotherium commune, animals allied to the Tapir and Horse. The latter having a long thick tail, resembling that of an otter, is supposed to have been amphibious. These remains are accompanied with a great quantity of vegetables, of which the species are extinct, but which belong to genera still living. It has been shewn by M. Adolphe Brongniart, that the vegetation of this period bore a great resemblance to that of the present day. "The Dicotyledonous plants," he says, "are from four to five times more numerous than the Monocotyledonous. As to the other classes, particular circumstances appear to have diminished their number. Thus we find but few ferns, equiseta, and mosses, and the agamic plants are only represented by some species of sea-weeds." Hitherto we have found no traces of man in the strata, and, therefore, it is probable that he was not created at the times when they were deposited. Of late years, however, there have been found in some caves in the south of France human bones, and even fragments of pottery, mingled with fossils belonging to species now extinct. This has induced some geologists to think that man was contemporaneous with these antediluvian animals, and that the catastrophe which destroyed them was the great deluge recorded in the Scriptures, and of which there are traditions among all nations; but it is not generally admitted that the human bones really belong to the same epoch as those of the mastodons and bears which occur along with them.

186. General Remarks.—The unstratified rocks found in this series are chiefly trachytes and basalts, which closely resemble the products of volcanoes, at present in action, and exhibit similar phenomena, insomuch that, in some places these ancient deposits are blended with those of modern times. In the tertiary deposits of England and the north of

France, however, none of these igneous rocks have been met with.

Although the commencement of the Tertiary series is defined by the chalk formation, its termination seems to have no definite characters, by which we might determine the origin of the presently-forming deposits, which, on the contrary, seem continuous with the Tertiary.

Recapitulation.

177. What position is occupied by the Tertiary Strata? Are their organic remains different from those of the Secondary Rocks?—178. Of what nature are the Tertiary deposits?—179. Give an account of Mr. Lyell's arrangement of them.—180. Into how many formations may the Paris Tertiary Strata be divided? What are the divisions of the Lower Formation? Give an account of the Plastic Clay. Describe the Calcaire grossier.—181. What are the stages of the Upper Tertiary Formation? Give an account of the Siliceous Limestone. Describe the Gypseous Deposit. What are the characters of the upper marine sands and sandstones? What is the nature of Buhr-stone, and what strata are associated with it?—182. In what districts do Tertiary rocks occur in Britain?—183. Describe the Lower series, or Plastic Clays and Sands. Give an account of the London Clay. Of what nature is the Crag or upper marine formation?—184. Are the Tertiary deposits continuous over vast spaces? Are the strata similar in different localities? Do all the genera of shells that occur in the Secondary Rocks reappear in the Tertiary?—185. Are the species of shells in the Tertiary deposits identical with those at present living? What other animal remains occur in them? What was the nature of the vegetation? Have any remains of the human species been found in the Secondary or Tertiary strata?—186. What igneous rocks are connected with the latter?

CHAPTER IX.

OF THE ALLUVIAL OR RECENT STRATA.

NATURE OF THE RECENT STRATA.—ALLUVIAL, CONCRETIONARY, CORALLINE, AND VEGETABLE DEPOSITS.

187. NATURE OF THE RECENT STRATA.—Under the head of Recent or Alluvial Strata, are to be included all those deposits which have resulted from the action of the elements, or from the progress of vegetation, in the course of the period which has commenced after the deposition of the tertiary strata, and has continued to the present day. In this series, however, are not included the products of volcanoes. Since the period of the Deluge, it does not appear that any of those great convulsions, of which we have seen indications in the disruption and disturbance of the various formations, have occurred, although the agency of volcanoes and earthquakes has produced analogous effects in a slight degree. In the strata of recent formation we have thus to consider deposits of a more peaceful era, during which man has resided on the earth. They may be arranged under four heads: Alluvial Deposits, Concretionary Deposits, Coralline Deposits, Vegetable Deposits.

188. ALLUVIAL DEPOSITS.—To this genus belong depositions of mud, sand, gravel, and other substances.

By many authors alluvial deposits are divided into two kinds: Old Alluvium, or Diluvium, and Recent Alluvium. The former, which is now generally referred to the tertiary series, consists of clay, sand, gravel, pebbles, and large rolled stones, extended over plains, platforms, and the sides of mountains. They fill up the bottom of valleys, caves, and fissures of rocks; and often contain remains of animals, which more or less resemble those living at the present day. Bones and teeth of Elephants, Mastodons, Rhinoceroses, Tapirs, and Horses; as well as of large ruminating animals, oxen, deer, and antelopes; and of predaceous species, as tigers, bears, and hyenas, are frequently found in them. In Siberia, there have been found in deposits of this nature now covered with ice, entire elephants of an extinct species, on which the flesh, and even the skin and hair, remained. In many caverns in different parts of the globe are found deposits of mud, intermixed with bones of carnivorous and ruminating animals. Some of these are supposed to have afforded places of retreat to bears and hyenas, which dragged into their dens the bones of oxen and other herbivorous species, portions of which are found as if they had been gnawed.

The Recent Alluvia are deposits of the same nature, but such as are produced by causes now in operation. They comprehend the gravel, sand, and mud of rivers, lakes, and the sea, together with all sorts of detritus produced on the land by the action of the elements, including moraines, or deposits of detritus carried down from alpine valleys by glaciers. By means of the great rivers, such as the Mississippi and the Nile, vast quantities of sand and mud are carried down from the interior of the continents, and deposited in their course, but especially towards their mouth, so that not only is the soil there elevated, and the river gradually raised, but large accessions are made to the land on the coast. On many parts of the sea-shore, vast quantities of fine sand are seen, which, being heaped up by the surf, are dispersed by the winds, and form hillocks, or overwhelm the adjacent lands. Deposits are also forming at the bottom of the sea, and along the coasts. It is a very remarkable fact, ascertained by various accurate observers, that the bottom of the sea in many parts has been elevated within historical times, so that large tracts have emerged along the shores. Ancient sea-beaches have also been elevated to a great height beyond the reach of the present tides.

189. Concretionary Deposits.—Under this head are included calcareous and other depositions from springs, sta-

lactites, travertines, bog iron-ore, and salt. Calcareous Tufas are formed by water charged with carbonate of lime, which is gradually deposited. Stalactites are produced in somewhat the same manner in caverns. Bog Iron-ore is deposited from water which has traversed strata highly impregnated with iron. Salt and natron are produced by the evaporation of lakes, or deposited on the surface of sandy deserts. Sometimes the sands on the sea-shore are converted into solid masses of sandstone by means of some agglutinating substance. Of this kind are the maritime deposits of Guadaloupe, so celebrated for containing human bones, along with various implements.

190. Coralline Deposits.—By the gradual increase of myriads of marine polypi in warm climates, and the secretion or deposition by them of calcareous matter, there are formed in the sea vast banks, shoals, and islands, entirely composed of corals. These islands generally form circular reefs, having a lagoon in the centre, which is gradually filled up. The action of the waves heaps up fragments and sand, seeds of plants are wafted to these reefs, floating timber is drifted upon them, and in the course of time they are clothed with vegetation, and become the abodes of human beings.

191. Vegetable Deposits.—A general layer of Soil occupies the surface of the globe, covering the antecedent deposits, although not continuously. Its composition is extremely variable, but in a general sense it may be said to be formed of sand, gravel, or clay, intermixed with ferruginous matter, and more or less of decomposed vegetable substances. In marshy places and in thick woods, in warm climates especially, a layer of vegetable matter of great thickness is formed; and in colder countries, the imperfect decomposition of carices, rushes, heath, moss, and other plants, forms accumulations of a more or less spongy or compact, combustible substance, named peat. In this peat are often found portions of decayed trees, but it is not generally, as some have alleged, formed of them alone. Professor Jameson

has given a very good description of these deposits, in his Mineralogy of the Shetland Islands. "In describing the general appearance of a peat moor, we may conceive an almost entire flat of several miles extent, of a brown colour, here and there marked with tufts of heather, which have taken root, owing to the more complete decomposition of the surface peat; no tree or shrub is to be seen; not a spot of grass to relieve the eye, in wandering over this dreary scene. A nearer examination discovers a wet spongy surface, passable only in the driest seasons, or when all nature is locked in frost. The surface is frequently covered with a slimy black-coloured substance, which is the peat-earth so mixed with water, as to render the moor only passable by leaping from one tuft of heather to another. Peat is found in various situations, often in valleys or plains, where it forms very extensive deep beds, from three to forty feet deep, as those in Aberdeenshire: it also occurs upon the sides of mountains, but even there it is generally in a horizontal situation. The tops of mountains, upwards of two thousand feet high, in the Highlands of Scotland, are covered with peat of an excellent kind." To the head of vegetable deposits may also be referred the drift-wood carried down by rivers, and accumulating at their mouth.

192. General Remarks.—The igneous rocks which occur in the alluvial deposits, belong entirely to volcanoes, recently or at present in action, and will be spoken of elsewhere. The organic remains belong partly to species still in existence, and partly to extinct animals. Of the latter may be mentioned the Mammoth or Great Elephant, two Mastodons, a Hippopotamus, the Great Stag, a species of Ox, a Beaver, Hyæna, Tiger, and Dog. In the lacustrine deposits are shells of the same species as inhabit similar localities at present, and the same is to be said of the littoral deposits. Having thus obtained a general view of the entire series of Stratified Rocks, we have now to examine the Unstratified or Igneous.

Recapitulation.

183. What is meant by Recent or Alluvial Deposits? How may they be arranged?—184. Of what nature are alluvial deposits? What remains of animals have been found in them? What organic remains have been observed in the mud of caverns? What is the difference between the older and recent alluvia? Mention examples of the latter.—185. What is meant by concretionary deposits?—186. How are coral deposits formed?—187. What vegetable deposits appear at the surface? Give an account of a peat moor.—188. What igneous rocks occur among alluvial deposits? Do any of the organic remains belong to species still in existence?

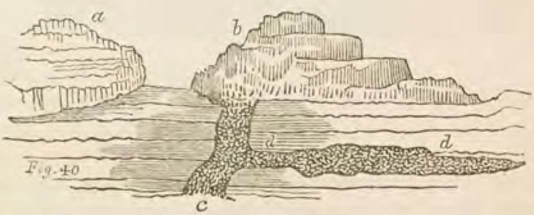
CHAPTER X.

OF THE MASSIVE, UNSTRATIFIED, OR OVERLYING ROCKS.

GENERAL CHARACTERS OF TRAP ROCKS, THEIR STRUCTURE AND CLASSIFICATION.—CLAYSTONE AND FELSPAR SERIES, PORPHYRIES, AMYGDALOIDS, BASALT, GREENSTONE, AUGITE ROCK, HYPERSTHENE ROCK, SYENITE, GRANITIC MIXTURES, JASPER, TRAP CONGLOMERATE.—GENERAL REMARKS.

193. General Characters of Overlying Rocks.—Many of the rocks usually termed Plutonic, Igneous, Trap, or Overlying, are so intimately related to granite, as scarcely to be distinguished from it, while others as obviously pass into lava and other products of active volcanoes. The phe-

nomena which they present, their relations to the stratified rocks and to each other, the alterations produced by their contiguity with other deposits, and their gradual transition into each other, assign to them a similarity of origin, and indicate their igneous nature. Perhaps too much importance has been attributed to the differences which they present in their mineralogical character, and the number of species into which they have been divided may be unnecessarily great; but still, it is neither uninteresting nor useless to distinguish their gradations. As a whole, the trap rocks are generally distributed, but their varieties are confined to particular spots. Sometimes they form mountains of great height, or hills of less elevation, or merely summits unconnected with the subjacent rock otherwise than by contiguity. Such masses are usually amorphous or columnar, but sometimes they present indications of stratification. Frequently they form veins and dykes, which intersect the stratified rocks, and may sometimes be traced to amorphous masses. They are found in contact with all the rocks, from granite upwards. In granite they occur only in veins; but in the stratified rocks they present not only veins, but masses, often stratiform, intruded among the strata, or surmounting them. It is supposed, that the great mass from which these veins and masses have emanated lies beneath the granite, and therefore, although portions of them overlie the secondary rocks, they might with more propriety be named Underlying or Plutonic.



The accompanying figure represents two masses of trap exposed at the surface, *a*, *b*; *c* is a vein or dyke from which has emanated an interjected mass, *d*, as well as the incumbent mass, *b*.

194. STRUCTURE OF TRAP ROCKS.—The rocks of this class present many of the modifications of texture described in § 101. Thus, they may be compact, granular, crystalline, laminar, porphyritic, amygdaloidal, fragmentary, or conglomerated. In their structure they may be massive, tabular, or prismatic. The latter kind of structure is very common among them, and frequently presents itself in the most perfect form, or in that of columns, having three, four, five, or more sides. The columns are often vertical, and at right angles to the imperfect seams of the mass, but they are also occasionally curved, or confused. Very frequently the masses are amorphous; but it seldom happens that more or less parallel seams or fissures, resembling in some degree those of stratified rocks, are not observed. The simple minerals which enter into the composition of these rocks have already been described. The most common are felspar, hornblende, augite, hypersthene, mica, and quartz.

195. CLASSIFICATION OF TRAP ROCKS.—Many authors arrange the rocks of this series in chronological order, according to the strata in connexion with which they appear; and were particular species of trap rocks invariably connected with particular formations of stratified rocks, this arrangement would perhaps be the best; but as the same trap rock traverses many of the secondary and primary series,

and besides often presents great variations in structure and composition in the same mass, it appears better to describe them in a manner which may render their kinds or variations intelligible to the student. We may thus begin with the more simple.

196. WACKE', INDURATED CLAY, CLAYSTONE, CLINKSTONE, COMPACT FELSPAR, HORNSTONE, PITCHSTONE.— These substances appear to form a series rendered continuous by their gradual transition into each other.

WACKE' resembles hardened clay, of a greyish or yellowish colour, with an earthy, smoothish, even fracture, and shining streak. It is generally compact, but may contain crystals of quartz, or amygdaloidal cavities filled with various substances.

INDURATED CLAY has also a dull earthy fracture, and varies in colour from greenish-grey to greyish-white, or red, or brown, or even black.

CLAYSTONE is harder than the preceding, but still presents an earthy aspect, with an uneven more or less conchoidal fracture, and is of various colours, often yellowish, purplish, or reddish. In structure it may be massive, with irregular fissures, or more or less prismatic or laminar. It frequently contains crystals of felspar or quartz, and occurs in veins, as well as in mountain masses.

CLINKSTONE is still harder than Claystone, and has a more conchoidal and splintery fracture, with considerable lustre, some degree of transparency on the edges, and usually presents darker colours. Sometimes it has a laminated structure; and, when a thin piece is struck with the hammer, it emits a sharp or somewhat ringing sound, whence its name.

COMPACT FELSPAR excels the preceding species in hardness. Its colours are various, its texture compact, its fracture conchoidal, uneven, and scaly, the edges translucent. It is seldom without being porphyritic in some degree, often presents extensive masses, and also occurs in veins. Some kinds of HORNSTONE appear to be Compact Felspar much indurated, somewhat translucent, with splintery fracture.

PITCHSTONE generally occurs in veins, and is much less frequent than the preceding rocks. It presents an imperfectly prismatic, or lamellar, or concretionary structure, varies in colour from black to grey, has a splintery, uneven, or conchoidal fracture, and is slightly translucent on the edges. Sometimes it presents an aggregation of irregular grains, resembling pearlstone.

197. PORPHYRIES.—When Claystone, Clinkstone, Compact Felspar, or Pitchstone, contain crystals of felspar or some other substance interspersed through their mass, and easily distinguishable from it, they constitute Porphyries. Thus, Claystone with crystals of felspar is named Claystone Porphyry. But as Porphyry is not, properly speaking, a generic term, since it merely indicates a state or condition of a given substance, it would be preferable to name such simple varieties Porphyritic Claystone, Porphyritic Clinkstone, &c. When, however, there is an intermixture of crystals of various kinds, so that the base is indistinguishable, it is difficult to imagine what terms might be employed to designate all the varieties. Porphyries are of common occurrence, often forming vast masses, and present a great variety of aspects, as may be easily understood when it is stated, that not only the substances mentioned above may be porphyritic, but also Basalts, Greenstones, Syenites, and Granites.

198. AMYGDALOIDS.—When Claystone, Compact Felspar, Greenstone, or any other rock of this class contains, not angular crystals, but roundish or ovoidal bodies of a different substance, such as chloritic earth, calcareous spar, calcedony, or agate, they are named Amygdaloids. The remark made above as to the nomenclature of Porphyry applies equally to that of Amygdaloid. The proper method of naming such rocks is Amygdaloidal Claystone, Amygdaloidal Felspar, Amygdaloidal Greenstone.

199. Basalt.—It is impossible, from the definitions of basalt given in books, to form any very definite idea of it. Professor Jameson defines it a substance of a greyish or greenish-black, rarely inclining to grey; internally dull or feebly glimmering; the fracture in the coarser varieties large or small-grained uneven; in the more crystalline varieties even, inclining to large and flat conchoidal, and seldom to splintery; opaque, or feebly translucent on the edges; with a pale grey-coloured streak; semi-hard, bordering on hard; rather brittle, and difficultly frangible. According to him there are two kinds of basalt: one is an intimate combination of hornblende and felspar, and the other of augite and felspar; the felspar generally appearing to be of the compact kind. Basalt is thus greenstone in very minute grains, and it has thus been defined at p. 80, § 78. Dr. MacCulloch considers "hornblende compacted into a solid mass, and apparently consisting of minute crystalline particles," with the fracture more or less coarse-grained, uneven, splintery, or conchoidal, sometimes considerably glistening, as what some authors describe as basalt, or as one of the varieties of that substance; but remarks that the analysis of basalt yields soda, which, however, is not contained in hornblende. It does certainly appear, that the very fine-grained or compact blackish rocks of this class have all been considered by some authors as basalt. The columnar structure is not peculiar to this substance, being found in greenstone and other rocks. Basalt occurs in veins, beds, and overlying-masses. According to Mr. Bakewell, "it frequently contains yellowish grains of a mineral called Olivine; it contains also grains of iron-sand, and a considerable portion of the black oxide of iron. It is fusible into a black glass, and is magnetic. The iron which it contains passes into a farther state of oxygenation when exposed to the air: hence basaltic rocks are generally covered with a reddish-brown incrustation. Very black basalts are chiefly composed of augite." This rock is occasionally porphyritic, and is then called Basaltic Porphyry, or Porphyritic Basalt.

200. GREENSTONE.—The rock usually named Greenstone is a compound of hornblende and felspar in nearly equal proportions, and having a granitic structure. The name is not very appropriate, for although it sometimes has a greenish appearance, it is not uncommonly reddish or whitish, the colour depending chiefly on that of the felspar, which is generally compact, or at least not highly crystalline. When the crystals are large, it assumes the appearance of syenite or granite, and when very minute, it passes into basalt and clinkstone. Sometimes distinct crystals of felspar are contained in it, and it becomes Porphyritic Greenstone. Sometimes also it is amygdaloidal, containing zeolite, or calcareous spar. Veins of calcareous spar, quartz, heavy-spar, red hematite, and other minerals, frequently intersect greenstone. It occurs in veins, beds, and extensive masses, and is very widely distributed.

201. AUGITE ROCK.—Dr. MacCulloch, who instituted this name for a particular kind of trap rock, defines it a compound of augite and compact felspar, the former predominant, or in equal proportion. It varies in appearance, like greenstone, which it resembles, especially when its component parts are minute, in which case it also passes into basalt. But many authors consider greenstone as formed either of augite or of hornblende, together with felspar.

202. HYPERSTHENE ROCK is a compound of hypersthene and felspar, the latter being compact, crystalline, or glassy. "These," says Dr. MacCulloch, "form three varieties of a rock hitherto unknown, and to which I have given the name of hypersthene rock. It occurs in large granitiform beds, in mountain masses; and is found in Sky and Ardnamurchan. As yet I have never observed it either in a columnar form or in that of veins. It occasionally exfoliates like the granites, in a solid form, by the action of the weather. In other cases, it possesses a foliated structure like Gneiss, arising from the parallel disposition of the hypersthene. More generally, the structure is granitic, and varies exceedingly according to the magnitude of the parts and

their relative proportions. Pyrites, garnets, and octohedral oxidulous iron, occur in hypersthene rock; and the latter in such abundance as to modify its character and aspect."

203. Syenite or Trap Syenite.—By these terms is generally meant a trap rock, composed of the same ingredients as Greenstone, but with felspar predominant, and sometimes containing quartz or other minerals. It may be porphyritic like the other rocks of this class. The distinction between it and Greenstone is insignificant; and when we examine the numberless masses of this nature, composed of from two to eight or ten simple minerals, we find it as impracticable to reduce them to systematic order, as it would be useless to do so.

Granitic Mixtures.—When a greenstone or syenite, composed of hornblende and felspar, exhibits intermixed crystals or portions of quartz, it often becomes indistinguishable from Syenitic Granite, already described, p. 115. Granitic rocks of this kind present numberless combinations, and vary extremely in colour, and texture. The minerals observed in them are felspar, hornblende, augite, chlorite, steatite, mica, quartz, prehnite, mesotype, stilbite, pyrites, epidote, and several others.

204. Trap Conglomerate.—Among other indications of analogy of origin between the Trap and Volcanic Rocks, is the existence of Conglomerates formed of fragments of greenstone, basalt, or claystone, together with portions of stratified rocks, more or less rounded by attrition, and imbedded in a paste of the same nature, or having their intervals filled up by it. Such deposits, usually in the form of irregular beds, are named by many geologists Trap Tufa. They vary extremely in composition and in the size of their imbedded masses or fragments, which may be several feet in diameter. They are often regularly stratified, and when fine-grained, or of the consistence of indurated clay, are sometimes minutely laminated.

205. Jasper.—Many substances differing in their nature and origin have been considered as Jasper, which may be

defined as a mineral nearly as hard as quartz, very brittle, with a flat or conchoidal fracture, a dull, earthy, or somewhat glassy lustre, and of various, often brilliant, colours. It occurs in veins generally very slender, in trap rocks, and is said also to form large masses; but it is also found among volcanic rocks, as well as in the primary and secondary series. It is a state or condition of argillaceous matter rather than a distinct mineral; and it is for this reason that it presents itself in so many different situations.

206. General Remarks.—Granite, which we assumed as the unstratified basis of the series of primary, secondary, tertiary, and alluvial rocks, is intimately connected in composition and general characters with the Syenites and Greenstones of the Trap series. On the other hand, the latter are evidently connected with the Volcanic Rocks by means of Pitchstone, which is closely allied to Obsidian. Trap Rocks, moreover, differ little in mineral composition from the volcanic, and this circumstance, together with the similarity of their relations to the stratified rocks, renders it probable that, through fissures intersecting the strata, they had been ejected from beneath, and poured out upon the surface of the stratified masses. The products of volcanoes, however, are much less compact, and often highly porous. This difference is accounted for by their being poured out in the open air, while the trap rocks were deposited under the sea.

Recapitulation.

193. What is the nature of the Rocks called Plutonic?—194. How many varieties of structure do they present? Is the prismatic or columnar structure common in them?—195. How may the trap rocks be arranged?—196. Give some account of Wacké, Indurated Clay, Claystone, Clinkstone, Compact Felspar, and Pitchstone.—197. What is meant by

porphyry?—198. What distinguishes an amygdaloid?—199. Describe basalt. To what rocks is it allied?—200. Describe Greenstone.—201. In what respect is augite rock different?—202. Give an account of Hypersthene Rock.—203. What is Syenite? Are there many varieties of it? What relations have the Trap to the Volcanic Rocks?—204. What is meant by Trap Tufa or Trap Conglomerate?—205. Describe Jasper. Does it occur eslewhere than among the trap rocks?—206. How is Granite connected with these rocks? What relation have they to the Volcanic?

CHAPTER XI.

OF VOLCANIC ROCKS.

NATURE AND ORIGIN OF VOLCANIC ROCKS.—PRODUCTIONS OF EXTINCT VOLCANOES.—TRACHYTE, PUMICE, OBSIDIAN, TRACHYTIC TUFA.

207. NATURE AND ORIGIN OF VOLCANIC ROCKS.—The Trap Rocks described in the preceding chapter are intimately related to those which are now to engage our attention. They have been erupted from the interior of the earth at periods antecedent to the deposition of the Tertiary rocks, and having flowed at the bottom of the sea, under the pressure of its waters, present a more dense structure than the deposits of the modern volcanic vents, which have been poured out upon the surface of the dry land. Some volcanoes have been for ages extinct, while others are in operation at the present day; and these circumstances give rise to a kind of distinction between volcanic products into ANCIENT

and MODERN. Of the productions of extinct volcanoes may be mentioned Trachyte, Pumice, Obsidian.

208. TRACHYTE.—This name, derived from τραχυς, rough, has been applied to a set of rocks analogous to the porphyries of the preceding chapter, from which they are distinguished by their porosity. According to the greater or less degree of fluidity which they possessed at the time of their eruption, they have been produced sometimes in the form of domes, or cones covered with debris, sometimes as veins, currents, or sheets, alternating with layers of trachytic conglomerates. The trachytic deposits, moreover, present various porphyritic, semi-vitreous, or glassy rocks, in heaps grouped in a certain order, but having no indications of regular stratification, nor any vestige of volcanic crater. Trachyte is generally of a whitish or greyish colour, sometimes inclining to red or brown, with a dull earthy fracture, but sometimes harder, with a fracture inclining to even. It varies in density, being sometimes friable, and sometimes compact. It easily melts into a white or greyish glass. Its basis appears to be felspar, and it generally contains interspersed crystals of glassy felspar, together with crystals of augite, hornblende, mica, laminæ of specular iron-ore, grains of iron-sand, and crystals of quartz. Sometimes, when augite prevails, it is of a dark colour, and melts into a black glass. Pearlstone is considered to be merely a variety of trachyte in a state of fusion. Obsidian and pumice seem also to be the same substance in different states. Trachytes are frequently found in connexion with syenites and porphyries on the one hand, and on the other with basalts.

209. PUMICE, OBSIDIAN, TRACHYTIC TUFA.—Pumice ap-

pears to be trachyte which has been exposed to an intense heat, and reduced to a fibrous and vesicular mass. In the Island of Lipari is a mountain formed entirely of white pumice, in balls of various sizes, some not larger than a hazel nut, while others exceed a foot or more. Some of them are apparently compact, and resemble glass, but they all float on water. Humboldt states that he has seen black pumice, in which augite and hornblende could be distinguished, and supposes it to have been derived from basaltic lava. Obsidian bears a considerable resemblance to Pitchstone, but is more glassy, with a smooth, conchoidal, shining fracture, generally of a black colour, but often tinged with blue or grey, and frequently streaked as if of a laminated texture. It is harder than glass, and produces sparks when struck with steel. Obsidian occurs in the Lipari Islands, Teneriffe, the Andes, Iceland, and other volcanic districts. Colonel Imrie mentions two currents of lava which he examined in Felicuda, one of the Lipari Islands, as exhibiting the transition of obsidian into pumice and lava. "The obsidian, when in mass, appeared almost black and opaque; but at the edges of its beautiful conchoidal fracture, it was in some degree translucent, and there showed a muddy-brown colour. In some parts of this obsidian, it is seen deviating from its brilliancy and from its compact vitreous texture, and is evidently seen passing into a granular lava; but the marks of this gradual transition are soon lost, and the lava into which the obsidian had passed, is then not to be distinguished in colour, in fracture, or in texture, from the general lava of the other parts of the stream. Where this obsidian appears in mass, and in a state of perfect glass, it is very near to where it has been first ejected from the side of the crater, and in a situation where it must have undergone a rapid cooling. In some parts of these congealed streams, I could trace a transition of the obsidian into pumice. In those places, the obsidian was seen to contain scattered air-globules, which were almost always lengthened in the direction of the stream. These globules gradually augmented in number until the whole of the substance became a light, fragile, and frothy pumice." Beds and irregular deposits of conglomerate, composed of fragments of trachyte and other volcanic substances, are often abundant in volcanic districts. When reduced to the state of sand or powder, they form beds of tufa, analogous to those described as occurring in the trap series.

210. Clinkstones, Basalts, and Greenstones.—The trachytic rocks, becoming hard and compact, assume a laminar structure, and present the appearance of Clinkstone. Sometimes also, becoming dark-coloured, and containing augite, they resemble Basalt and Greenstone. When several different minerals are interspersed, they occasionally assume the aspect of Syenite. In short, all these rocks seem to graduate into each other. The greenstones, basalts, and clinkstones of this series differ, however, from those of the trap series, in being always more or less vesicular. When a trap rock presents a vesicular appearance, it will be found that the substances originally contained in its vesicular cavities have been decomposed.

211. Products of Modern Volcanoes.—The matters ejected by volcanoes at present in action resemble those of the ancient or extinct volcanoes, and may in many cases be considered as basalts or trachytes melted a second time. They are augitic or felspathic rocks, vitreous, stony, or earthy, often porous and slaggy, which issue from funnel-shaped cavities, situated at the extremity of truncated cones.

These cones have the margin notched or broken in one or more places, and their sides covered with bands of scoriæ, a kind of cinders left by the currents of lava which have emerged from the crater, and flowed down the sides of the mountain. Lava, scoriæ, tufa, and mud, are the principal products of volcanoes. In these substances various minerals are found, especially felspar, hornblende, augite, garnet, leucite, mica, melanite, tourmaline, sommite, arragonite, and specular iron-ore.

212. Lava.—This substance in its ordinary state differs from basalt chiefly in being porous; but it presents several varieties. It may be compact, of a dark grey colour, with an uneven fracture, and glimmering lustre; vesicular, of similar characters, but with numberless vesicular cavities of various forms; Slaggy, of a semivitreous aspect and vesicular; Spumous, so vesicular as to float on water; but all these varieties are merely gradations of the same substance. Lava generally presents itself in long streams, and sometimes in broad expansions. It is often accompanied with deposits of volcanic powder or dust, mud, and scoriæ or cinders. These loose materials become consolidated by the action of water, and the tufas thus formed are often sufficiently solid to be used for building.

213. Concluding Remarks.—We have now obtained a general view, imperfect, but sufficient for the object in contemplation, of the materials of which the globe is composed, and the disposition of the strata and irregular masses of rock. The animal and vegetable remains included in the various deposits have also occasionally been alluded to. We have seen that the crust of the globe is composed of strata, broken up, variously inclined, and placed at various heights, together with veins and masses of unstratified substances, to the intrusion of which would seem in many cases owing the disturbances of which the traces are so evident. Volcanic funnels have poured out streams of lava and mud at the surface; and the superficial layer of the globe is composed of gravel, sand, and soil. Elevated ridges traverse the continents and islands, forming slopes, of every degree of inclination; water-courses and lakes occupy the lowest levels of

the land. The ocean covers four-fifths of the earth's surface, and of the remaining portion a large space is rendered uninhabitable by being enveloped in perennial snow and ice, or formed of arid sand, or bare rock. We have now to acquire some idea of the causes which have operated in producing the various rocks, in reducing them to their present condition, and in effecting the changes upon the surface of the globe which have rendered it fitted for becoming the habitation of man.

Recapitulation.

207. What is the origin of the Trap Rocks? Have they analogy to the volcanic?—208. What is the nature of Trachyte? What are its mineral characters? With what rocks is it connected?—209. What is the nature of Pumice? Describe Obsidian. Mention an instance of the transition of lava, pumice, and obsidian, into each other. Are there conglomerates and tufas among volcanic rocks?—210. Are the clinkstones, basalts, and greenstones, similar to those of the trap series?—211. What are the products of existing volcanoes? What simple minerals are found in them?—212. How many kinds of Lava are there? How does lava present itself?

SECTION III.

CAUSES OF THE PRESENT STATE AND RELATIONS OF THE MATERIALS OF THE EARTH.

CHAPTER I.

FORMATIONS OF THE PRESENT PERIOD OF THE GLOBE.

GENERAL CHARACTERS OF THE MODERN EPOCH.—VEGETABLE SOIL, DEBRIS OF ROCKS, DETRITUS OF RIVERS.—ACTION OF RUNNING WATER.—DEPOSITS IN THE COURSE OF RIVERS, AND AT THEIR MOUTHS.—DEPOSITS IN LAKES.—MARINE DEPOSITS.—ACTION OF MARINE CURRENTS.—DRIFT SANDS.—PEAT AND FOSSIL FORESTS.—MADREPORE LIMESTONES.

214. INTRODUCTORY REMARKS.—In endeavouring to obtain a general and connected view of the causes which have operated in producing the phenomena presented by the materials of which the exterior of the globe is composed, the object is not to elicit a theory of the earth, but to place before the reader circumstances which may enable him to appreciate the statements and hypotheses of geologists. It will be kept in mind that this essay is merely a compilation of facts and phenomena intended for an introduction to the study of geology. A retrospect of the series of formations, in which details necessarily omitted in the preceding sec-

tions, it is presumed will afford a convenient means of presenting useful explanations. We shall therefore commence with the surface, speculate upon the interior, and describe some phenomena connected with the intermediate space. This chapter is, in a great measure, a translation from M. Delafosse.

215. Characters of the Modern Epoch.—The present period comprehends all the deposits which owe their origin to causes now in action, and has reference to the phenomena which are taking place at the surface of the earth. The present population of the globe, characterized especially by the human species, is too varied to be spoken of in detail. It contains all the orders of plants and animals, from the highest to the lowest, although many species and some genera have disappeared from the face of the earth, and are known to us only by their fossil remains. The mineral deposits which are at present forming, whether in contact with the air or beneath the waters, contain remains of this population in various degrees of preservation. They are seldom petrified, or penetrated by mineral matter, as is the case with those of preceding epochs. Shells become friable, having been in part destroyed by acid waters, bones lose their animal matter, plants are carbonized, often so completely as to form deposits of peat. With the exception of the volcanic rocks, which are ejected from the interior of the earth, those which belong to this period have usually little consistence, most of them being merely accumulations of fragments resulting from the disintegration of preceding deposits, transported to the places where we now find them by causes at present in action, by gravitation, water, and even the winds. It will thus be understood that in general these deposits must be formed of very different materials, commonly mixed without order, and destitute of regular stratification. Their most distinctive characters are their increasing under our eyes, and their containing remains of man, and traces of his industry.

216. Vegetable Soil.—By vegetable soil is meant the

external thin layer in which plants grow, and which is composed of fragments of minerals, vegetables, and animals, reduced to a great degree of tenuity. The soil often partakes greatly of the nature of the neighbouring rocks, but it may also be often of a different nature. In the plains and valleys its structure is more complex than on the sides of mountains or on table-lands. In elevated tracts, when the rock is easily acted on by the weather, the layer of soil is composed of its detritus, often in a state of purity; but in the lower grounds, where strata intervene between it and the subjacent rock, it is usually very different. This layer of soil may be said to cover the entire surface of the dry land, although in extensive tracts it may scarcely be said to exist. Its nature influences the vegetation, not so much by the mineral matters of which it is composed, as by its varying capability of retaining moisture; but this influence is slight compared with that of temperature. Thus the Jura mountains and those of the Vosges have nearly the same elevation, and their vegetation presents no appreciable difference; yet their mineralogical constitution is entirely different, the former being composed of limestones and marls, the latter of sandstone, gneiss, porphyry, and granite. On the other hand, the same soil in different latitudes produces an entirely different vegetation. This is well illustrated by the familiar case of our hot-houses, in which the productions of the tropics are made to grow in the same kinds of soil that nourish our common plants. The origin of soil is easily intelligible, as we see it forming by the action of the atmosphere, which gradually decomposes or disintegrates the solid rocks, and by that of the waters, which transport the fragments and leave them on the lower grounds; while the more or less decayed portions of vegetables mingle with it, and sometimes form its principal part.

217. Debris of Rocks.—At the foot of precipices, in the mountains and along the coasts, are seen heaps of fragments produced by the crumbling of the overhanging rocks. These accumulations assume various forms, but their upper

surface always approaches to that of a cone, unless at the foot of large rectilinear ridges, as in the Jura mountains, when the debris forms an inclined plane, although in reality this plane may be sectioned into a series of cones. Although the materials which form a slip of this kind are much mixed, they yet show a certain order determined by the laws of mechanics, the heaviest fragments being the farthest from the point of departure, so that the large stones always occupy the base of the cone, while the small particles are at the top. Slips are the result of two well-known causes: the infiltration of water, and the variations of temperature in the mineral masses. In the neighbourhood of cliffs, water insinuating itself into the cracks of rocks, carries with it the soft or loose particles, and thus forms vacuities between the solid parts, which, being traversed by fissures, break from their weight, and crumble down. In winter, the water contained in the fissures congeals, and the expansion of the ice often produces a force sufficient to displace some of the parts. During thaw, the ice melting permits the separated parts to fall or be washed away. This cause produces powerful effects in high mountains, whence after thaw enormous masses of rock are often seen to fall, and carry along with them whatever comes in their way. Mineral masses being bad conductors of caloric, the variations of temperature cause fractures in them, which powerfully contribute to the same effect. Generally slips do not take place suddenly, but the rocks exposed to destructive agents disintegrate gradually, and the talus or heap at their base slowly enlarges.

218. Preserving Effects of Debris.—It might at first be supposed that the effect thus produced has no limits, and that mountains might gradually crumble away until they were entirely destroyed. This, however, would be a very erroneous idea, for the heaps formed at the base of cliffs, by gradually rising, preserve the parts which they cover, and a time will necessarily come when the escarpment will be entirely covered by the debris. The heaps themselves are liable to the destructive agency of water, which carries por-

tions of them away, but an equilibrium is finally established, and the slope becomes covered with vegetation. In all mountain-chains, we find heaps which have acquired their full development, and others which are in progress. The slopes of many of the granitic mountains of Aberdeenshire are composed of debris of this nature, but in the gneiss and mica-slate districts the disintegration has gone on less rapidly. In general, the heaps are more advanced the lower the mountains are; and in the Vosges, the Ardennes, and the Jura mountains, they are more complete than in the Alps and Pyrenees. As to the cliffs on the sea-shore, which are broken down by the undermining action of the waves, their destruction is prevented by the protection afforded by the fallen blocks.

219. Detritus of Rivers.—From the action of the atmosphere upon rocks, there result blocks of various sizes, gravel, sand, and clay, which are the more abundant the more easily the rocks from which they are derived disintegrate. The rain waters carry off part of these matters, and at the same time attack the friable rocks which occur in their course, the materials suspended in the water being transported so long as its velocity is sufficient to overcome the effect of gravity, but whenever this latter force predominates, the suspended substances subside. The velocity of a current of water is destroyed by the obstacles which it encounters; and, as the number of these obstacles is in the direct ratio of the space which the current traverses, the heaviest fragments are first deposited, and the lightest carried to the greatest distance. Most large rivers are more or less filled with detritus, which often forms islands, that are generally covered during floods; and the vast deposits formed in their course are often exposed in the steep banks formed by the varying action of the waters.

220. Deposits from Glaciers.—In very elevated regions, such as the Alps of Savoy, which have been more correctly examined, the high valleys contain extended sheets of ice, named glaciers, which are continually advancing

along the inclined planes formed by the bottoms of these hollows. When the rocks that bound the valleys are disintegrated by the action of the weather, the fragments separated fall upon the margins of the glacier, and are gradually carried along with it, in the form of continuous lines or ridges named moraines. The lower extremity of the glacier gradually melts away in summer and autumn, thus depositing the detritus carried down in the form of heaps of rubbish. Glaciers opening upon the sea, as they frequently do in Greenland and Spitzbergen, and breaking off in masses, forming ice-bergs, also carry with them fragments of rock, to be deposited in the sea: and in this way some have naturally enough accounted for the blocks now scattered over the surface of great plains at a distance from mountains.

221. Action of Running Water.—Should an obstacle oppose itself perpendicularly to the current, it is evident that at this point its velocity will cease, and all the substances held in suspension, of which the density is greater than that of water, will be deposited. But if the obstacle be oblique to the direction of the current, the latter will lose only a part of its velocity, and will allow to subside only the bodies whose weight will prevail over the remaining velocity. Succeeding obstacles will produce similar effects, and thus all the larger fragments will be successively deposited, and only the smaller carried as far as the estuary or mouth of the river. Thus, the fragments of the same substance, carried away from the same point, are disposed along water-courses in the order of their bulk, the largest being at the point of departure, and the smallest at the termination of the river; which is just the reverse of what happens in slips. The velocity of a river diminishes from the middle to the margins, at which the depositions therefore usually take place. When a current is reflected by an obstacle, its direction is changed, and it is carried against the opposite side, where, by its continual action, it produces a bank or bluff. The obstacles which it there meets force it back obliquely to the first side,

and in this manner a second bank is formed; so that rivers, in the winding parts of their course, present an alternation of bluffs and taluses, the taluses occupying the salient angles, and the bluffs the re-entering angles. In the straight parts of the bed, the velocity being about equally diminished on both margins, the taluses are formed on both sides, and the bottom rises equally.

222. Deposits in the lower parts of Valleys.—The horizontal portion occupying the bottom of valleys, and in which the beds of rivers are scooped, is formed by the current by which it is traversed. On examining the steep banks of a river, we perceive that the deposit in which they are excavated owes its existence to the present order of things: it contains beds of sand, rolled pebbles, and clay, entirely similar to those of the margins, fragments of pottery, bricks, and other manufactured articles, bones of species now living, often mixed with human bones, land and fresh-water shells, which live in the country, wood partly carbonized, and other matters. This horizontal part of the bottom of valleys is, therefore, a modern deposit, and is every day increasing. The rain-waters which flow into the bed of a river, carrying with them a great quantity of debris, suddenly raise its level, sometimes to overflowing. The mass of water being thinner in proportion as it is diffused over a larger surface, and the number of obstacles increasing in proportion to the surface covered, the velocity diminishes more and more. Then the matters held in suspension are deposited, and form a thin layer. But in the bed of the river, where the velocity has augmented in place of diminishing, there is much less deposition than on the banks, frequently none at all. As the same phenomena recur at each overflowing, the consequence is, that the banks of the river gradually rise, and that they are so much the higher the more frequent the inundations. These are not all of the same magnitude, there being many more small than great inundations, which explains why, on each side of a river subject to everflowing, the land, in place of being

perfectly horizontal, forms an inclined plane, which rises as it approaches the bed. This phenomenon is very perceptible on the banks of the Nile, the Po, and the Mississippi.

223. Deposits at the Mouths of Rivers.—It is thus seen that rivers, in their overflowings as well as in their natural state, deposit on their margins a great part of the materials which they carry along with them; but the lightest parts are transported as far as the estuary, or lakes, where the running waters entirely lose their velocity, and there are then formed deposits which often obstruct the entrance of rivers. In the sea, the effect of the tide, combined with that of the fresh-water current, gives these deposits the form of large bars placed before the mouths of rivers, and which it is necessary to destroy or modify by artificial means, to allow a free entrance to vessels. In the Mediterranean, where the tides are scarcely perceptible, the deposits are spread out pretty uniformly; but as the action of the rivers continually destroys the parts most advanced in their waters, it gives to the deposition the form of a triangle, of which the summit is found to be the most advanced point in the bed of the river. These deposits are named DELTAS, from their resemblance to Δ, the Greek letter of that name.

224. Delta of the Nile.—All the large rivers that enter the Mediterranean have a delta, but the most celebrated is that of the Nile, which is of great extent, contains several lakes, and is traversed by two principal currents. It is well known that the annual inundation of the Nile, which is the fertilizer of Egypt, is the result of the great rains which fall in Abyssinia in spring. The waters coming from these rains, carry into the bed of the river the detritus of the districts over which they pass. The heavier parts are arrested by the numerous cataracts which occur in the course of the Nile, before it enters Egypt. In extending over the soil of that country, it yields a great portion to form the layer of mud which fertilizes the fields; and at length the finest particles are carried as far as the sea, and go to increase the delta. The filling of the Nile commences

in June, attains its maximum in August, and gradually diminishes until next May. It has been calculated that the Delta has increased about 20,000 metres since the time of Herodotus; and according to the calculations of M. Girard, the Nile must have raised the surface of Upper Egypt about six feet and a half since the commencement of the Christian era. Other great rivers present at their mouths deposits of a similar nature, which, although not perhaps calculated to attract much of the attention of ordinary observers, are of gigantic dimensions. "If all the nations of the earth," says Mr. Lyell, "should attempt to carry away the lava which flowed during one eruption from the Icelandic volcanoes in 1783, and the two following years, and should attempt to consign it to the deepest abysses of the ocean, wherein it might approach most nearly to the profundities from which it rose in the volcanic vent, they might toil for thousands of years before their task was accomplished; yet the matter borne down by the Ganges and Burrampooter, in a single year, probably very much exceeds, in weight and volume, the mass of Icelandic lava produced by that great eruption."

225. Deposits in Lakes.—When a river enters a lake, it also forms deposits, which gradually raise the bottom, diminishing the depth, and sometimes at length filling the lake. This happens chiefly in small lakes among mountains, where the debris is abundant, the slopes highly inclined, and the water acquires greater velocity than in the plains. There are large deposits of this kind at the entrance of the Rhone and Rhine, into the Lakes of Geneva and Constance. Saussure, who made many observations on those of the former river, was of opinion, that, in the course of ages, the basin of the lake would be filled up. The mechanical depositions which form in the bottom of a lake, have an inclination equal to that of the bottom, and the materials in each layer are disposed in the order of gravity, proceeding from the margin, precisely as in the bed of a river. Thus, on the banks are found the blocks and pebbles, while at a certain distance there is nothing but sand and

marl. After great rains, and the melting of snow, large sheets of water are often seen in low places, which after a time dry up, leaving a deposit of mud, which is renewed as often as the inundation takes place, and gradually raises the ground, so that if the reservoir is not very deep, a time will come when the waters can no more collect in it.

226. SUDDEN ERUPTIONS OF WATER.—The phenomena spoken of above are progressive, and the causes which produce them act in a continuous manner; but phenomena of the same kind are produced by sudden and violent causes. Masses of snow fall from high mountains, and carry with them portions of rocks, which assist them in destroying whatever comes in their way. Torrents of water, resulting from heavy rains or subterranean eruptions, sometimes precipitate themselves into the bottom of valleys, which they cover with a mass of debris torn from the rocks over which they have passed. The lakes of high mountains, whether permanent or accidental, often owe their existence to a bar of alluvial matter, which retains the water, and against which the latter exercises a continual effort, tending to burst it. A sudden increase of the water, or any other cause, sometimes ruptures the bar, and the lake suddenly rushing out, produces effects similar to those of the masses of water which precipitate themselves on the sides of mountains. In the Valley of Bagnes, in the Valais, the course of the Drance having been obstructed by avalanches of ice and snow, there formed before the bar a large lake which threatened the country beneath with destruction, as soon as the heat should destroy the ice and allow the waters to escape. The inhabitants had the idea of boring a gallery into the ice, to let the water flow off gently, and in this manner they succeeded in discharging a third part of it; but the bar having burst, a torrent broke forth with extreme violence, carrying along enormous blocks of rock, trees, and houses, destroyed a part of the village of Martigny, and proceeded to join the Rhone, gradually losing its velocity. The surface of the country which it traversed was covered with debris, and several trees

which had been swept away, with nearly all the earth attached to their roots, remained standing. Mr. Bakewell states that a similar inundation, in the valley of the Upper Doron in the Tarentaise, took place in the following year. Numerous blocks of stone, of many tons weight, were brought down by the torrent, and scattered over a small plain at the mouth of the lateral valley, along which they had descended.

227. MARINE DEBRIS.—The debris of the bottom of the sea is connected with that of rivers by the deposits formed at the mouths of the latter, in which the river and the sea alike operate. In great storms, and at high tides, the sea sometimes bursts into fresh-water lakes, carrying with it matters torn from the rocks which form its bottom. The waves of the sea continually erode the deposits which the fresh waters form in it; they attack at the same time the friable rocks of the bottom, and are thus charged with sand, clay, and solid fragments, which they continually drive against the shore. This is done as follows:—as the wave extends over the flat ground, it loses its velocity, and there comes a moment when, this velocity having entirely ceased, the substances held in suspension are deposited; the wave, which slowly retires, carries back but little or none, especially when the inclination is not great. The same phenomena recurring at each undulation, it may be conceived that the deposits thus formed must increase very rapidly, and that if the bottom of the sea is not very far distant from the surface, it may in a short time be elevated above it. It is in this manner that the greater part of the soil of Holland has been formed, and that Aigues Mortes, where St. Louis embarked for the Holy Land, is now more than a league from the sea. But these deposits on drying decrease in height, and are liable to be again inundated.

228. MODERN MARINE CONGLOMERATES.—In some cases the sea throws on its shores sand mixed with remains of shells and corals, which are agglutinated by a calcareous cement, and at length take a pretty firm consistence. Rocks

of this nature are daily forming on the shores of Sicily, and are very abundant in the West Indies. The most remarkable deposit of this kind is that on the north-west coast of Guadaloupe, which is still forming, and contains human skeletons. It occupies a kind of glacis resting on the steep coast of the island, and partly covered at high water. The human bones found in it are probably those of shipwrecked persons. In St. Domingo there are deposits of exactly the same nature, in which are found fragments of pottery. The sands of the outer Hebrides, which are chiefly comminuted shells, sometimes form patches of solid sandstone.

229. Pebbly Beaches.—The shores of the sea are often covered with rolled pebbles which may have been heaped up by the waves, or by other causes of which the action has ceased. The present sea has a very considerable action on these pebbles, always driving them inwards according to the direction of the prevailing winds of the country. The southern coast of England presents many examples of this phenomenon. These pebbles, if they do not belong to the diluvial period, come from fragments of rocks torn from the bottom of the sea, or from blocks which have fallen from the cliffs, and are reduced to fragments by being tossed against each other.

230. Heaps of Shells.—Among the pebbles and sands which cover the beaches are always shells and other marine animals, belonging to species which live on the coast. It not unfrequently happens that large heaps of testaceous mollusca have been accumulated on certain parts of the coasts, and their identity with those of the neighbourhood, as well as the continuation of the formation of these deposits, show that they are owing to causes at present acting. Heaps of shells of the same nature have also been found considerably elevated above high-water mark, in beaches that have been elevated by causes acting locally. Whales and dolphins are sometimes cast ashore, and if these animals are left untouched by man, their flesh putrefies, and the sands at length cover them. It is not very uncommon to find in the

sands on the sea-shore entire skeletons of large animals which have been buried in this manner. At high tides, and in great storms, the sea bursting over the natural barriers, forms in the interior pools, which, on drying, leave a marine deposit impregnated with salt. In the same circumstances it sometimes flows into fresh-water lakes, in the bottom of which there must subsequently form a marine deposit. From this it is seen that if the fresh waters carry terrestrial and fluviatile productions into the midst of marine deposits, the sea also transports its products into the midst of fresh-water deposits.

231. Deposits formed by Marine Currents.—The waters of the ocean are continually eroding the bottom, and carrying along shells, corals, and part of the detritus deposited in the sea by rivers, which they allow to subside when the velocity of the currents is retarded or ceases. In this manner are formed deposits often of great extent, many of which are shoals dangerous to navigators. Marine currents also transport great quantities of wood, which accumulate in small bays. The banks formed by them are very numerous on the coasts of England and Holland. We have no direct proof of the formation of chemical deposits in the waters of the present seas, but as they hold in solution various mineral substances, and as mineral springs in all probability arise in them, it is reasonable to suppose that depositions take place in them. All the deposits spoken of above contain remains of marine animals, especially of such as live in the vicinity of the countries where they are deposited. Land and fresh-water productions, even bones of men and products of human industry, often occur in these deposits mixed with marine bodies, especially near the coasts.

232. Sands and Downs.—In countries where the winds blow upon the coast with considerable violence, the sand thrown up by the sea is transported to some distance inland, and often forms heaps or hillocks, named downs or sand-hills. This phenomenon is produced on a great scale

along the coast of France, from Bayonne to Dunkirk. On inspecting a mass of downs, it is seen to be composed of hillocks, often of considerable height, placed side by side, and sometimes arranged in a manner somewhat similar to that of mountain-chains. From Bayonne to Calais the masses assume the form of a triangle, of which the base is on the coast and the apex inland. On the coasts of Scotland, however, the hillocks seem to have no determinate form or direction. Between the Dee and the Ythan, they form a belt parallel with the coast; in Morayshire an irregular expanse, sometimes flat, sometimes hilly; and in the outer Hebrides, at one time they present a nearly flat surface, on the breaking up of which by the winds, steep hillocks with flat grassy tops are formed, and subsequently an undulating surface of drifting sand. Downs are generally formed of irregular layers of fine quartz sand, with a little calcareous matter intermixed, frequently also fragments of shells; but in some countries the sand is almost entirely calcareous, being composed of comminuted shells or corals.

233. Drift Sands.—When the particles are fine, the winds transport them with more facility, and in stormy weather the air is often loaded with them. All travellers who have visited the coasts of Africa have observed this phenomenon, which is extremely annoying. At the mouth of the Garonne and Adour the sands advance with great rapidity eastward, covering the fields, woods, and villages. In many parts of England and Scotland great devastations have been committed by sand floods. But it is in the eastern countries that their ravages have been most extended. "The sands of the Libyan desert," says De Luc, "driven by the west winds, have left no lands capable of tillage on any parts of the western banks of the Nile, not sheltered by mountains. The encroachment of these sands on districts which were formerly inhabited and cultivated is evidently seen." M. Denon informs us in his Travels in Lower and Upper Egypt, that summits of the ruins of ancient cities, buried under these sands, still appear externally; and that

but for a ridge of mountains called the Lybian chain, which borders the left bank of the Nile, and forms, in the part where it rises, a barrier against the invasion of these sands, the shores of the river, on that side, would long since have ceased to be habitable. "Nothing can be more melancholy," says Denon, "than to walk over villages, swallowed up by the sand of the desert, to trample under foot their roofs, to strike against the summits of their minarets, to reflect that yonder were cultivated fields, that there grew trees, that here were even the dwellings of men, and that all have vanished." Drift sands on the sea-coast may be fixed by planting them with Arundo arenaria, as has been practised in France, or by covering them with square pieces of turf placed at short intervals, as has been done to a small extent in the Hebrides.

234. Formation of Peat.—In the low parts of plains, where water stagnates, in the bottom of hollows on the sides of mountains, and even occasionally on their summits, are found in cold and temperate climates, masses of a brown carbonaceous substance, burning with an empyreumatic smell, and leaving behind a great quantity of ashes. This substance, which is called peat or turf, is formed by the gradual decomposition of successive layers of vegetables. In the upper parts of a mass of peat we observe roots, slender stems, and leaves, coming from a great variety of woody and herbaceous plants; farther down, these substances are more decomposed, and the peat has a darker colour, and denser texture, which increase until in the lower part it is almost solid and nearly black, although even there vegetable fibres can easily be distinguished, and frequently even roots and twigs of trees. In low places covered with water during a great part of the year, succulent vegetables, easily decomposed, usually grow. They die in winter, and, falling to the bottom, form a thin layer. Year after year a similar deposit is made, until at length the mass acquires a great thickness. In Britain, however, peat is generally formed in a different way. Mosses, lichens, carices, and other plants,

including heath, cover the surface, and gradually increase; every year a portion of the roots, and the stems and leaves of the herbaceous species, die, and form an addition to the soil; and in this manner the peat, composed of the partially decomposed vegetation, accumulates. In the Hebrides, for example, the most common kind of peat is of a spongy texture, composed almost entirely of the roots of Scirpus cæspitosus, Carices, Junci, and Eriophora. It is generally more or less continuous at the surface, and frequently occupies the gentler slopes and lower tracts. Beneath this more spongy peat, there is generally a layer, more or less deep, of a darker, more compact, and less fibrous kind, from which the natives extract their fuel. Peat of this kind also occurs in the lower parts of valleys and hollows, where it presents an irregular surface, formed of tufts of heath elevated above the general level, surrounded by mud, and in winter generally converted into islands. The pasturage in these low bogs is of the worst description, and cattle not unfrequently perish by sinking in the mud, as they attempt to pass from one tuft to another. When the depth of soil is not great, and the declivity considerable, the peat is generally of a light brown, somewhat earthy appearance, friable when dry, and much impregnated with iron, leaving a great quantity of reddish ashes when used as fuel. Heath is the predominant plant which this variety yields. When peat has formed in lakes or marshes, or on the margins of rivers, floods deposit a thin layer of sand or mud, which is overgrown with peat; and thus a succession of layers may sometimes be observed. Large tracts of peat bog, on the Continent, as well as in Ireland and Britain, have been formed chiefly, or in great part, of decayed forests.

235. Preservation of Organic Bodies in Peat.—The organic remains that occur in peat belong to species still living, or which have lived since the creation of man. The occurrence of trees in peat bogs is very common, and the species usually found are oak, birch, alder, hazel, and pine. Sometimes portions remain standing, and frequently

the trunks all lie in the same direction, as if they had been levelled by a tempest. Peat has a very remarkable antiseptic property, insomuch that the bodies of men and animals have been found entire in it, after a lapse of many years. In some of these cases the flesh was converted into adipocere. Horns of stags, frequently with the skull attached, are often found in peat in Scotland. In various parts of Europe, as well as in Britain and Ireland, bones and horns of the Red Deer, Roe, Aurochs, and Boar, together with land and fresh-water shells, have been found. Remains of ships, canoes, stone hatchets, arrow-heads, and other works of art, have frequently occurred in peat.

236. Madrepore or Coral Deposits.—The calcareous deposits formed by zoophytes are of vast extent in the Pacific Ocean, the Indian Archipelago, and other portions of the globe. Coral islands, however, are not exclusively the work of these animals, but are partly formed of shells, echini, crustacea, and other marine productions. The reefs are usually of a circular form, with a lagoon in the centre, where the smaller species find a tranquil abode; but frequently, also, they are elongated, and all are surrounded by a deep sea. It has been supposed that they are placed on the summits of submarine mountains, and that those of a circular or oblong form occupy the edges of volcanic craters. "This opinion," says Mr. Lyell, "is strengthened by the conical form of the submarine mountain, and the steep angle at which it plunges on all sides into the surrounding ocean. It is also well known that the Pacific is a great theatre of volcanic action, and every island yet examined in the wide region termed Eastern Oceanica, consists either of volcanic rocks or coral limestones. In the Pacific Ocean the reefs are sometimes of great extent: thus the inhabitants of Disappointment Islands, and those of Duff's Group, pay visits to each other, by passing over long lines of reefs from island to island, a distance of six hundred miles, and upwards." Beds of corals have been found, in a few instances, to alternate with volcanic products. The

interior of the earth contains a vast quantity of fossil zoophytes, some limestone beds being almost entirely formed of them. This proves that these animals were at least as numerous in the ancient seas as in that of the present day, and that they laboured precisely in the same manner.

237. Deposits formed by springs.—Water is never perfectly pure, but contains some substances in solution; and many springs are so impregnated with mineral matter, as to form deposits of considerable extent. Of this kind are the Travertines or Calcareous Tufas, which are composed of carbonate of lime held in solution by springs, which, on being deposited, forms a limestone often sufficiently hard for building, and frequently enveloping animal and vegetable substances. The hot springs of San Philippo, which contain silica, sulphate and carbonate of lime, sulphate of magnesia, and sulphur, and in which Confervæ grow, notwithstanding their high temperature, have covered the ground with a bed of travertine, which is daily increasing. The plain which extends from Rome to the mountains of Tivoli is covered with a deposit of travertine, in which are imbedded Limnæi and Snails. A similar deposition sometimes takes place in lakes and marshes.

238. Stalactites.—The calcareous deposits which decorate the interior of many caves in the form of stalactites, are formed by the evaporation of water holding carbonate of lime in solution. Drops of this water fall successively from a particular place, in which some particles of limestone are deposited. These increase, until a small protuberance is formed. The water trickling over this protuberance, leaves upon it a series of conical pellicles; and the body thus formed may become elongated, so as even to reach the floor. The carbonate of lime is generally pure white and crystalline, but sometimes yellow, being coloured by iron. Water dropping on the floor of the cave, or trickling along the walls, deposits sheets of solid matter, which in this case is named Stalagmite. This substance, thus formed in the bottom of caves, incrusts and covers over the substances lying there.

In this manner have been preserved, from time immemorial, great quantities of bones, earthenware, and other works of art, which are now found on breaking the layer of stalagmite that covers the floor of certain caves. Siliceous stalactites and stalagmites also, but less frequently, occur, and are deposited from the hot waters of volcanic districts.

239. Bog Iron-ore.—Oxide of iron existing in solution in almost all water, ferruginous depositions are often formed, of which the most important is that named Bog Iron-ore. It frequently occurs at the bottom of peat mosses, covering large spaces, but not of great thickness; and in marshy places is sometimes found in deposits, of sufficient importance as to be worked as an ore of iron. Of this nature also is the thin layer of ferruginous matter, often crusted with sand or gravel, which sometimes forms below the soil, a plate, or "pan," impermeable to the roots of trees. Other deposits of mineral matters are formed in a similar manner; but of them it is not necessary to speak here. To this modern period belongs the great series of volcanic phenomena, together with those of Earthquakes, which will form the subject of a separate chapter.

Recapitulation.

215. What is meant by the Modern Epoch? What are its principal characteristics? Of what nature are its deposits? —216. What is vegetable soil? Is it widely extended? How does it influence the vegetation?—217. How are rocks disintegrated? In what order are the fragments of slips deposited? How does water act in decomposing rocks? Describe the action of frost?—218. How do debris act in preserving rocks from farther disintegration? What circumstances relative to them are worthy of being noticed? —219. Describe the manner in which detritus is carried

along and deposited by rivers.—220. Give an account of glaciers and moraines.—221. How does running water act on its banks? At what part of a river is the velocity greatest? What are the highest parts of the banks of a winding river?—222. How are the deposits in the lower parts of valleys formed? Are depositions more abundant in the bed of a river than on its margins? What effect is produced by these depositions?—223. What kind of detritus is carried to the mouth of rivers? How is it deposited there? What are deltas?—224. Describe the delta of the Nile. Whence comes the mud of that river?—225. Are deposits formed in lakes? Are lakes ever filled up by them? In lakes, what is the order of deposition of the detritus? How are hollows in the land sometimes filled up by deposits?—226. What effects are produced by sudden eruptions of water? Give an example.—227. How is the detritus of the sea connected with that of rivers and lakes? In what manner do the waves heap up detritus on the shores?—228. Give some examples of modern marine conglomerates?—229. How are pebbly beaches formed?—230. Are heaps of shells ever deposited on the shores? What other animals are sometimes buried there? May fresh-water and marine organic bodies be mixed together?—231. What deposits are formed by marine currents?—232. How are downs formed?—233. Give an account of sand-floods. How is sand-drift prevented?—234. What is peat? How is it formed? Mention some of its varieties.—235. What substances are preserved in it?—236. What is the form of coral islands? Why are they supposed to be placed on the summits of volcanic mountains? Are the reefs sometimes of great length?—237. What deposits are formed by springs? What is the nature of Travertine?—238. Describe the mode of formation of stalactites and stalagmites.—239. How is Bog Iron-ore formed?

CHAPTER II.

OF VOLCANOES AND EARTHQUAKES.

NATURE, DISTRIBUTION, ERUPTIONS, AND PRODUCTS OF VOLCANOES. EXTINCT VOLCANOES. CRATERS OF ELEVATION.—CONNEXION OF VOLCANOES AND EARTHQUAKES. PHENOMENA AND EFFECTS OF EARTHQUAKES.

240. Nature of Volcanoes.—Among the agents which have produced the greatest modifications upon the surface of the globe, Volcanoes and Earthquakes occupy a conspicuous place. Volcanoes are openings in the crust or outer layer of the globe, through which are emitted, at intervals or continuously, various substances, generally in a state of fusion or incandescence, together with aëriform fluids. They are usually situated on the summit of detached mountains, and present at their extremity the form of a funnel, to which the name of Crater is given. These mountains, which are always formed of substances ejected from the interior of the earth, are generally seated on old volcanic deposits, which differ in some respects from the modern products of volcanoes.

241. Distribution of Volcanoes.—Volcanoes are very extensively distributed, although large portions of the globe are entirely free from them. They usually form series of immense extent, frequently running in right lines, although widely separated from each other. Of these great series, one of the most remarkable is that presented by the chain of the Andes, which, extending from Patagonia along the western coast of South America, forms the isthmus by which the two great portions of the western continent are united, traverses Mexico, and continues its course northward into the Rocky Mountains of North America. From Patagonia to Mexico upwards of sixty volcanoes are known

to exist in this range. Another great range of volcanic action commences in the Aleutian Archipelago, and extends to Kamtschatka, the Kurile Isles, the Japanese and Philippine Islands, Loo Choo, Celebes, and the Moluccas, where it branches off to the east and west. In Europe there are few active volcanoes: Mount Etna in Sicily, Vesuvius on the opposite coast of Italy, Stromboli in the Lipari Islands, Hecla and five others in Iceland, are all that are known. But along with these may be mentioned the Azores, among which new islands have been protruded, Ischia and the Ponza Isles, Santorini and some neighbouring islands, which, although not active volcanoes, are seats of volcanic action. According to D'Aubuisson, M. Ordinaire estimates the number of active volcanoes at 205, of which 107 are in islands, the other 98 on the continents. It is a remarkable circumstance, that all the volcanoes which are at present in a state of activity are situated in the vicinity of the sea. It is also well known that there exist many submarine volcanoes, of which the island formed in 1707 near Santorini, those in 1638, 1720, and 1811, near St. Michael in the Azores, that in 1783 on the south-west coast of Iceland, that in 1831 not far from Sicily, and other phenomena of a like nature, afford ample proof.

242. Eruptions.—Volcanoes do not always continue in a state of activity, but experience periods of cessation, and even remain quiet for centuries. Others that have formerly been in action are now to appearance finally exhausted, and are called Extinct Volcanoes, of which there are upwards of a hundred in Auvergne, the Vivarais, and the Cèvennes in France. The first symptoms of volcanic action are subterranean noises, shakings of the ground, and the emission of smoke by the crater. The quantity of smoke increases, is mixed with ashes, and, in calm weather, is seen rising in the form of a vast column, which having attained a certain height, spreads out so as to represent the expanded summit of a pine. When the air is agitated, the smoke rolls along in immense clouds, which cover the surrounding

country with darkness. Jets of burning sand and ashes from the volcano traverse these columns and clouds, which sometimes emit lightnings. Then follow eruptions of incandescent masses of stone, which are projected into the air, and fall in all directions around the volcano, in the form of sand, dust, cinders, or stones. The shakings of the earth continue; the melted matter contained in the volcano ascends into the crater, and overflowing the lowest part of its edge, descends along the sides of the mountain, sometimes with great velocity, but more usually in a stream flowing with slow and majestic motion. Frequently an opening takes place in the side of the mountain, through which the lava makes its escape. Enormous currents of mud and water sometimes burst forth, and torrents of rain fall from the atmosphere, while the noxious exhalations often spread over the surrounding country, and destroy animal and vegetable life. The earthquakes which usually extend to a variable distance around the volcano, diminish or cease when the lava has flowed for some time, the explosions are discontinued, and the volcano attains a kind of rest, but often bursts forth again with redoubled fury, until it at length becomes quiet, and remains so perhaps for a long series of years.

243. Products of Eruptions.—The smoke of volcanoes generally consists of aqueous vapour, impregnated with hydrogen and carbonic acid gases, or sulphurous acid. The ashes consist of powder of a grey colour, in a state of extreme tenuity, and are usually mixed with sand. In the eruption of Hecla in 1766, complete darkness was produced by the clouds of ashes, to a great distance, and in 1812, a cloud of volcanic ashes and dust, from a volcano in the island of St. Vincent, covered the whole of Barbadoes, producing such a degree of darkness, that at noon the nearest objects could not be distinctly perceived. An eruption which took place in Sumbawa, one of the Molucca Islands, in April, 1815, covered Java, three hundred miles distant, with clouds of ashes, which fell on the fields to the height

of several inches. Volcanic sand consists of small cinders, usually mixed with crystals of augite and felspar, and forms the greater portion of the substances projected by volcanoes. Scoriæ or cinders consist of portions of the melted lava projected by the escape of elastic fluids. One of the most remarkable substances produced by volcanoes is sulphur, which, Humboldt remarks, is very rare in craters which are still burning, while all the old volcanoes ultimately become solfataras. Besides these matters, lava and mud are ejected in vast quantities.

244. Lava.—The mass of incandescent and melted matter, which, carried upwards to the mouth of the crater by the force of the elastic fluids, escapes at the lowest part of the brim, or through an aperture formed in the side of the mountain, is what is termed Lava. In descending along the sides, its currents scoop out grooves in the sand and ashes, carry part of these substances with them, and on arriving at the bottom relax their speed, and spread out or divide into branches. By the eruption of Skaptar Jokul in Iceland, in 1783, two vast streams of lava were produced, one of which was 50, the other 40 miles in length, with a breadth in some places extending to 15 miles, and an average depth of 100 feet. According to Dolomieu, these currents have two kinds of progressive motion, the matter of which they are composed sometimes rolling upon itself, and sometimes flowing beneath the consolidated surface as beneath a bridge. The velocity with which they move varies exceedingly, depending upon the inclination of the subjacent surface, and the mass and viscosity of the matter. Von Buch, who witnessed the eruption of Vesuvius which took place in 1805, saw a torrent descend from the summit to near the sea, over a space of about 4½ miles in three hours. In general, however, currents of lava move with extreme slowness, and Dolomieu mentions one which took two years to traverse a space of 380 metres. The tenacity of lavas is usually so great, that it is difficult to thrust a stick into them while they are flowing, and Spallanzani

hardly produced any impression upon a current, by throwing very large stones upon it. Lavas also take an extraordinary time in cooling. Currents are mentioned which were still progressing ten years after their eruption. Spallanzani, while passing over a current which had ceased to flow for eleven months, saw through the cracks in its surface that it was still red. Lava is generally composed of felspar, augite or hornblende, and oxide of iron; besides which there are often found in it olivine, leucite, garnet, epidote, stilbite, uranium, copper, lead, and arsenic.

245. Mud.—Besides these matters, torrents of water and mud are often ejected by volcanoes. Breislak is of opinion that most of those which are alleged to have issued from Vesuvius and Etna, were produced by heavy rains, the water of which, mixing with the ashes and sand, flowed to the bottom of the mountain, and were presumed to have come from its crater. Such volcanoes as rise into the region of perpetual snow, often cause torrents, which do not issue from the crater, but are produced by the melting of the snow and ice. Condamine relates, that six hours after an eruption of Cotopaxi, a village, 30 leagues distant in a straight line, was swept away by a torrent of this kind. At other times they arise from water accumulated in fissures and subterranean caverns; and, in general, cannot be supposed to come directly from the focus of volcanic action.

246. Volcanic Dykes.—The volcanic matters accumulated around a crater, are often cracked by the shocks to which they are exposed during eruptions. The fluid lava introducing itself into the crevices, fills them entirely, or in part, and forms a kind of veins or dykes. Sir E. de la Bèche informs us that the matter of these dykes differs considerably from that of lava, augite being more abundant in it, while the leucite, so common in lava, is of rare occurrence. In the middle, the texture is more crystalline than towards the side. According to Dr. Daubeny, dykes of a cellular trachytic lava are seen traversing volcanic tufa in Stromboli and Vulcanello. The old lavas of Etna are intersected by

dykes of a porphyritic rock. During an eruption of Vesuvius, in 1794, a rent was formed near the bottom of the mountain, 2375 feet in length, and 237 feet in breadth, which was filled with compact lava. These phenomena afford an explanation of the formation of trap dykes in the stratified rocks.

247. Extinct Volcanoes.—Many volcanoes are known, which, although their craters remain entire, and are surrounded by currents of lava, scoriæ, and ashes, have not been observed in action. These extinct volcanoes are found in almost every part of the globe; but the most celebrated are those of Italy, the Grecian Archipelago, Spain, Portugal, the banks of the Rhine, and Auvergne. In the latter country, in particular, the phenomena resulting from volcanic action are displayed in the most interesting manner; craters remaining entire, lava currents, tufas, and ashes, with remains of animals and plants overwhelmed by them. Extinct volcanoes are seldom isolated, but form groups often of vast extent; their craters are frequently of enormous size; and from the appearances which they present, it is to be inferred that volcanic action was formerly much more energetic and extended than it is now. These ancient volcanoes connect the modern volcanic with the trachytic series, and the latter pass into the basaltic and other trap rocks, to all of which therefore, including the porphyries and granites, a common origin must be assigned, although, from being placed under different circumstances, they vary in their phenomena.

248. Craters of Elevation.—Besides the craters of eruption, it has been maintained, by Von Buch and others, that many volcanic mountains present more extensive craters, which have been formed by the elevation of the ground previous to volcanic eruptions, and are therefore called craters of elevation. "Suppose," says Mr. Bakewell, "successive beds of lava were poured through a chasm, over the bottom of the ocean, and were consolidated over each other, filling and covering the chasm, through which they had been erupted. In a future volcanic paroxysm, the lava

being prevented from ascending through the former opening, and the force acting with compressed intensity, might upheave the beds of submarine lava, and the subjacent rocks, to a considerable height above the sea, before a new passage was opened for a subsequent eruption. This would be a crater of elevation. With the ancient lava, the lower beds of granite or other rocks might also be raised up."

249. Position of Volcanic Fires.—That a connexion exists between volcanoes situated at a vast distance from each other, is proved by many facts. Thus, in 1783, when a submarine volcano on the coast of Iceland suddenly ceased its eruptions, a volcano burst out in the interior of that island, at the distance of 200 miles; and four new volcanoes appeared in the Andes on the night in which Lima and Callao were destroyed by an earthquake. The source of the volcanic fires must therefore be situated deep in the interior. This is farther proved by the existence of several craters upon the oldest rocks in the series, and by the frequent ejection of fragments of these rocks. Besides, were these foci not deeply seated, the ground in the vicinity of volcanoes would sink down.

Other circumstances relative to volcanoes might be stated; but, as our space is limited, we must proceed to the consideration of earthquakes.

250. Connexion of Volcanoes and Earthquakes.—Earthquakes are most numerous and most violent in volcanic countries, and the regions in their vicinity. Sometimes they are confined to the district immediately surrounding a volcano; but, more generally, they extend to great distances with extreme rapidity. The great earthquake which destroyed Lisbon in November 1755, extended nearly over the whole of Europe, and even to the West Indies. St. Eubals, 20 miles south of Lisbon, was engulfed; a wave, 60 feet high, swept over the coast of Spain; at Tangier, in Africa, the sea rose and receded eighteen times; at Funchal, in Madeira, it rose 15 feet above high-water mark; and at Barbadoes it rose 20 feet. At Algiers, Fez, and

Morocco, the agitation was violent; and tremours were felt in Italy, Switzerland, Holland, Germany, Sweden, and Norway, as well as in Antigua and Barbadoes. "Earthquakes and volcanoes," says Mr. Bakewell, "may be considered as different effects produced by the agency of internal heat. They frequently accompany each other, and, in all instances that have been observed, the first eruption of a volcano is preceded by an earthquake of greater or less extent. Volcanoes do not make their appearance in every country where the shock of an earthquake is felt, but earthquakes are more frequent in volcanic districts than in any other."

251. Phenomena of Earthquakes.—Earthquakes are generally preceded by an unusual state of the atmosphere, subterranean noises resembling thunder, the rolling of carriages, and sometimes discharges of artillery, the drying of springs and wells, and the agitation of quadrupeds and birds. There is generally an unusual movement of the waters of the ocean and lakes, and springs frequently pour forth torrents of mud. The shocks succeed each other with more or less rapidity, and are often continued at intervals for weeks or months. The sea is violently agitated; but it is maintained by some, that during earthquakes, as well as during volcanic eruptions, the atmosphere does not, in any corresponding degree, participate in the agitation experienced by the crust of the globe, and the waters which partially cover it. During the shocks, fissures and chasms are made in the ground, through which smoke and flames sometimes issue, but more frequently torrents of water.

252. Effects of Earthquakes.—The permanent effects of earthquakes are less conspicuous than those of volcanoes. The modifications effected on the surface by volcanic agency consist of extensive accumulations of ashes, sand, scoriæ, and mud, great streams and deposits of lava, which fill up ravines and lakes, and cover large portions of country, together with conical mountains, often of enormous dimensions, produced by the progressive heaping up of the mat-

ters ejected by the craters; but volcanoes, it has been alleged, have never raised up nor overturned the strata through which their apertures pass, and have in no degree contributed to the elevation of the great mountains that are not volcanic. However, if we connect the phenomena of earthquakes and volcanoes, and consider that both have a common cause, the upheaving of the ground may be attributed as much to the one as to the other. The action of earthquakes is the displacement or undulation of the solid parts, and the agitation of the liquid. When the paroxysms have ceased, little effect may be found to have been produced; but often also open fissures, subsidences of the ground, deep pits, and elevated ridges, remain. It is believed that depressions of the strata more commonly result from earthquakes, but examples of elevation to a great extent are also adduced.

253. EARTHQUAKES OF LISBON AND CALABRIA.—The first intimation of the approach of the great earthquake, which in November, 1755, destroyed the greater part of Lisbon, was a subterranean noise resembling distant thunder. Presently afterwards the city was shaken with such violence as to overthrow nearly all its houses, and in about six minutes 60,000 people perished. The sea retired so as to lay bare the bed of the harbour, but immediately returned, with a front at least fifty feet higher than its ordinary level. A vast number of inhabitants had collected on a new quay built of marble, as a place of safety; but at the next shock, the earth opened and swallowed up the whole, together with a number of small boats and other vessels, filled with people. The depth of the water in this place was afterwards found to be 600 feet. The earthquakes which devastated Calabria commenced in February, 1783, and lasted to the end of 1786. In a circle of twenty-two miles radius around the city of Oppido, all the towns and villages were destroyed. The convulsive motion of the earth resembled the rolling of the sea, and was like what might have been produced by the agitation of a vast mass of liquid matter under the ground.

Various singular effects were produced, massive buildings being thrown down in one place, while those slightly constructed remained uninjured, and in other towns the reverse took place. Fissures opened and closed, some of them so large as to engulf houses and trees; others remained open; the ground sunk in some places, and lakes were formed, which have since remained. Great quantities of earth were hurled from steep hills into the valleys; and a mass, 400 feet in diameter and 200 feet thick, travelled four miles. The plain of Rosarno, consisting of alluvial soil, was found covered with circular hollows, with fissures radiating from them in all directions. It was estimated that 40,000 persons were destroyed by the earthquakes, and nearly 20,000 more by epidemics resulting from famine and noxious vapours.

254. Elevation of Land by Earthquakes.—As related by Mrs. Graham, a succession of earthquakes, which agitated Chili from the 19th November, 1822, to the end of September, 1823, had the effect of permanently raising a great extent of country. On the first shock on the night of the 19th November, the sea in Valparaiso harbour rose to a great height, then receded so as to leave the small vessels that were before afloat dry on the beach, and afterwards returned, but without gaining its original level on the land. On the morning of the 20th all the rivers and lakes were much swollen, in consequence of the dislodgement of snow from the mountains; in all the small valleys the earth of the gardens was rent, and quantities of water and sand were forced up through the cracks to the surface; and in the alluvial valley of Vina a la Mar, the whole plain was covered with cones of earth about four feet high, occasioned by the water and sand which had been forced up through funnel-shaped hollows, the whole surface being thus reduced to the consistence of a quicksand. The bed of the lake of Quintero was full of large cracks, and the level of the lake had apparently sunk very much. The granite of part of the coast was found rent by parallel cracks, many of which might be traced from the beach to the distance of a mile and a half.

The whole line of coast, to the distance of above 100 miles, appeared to have been raised above its former level. An old wreck of a ship, which before could not be approached, was now accessible from the land. The alteration of level at Valparaiso was about three feet, at Quintero about four feet. The old bed of the sea was laid bare along the coast, with oysters, mussels, and other shells, adhering to the rocks on which they grew. Mrs. Graham found reason to believe that the coast had been raised by earthquakes at former periods in a similar manner, several ancient lines of beach, consisting of shingle mixed with shells, extending in a direction parallel to the shore, to the height of fifty feet above the sea.

255. General Effects.—The more usual effect of earthquakes is the fissures which they produce in the mineral strata, and which are frequently of great extent. Thus Ulloa relates that in Peru, during the earthquake of 1746, a crack was produced a league in length, and four or five feet in breadth; and Grimaldi states that, by the earthquake of 1783, in Calabria, a calcareous mountain called Zefirio was split in two for the length of nearly half a mile, and a breadth of many feet. Extensive chasms open, slips and subsidences of the ground take place, ravines, valleys, and lakes are formed, maritime cliffs fall, the alluvium and soil are heaped up, and parts of the earth's surface are permanently elevated or depressed to a great extent. By the earthquake which happened in Jamaica in 1692, the highest mountain of the island was sunk; and on the 11th of August, 1772, the largest volcano in Java suddenly disappeared, after a violent eruption.

D'Aubuisson is of opinion that the effects of earthquakes are greatly exaggerated in a geological sense. "If," says he, "the geologist confines himself to the facts which the historian relates and proves, he will find that earthquakes are nothing more than mere trepidations of the ground. The mineral masses remain in the same order, and with the same solidity, as before. A few cracks and fissures are the only geological effects that result from them." Mr. Lyell, on the contrary, thinks that the superficial alterations arising from earthquakes and volcanoes, important as they are in themselves, are still more so as indicative of far greater changes in the interior of the earth's crust. "The renovating as well as the destroying causes are unceasingly at work, the repair of land being as constant as its decay, and the deepening of the seas keeping pace with the formation of shoals. If, in the course of a century, the Ganges and other great rivers have carried down to the sea a mass of matter equal to many lofty mountains, we also find that a district in Chili, one hundred thousand square miles in area, has been uplifted to the average height of a foot or more, and the cubic contents of the granitic mass thus added in a few hours to the land may have counterbalanced the loss effected by the aqueous action of many rivers in a century. On the other hand, if the water displaced by fluviatile sediment cause the mean level of the ocean to rise in a slight degree, such subsidences of its bed as that of Cutch in 1819, or St. Domingo in 1751, or Jamaica in 1692, may have compensated by increasing the capacity of the great oceanic basin. To conclude; it appears from the views above explained, respecting the agency of the subterranean movements, that the constant repair of the dry land, and the subserviency of our planet to the support of terrestrial as well as aquatic species, are secured by the elevating and depressing power of earthquakes. This cause, so often the source of death and terror to the inhabitants of the globe, which visits in succession every zone, and fills the earth with monuments of ruin and disorder, is nevertheless a conservative principle in the highest degree, and, above all others, essential to the stability of the system."

256. Summary.—Considered with reference to the formation of the crust of the globe, the phenomena thus exhibited at its surface are of importance as analogues of those presented by that part of its interior to which we have access. If we reflect that such of the operations of nature as we can

observe, are now conducted chiefly at the surface, in the atmosphere, whereas those of former periods were, in respect to what is now dry land, performed in the midst of the waters, we may find reason to think that the analogies are not so wide as they might at first sight appear. The crystalline deposits from aqueous solution, of which we can now trace the progress, are few and of small extent. Mechanical deposits, analogous to the conglomerates, shales, and sandstones of former periods, are much more numerous and more extensive. We see imbedded in them remains of plants and animals, which occupy positions similar to those of the fossil species. Superficial layers of vegetable matter, sometimes alternating with others of sediment, also occur. Lastly, igneous products from the interior, disgorged by volcanic apertures, spread over the surface, and alternate with deposits of another nature. This analogy of materials would lead us to suppose a similarity in the mode of their production, and connect the modern products of volcanoes with the ancient masses of the trap and granitic rocks. From the surface, then, we may at once betake ourselves to the plutonic regions of the centre, where perennial fires are supposed to rage.

Recapitulation.

240. Define a volcano.—241. Are volcanoes extensively distributed? Mention some examples. Do any occur in Europe? Are any situated near or in the sea?—242. Are volcanoes continually in action? What are the symptoms of an eruption? Describe its progress.—243. What are the products of volcanic eruptions?—244. Give an account of lava. What kind of motion has it? Does it cool rapidly? —245. Whence come the torrents of mud and water that accompany volcanic eruptions? Give an example.—246.

How are volcanic dykes formed ?—247. Are extinct volcanoes numerous ? Are they generally isolated ?—248. What is meant by craters of elevation ? How have they been formed ?—249. Is the source of volcanic fire deep seated ? For what reason is it supposed to be so ?—250. How are volcanoes connected with earthquakes ?—251. Describe the phenomena of earthquakes.—252. Are the effects of earthquakes more conspicuous than those of volcanoes ? What are they ?—253. Mention some results of the great earthquake of Lisbon. Also of those of Calabria.—254. Is the land ever permanently raised by earthquakes ? Give an account of the earthquakes in Chili, as described by Mrs. Graham.—255. What are the general effects of earthquakes ? Is there a difference of opinion as to the extent of their effects ? What is Mr. Lyell's idea of them ?—256. Does the observation of the changes taking place at the surface throw any light on those of the interior ?

'CHAPTER III.

OF THE INTERNAL PARTS OF THE EARTH, AND THEIR ACTION UPON THE SUPERFICIAL.

CENTRAL HEAT.—INCREASE OE TEMPERATURE FROM THE SURFACE.—DEPOSITION OF STRATA.—ERUPTIONS OF IGNEOUS ROCKS.—PHENOMENA OF VEINS AND MASSES.—ELEVATIONS AND SUBSIDENCES.

257. Central Heat.—The phenomena of volcanoes and earthquakes seem to indicate, that the internal parts of the earth, in whole or in part, are in a state of incandescence. The lowest rock to which we have access, Granite, has not,

however, been actually observed in that condition. Yet the appearances which it presents, and the veins which have emanated from it, to penetrate the superficial strata, afford no proof or even probability, of its having a different origin. This granite itself is traversed by trap-rocks, which must have come from beneath; and their connexion with volcanic products, both in mineralogical structure, and in local continuance, is apparent. It is thus probable, that the original situation of all the trap and volcanic deposits is beneath the granite. The gradual increase of temperature from the surface towards the centre, tends further to confirm the belief of intense central heat.

258. INCREASE OF TEMPERATURE TOWARDS THE CENTRE.—M. Cordier, who has particularly directed his attention to the increase of temperature as we descend into the earth, has inferred, from observations made by himself and others in mines, and on the water of Artesian wells: 1st, That there is a subterranean heat, independent of that derived by radiation, from the sun, and which rapidly increases as we remove from the surface; 2dly, That the increase of heat is not the same in all parts of the earth; 3dly, That the differences are not in relation with the longitudes and latitudes of the places where the observations have been made; 4thly, That the heat increases with the increase of depth more rapidly than was previously believed, insomuch that, within an external crust of from fifty to a hundred miles in thickness, is a mass of melted matter; 5thly, That originally the entire globe was in a state of fusion, that the superficial parts have gradually solidified by cooling, and that the earth's crust is constantly growing thicker. Others again are of opinion, that, although the globe has originally been fluid from fusion, and has gradually cooled at the surface, a period has arrived when an equilibrium is established. "Since the commencement of historical records," say Messrs. Milne Edwards and Achille Compte, "the temperature of the globe has not perceptibly changed, and by scientific calculations it may be proved, that the surface of

the earth receives from the sun in the course of a year a quantity of heat about equivalent to that which it loses in the same space of time. The heat of the interior of the earth now exercises but an imperceptible influence upon the temperature of the surface, and before this almost extinct influence could be diminished to one-half, it would take upwards of 30,000 years to elapse."

259. Deposition of the Primary Strata.—When the surface of the earth, at first enveloped, perhaps, in a nebulous atmosphere of vast extent, like that of a comet, became sufficiently cooled, it may be supposed that it assumed an envelope of an aqueous fluid, in which were chemically dissolved the materials, which being gradually deposited, formed the successive strata of the primary series of rocks, in which no remains of plants or animals are met with. We know of no fluid at the present day capable of holding all these substances in solution; but neither can we, with much probability, conjecture what might have been the case under circumstances so very different from any of which we have had experience. It has been supposed that the waters of the globe, acting so as to abrade and disintegrate the superficial parts, have again deposited them from the mechanical mixture thus formed, and that the central heat has consolidated them anew, so as to form the primary strata. But these primary strata are crystalline, and not to any extent fragmentary, and the heat sufficient to consolidate and crystallize their upper parts, would have sufficed to obliterate from the whole mass of strata all indications of foliated structure. But, however this may have been, the primary strata having been successively deposited and solidified, they were subsequently disrupted and disturbed by a force acting from beneath, locally and periodically, which protruded amongst them the granitic and porphyritic masses.

260. Progress of the Formations.—Vegetables and animals having appeared upon the globe, a new character was given to it. The ocean and the atmospheric waters, together with convulsions arising from causes operating

within, altered the existing surface, producing deposits, containing remains of organic life, gradually becoming more abundant. The phenomena which we see produced at the present day have formerly taken place on a larger scale. Periods of quiet have intervened, when vegetable life flourished with a vigour now unknown, and imparted by the greater temperature indicated by the nature of their remains deposited in all parts of the globe. Great currents of water swept over the surface, producing beds of conglomerate, and depositing in estuaries and lakes vast quantities of vegetable productions. The detritus of the land was spread over the bottom of the sea, and intermixed with multitudes of marine animals. Elevations and subsidences of the land altered the level of these deposits, and inclined their strata in various degrees. The new land has been acted upon in the same manner, whence it is that we find strata of marine origin now far inland, and raised to the height of several thousand feet. Gradually we find an approximation to the present order of things, the remains of plants and animals being often of the same genera as those now living; and at length we arrive at the present epoch, in which the earth, many times altered, and having its strata broken up and variously disposed, has been once more remodelled, and fitted for the inhabitation of man, whose ultimate destiny, however, has reference to another sphere of existence.

261. Eruptions of Igneous Matter.—From the infra-granitic regions of the globe, have emanated successive eruptions, which making their way through fissures formed in the strata, have been poured forth at the surface, or interjected among the previous deposits, where, as well as in the fissures, they have cooled and become solid. The successive ages of these ejections may be in some measure known by noting the strata through which they have penetrated. Thus, if basalt be found decidedly incumbent upon chalk, as it is in the north of Ireland, we know that it must have been erupted posteriorly to the deposition of that substance. Of actual time, however, in reference to geological

phenomena, we can know nothing. The order of succession may be determined, but not the number of years intervening between one epoch and another.

262. Phenomena of Trap Veins.—From the circumstance of these veins sometimes appearing at the surface, and remaining undecomposed while the rock around them has crumbled, they are also named dykes. They are of all sizes, from the breadth of a hundred feet or more to that of an inch or less, and have in some cases been traced to a vast extent. Thus, the Cleveland Basalt Dyke extends from the western side of Durham, crosses the river Tees, and proceeds through the Cleveland Hills to the sea between Scarborough and Whitby, having a course of from fifty to sixty miles. Such veins, when they come into contact with compact limestone, often render it crystalline; and when they traverse coal, convert it into a kind of soot or charcoal for several feet, and at a greater distance into coke. Slate-clay and bituminous shale are changed into a kind of jasper, and sandstone is indurated or altered in colour. These phenomena are such as might have been expected from an igneous mass in contact with previously consolidated rocks, but do not accord with the idea of an aqueous deposit filling up a fissure from above, as some have imagined a trap vein to be. Greenstone and granite veins traversing gneiss and granite generally produce little alteration in the rock with which they are in contact, which may arise from its having been at the time of intrusion at a high temperature. Sometimes, however, they have considerably altered it, having given it a burnt and crumbling appearance.

263. Phenomena of Trap Deposits.—The appearances presented by deposits or irregular masses of trap and granite, when in contact with stratified rocks, are various. Granite very frequently produces a transition to its own nature in that of the neighbouring rocks, as is especially the case when the latter contain one or more of its ingredients. The blue crystalline limestone of Glen Tilt, when in contact with granite, becomes white, loses its large-grained crys-

talline texture, is much harder, effervesces slowly with acids, and contains a large proportion of siliceous matter. Frequently granite and syenite produce little, if any, alteration on gneiss and other primary rocks with which they are in contact. The trap rocks, however, which are interposed among or overlie the secondary strata, generally alter the texture and colours of the latter, converting clay into jasper, hardening sandstone, rendering compact limestone crystalline, and obliterating the shells which it contains, or producing an ultimate union of them with the substance of the rock. Trap rocks assume various appearances when spread out into masses, and affect all situations from the lowest up to the top of the chalk formation, extensive deposits of basalt covering the latter in the north of Ireland. Their phenomena can be explained only by the supposition of their having been ejected from the interior of the globe, and consolidated under the pressure of the superincumbent rocks and sea. Besides these effects of the internal agents of the globe, phenomena of a somewhat different kind remain to be spoken of.

264. Elevation of the Strata.—It appears from a multitude of observations made on rocks of various ages, that by some power acting in the interior, ranges of mountains and large tracts of flat country have been suddenly or rapidly elevated above their original level. It is also believed that vast tracts have been gradually raised up with a kind of expansion of the surface, caused by continuous subterranean action. Granite, as has been stated above, is generally admitted as the fundamental rock of our present continents, or the external consolidated part of the central igneous mass. Specimens of that rock, and of gneiss and mica-slate, from different parts of the globe, are found to be similar. It is therefore probable that the general crust of granite was formed at one and the same period. But although granite is the lowest and most extensive formation known, it is yet seen in various parts of the world elevated into great ridges, forming the bases and sometimes also the

summits of mountain-ranges of vast extent. It had been generally supposed that granitic mountains were crystalline masses deposited from a universal ocean, until Mr. Bakewell in 1823 showed that the granite of the Alps had not been elevated to its present position until after the deposition of the limestone beds, many of which are analogous to the upper secondary strata of England. M. Elie de Beaumont, from a more extended series of observations, has made a similar inference, and concluded that entire chains of mountains have been raised at one geological period, and that paroxysms of elevatory force have occurred at many successive periods.

265. SYSTEMS OF DISTURBANCE.—"The detritus of the first dry lands," says Dr. Buckland, "being drifted into the sea, and there spread out into extensive beds of mud and sand and gravel, would for ever have remained beneath the surface of the water, had not other forces been subsequently employed to raise them into dry land; these forces appear to have been the same expansive powers of heat and vapour which, having caused the elevation of the first raised portions of the fundamental crystalline rocks, continued their energies through all succeeding geological epochs, and still exert them in producing the phenomena of active volcanoes; phenomena incomparably the most violent that now appear upon the surface of our planet." The periodical convulsive efforts of this subterranean power, have given rise, according to M. Elie de Beaumont, to several distinct systems of mountain-ranges, distinguished by a particular aspect, and peculiar direction. For example, the whole chain of the Pyrenees, the northern Appenines, the limestone chains to the north-east of the Adriatic, nearly the whole of the Carpathian chain, and the Hartz mountains, belong to one of these systems, which was elevated after the deposition of the chalk-formation, it being found ruptured, contorted, and often raised to the very summits of the mountains. In the British Isles, according to Mr. Phillips, the following systems occur:

First, After the deposition of the Cambrian slates. The Grampians and Lammermuir; the ranges of Donegal and Cavan; the Cumbrian Mountains; Snowdonia; the Orcynian Chain of Devon and Cornwall.

Second, After the deposition of the Coal-measures. The greater number of dislocations in the coal-fields of Great Britain; the great Penine Fault, Craven Fault, and Ribblesdale Anticlinals; the Derbyshire Faults; those of Mendip, South Wales, were then produced.

Third, After the deposition of some parts of the New Red Sandstone Strata. The Tynedale Fault; Faults in the coal-fields of Shropshire and Dudley; on the northern border of Derbyshire; the ridge prolonged from the Breiddin Hills.

Fourth, After the oolitic period. In Yorkshire and Dorsetshire.

Fifth, After the marine Tertiaries of the South of England, Isle of Wight, &c.

266. GRADUAL ELEVATION AND SUBSIDENCE OF LAND. —With these violent agitations must not be confounded the gradual elevation which portions of continents have been found to undergo, although it is probably owing to the same internal cause. "In parts of Sweden, and the shores and islands of the Gulf of Bothnia," says Mr. Lyell, "proofs have been obtained that the land is experiencing, and has experienced for centuries, a slow upheaving movement." Playfair argued in favour of this opinion in 1802; and, in 1807, Von Buch, after his travels in Scandinavia, announced his conviction that a rising of the land was in progress. Celsius and other Swedish writers had, a century before, declared their belief that a gradual change had, for ages, been taking place in the relative level of sea and land. They attributed the change to a fall of the waters both of the ocean and the Baltic; but this theory has now been refuted by abundant evidence; for the alteration of relative level has neither been universal, nor everywhere uniform in quantity, but has amounted, in some regions, to several feet in a century, in others, to a few inches, while in the south-

ernmost part of Sweden, or the province of Scania, there has been actually a loss instead of a gain of land, buildings having gradually sunk below the level of the sea.

"It appears, from the observations of Mr. Darwin, and others, that very extensive regions of the Continent of South America have been undergoing slow and gradual upheaval, by which the level plains of Patagonia, covered with recent marine shells, and the Pampas of Buenos Ayres, have been formed. On the other hand, the gradual sinking of part of the west coast of Greenland, for the space of more than 600 miles, from north to south, during the last four centuries, has been established by the observations of a Danish naturalist, Dr. Perigel." "It has also been shown by Dr. Darwin, that, in those seas where circular coral islands abound, there is a slow and continued sinking of the submarine mountains on which these masses of coral are based; while in other areas of the South Sea, where coral is found above the sea level, and in inland situations, and where there are no circular or barrier reefs, the land is on the rise."

267. Relative age of Igneous Rocks.—As the fundamental rock on which the strata repose, namely, granite, is itself traversed by other igneous rocks, and as these latter have surmounted the various deposits, it would appear that, with respect to original position, they are successively placed nearer the centre. Assuming granite thus as the original crust of the globe, or as a limit between the superficial and internal layers, we should proceed outwards, through the primary, secondary, and tertiary rocks, together with their associated depositions of igneous rocks, and inwards, through layers of these latter rocks, which, however, not being objects of observation *in situ*, can be only inferred to occupy particular positions, from the phenomena of their successive appearance at the surface. "There are," says M. Rozet, "two distinct geognostical series, in which the order of their relative oldness is inverse. In the series of stratified rocks, which commences with gneiss, the oldness diminishes as we rise towards the surface; whereas in that

of the unstratified rocks, which commences immediately beneath the gneiss, the masses are newer the more deeply they are situated.

"It is not surprising, after this, that several of the masses of the second series are known only by the portions of mâtter thrown up at the surface of the earth, as lavas, basalts, trachytes, &c. It is even reasonable to think that the more deeply these masses are situated, the less is their extent at the surface of the globe. In fact, the granitic rocks assume at the surface a greater development than the porphyritic rocks; the latter are more extended than the trap rocks; and so on, until we are come to the lavas of modern volcanoes, which issue only by narrow apertures, and scarcely spread around in a radius of two or three leagues."

268. Change of Climate.—The fossil vegetables found in the coal-formation in Greenland, North America, New Holland, and India, are very similar to those which occur in Britain, and indicate at the period of their deposition, a universal temperature similar to that of the tropical regions at the present day. Animals of a nature not adapted for cold, or even temperate climates, such as large Pachydermata and Crocodiles, occur imbedded in the strata and diluvial deposits of the northern parts of both Continents. Hence a great diminution of the earth's temperature is apparent, which can be satisfactorily accounted for only by the original fusion of the mass of the globe, and its gradual refrigeration. In concluding this chapter, I cannot do better than present an abridgment of M. Delafosse's remarks, entitled, "Conjectures respecting the internal mass of the globe."

269. Igneous Fusion of the Globe.—The nature of the agents which have their seat in the interior of the earth, and consequently that of the mass in which they take rise, being for ever concealed from direct observation, we can only hope to obtain some idea of them, by endeavouring to ascend by reasoning from effects which are known, to the causes which produce them. In the first place, then, the

flattened form of the earth would lead us to suppose that it had been originally fluid, it being exactly what would have resulted from its rotation. There is another fact which confirms this result, while it at the same time affords an explanation of it; namely, the internal heat of the earth, independent of that which it receives from the sun. This high temperature, the remains of its original heat, of which only a part has been dispersed, is shown by calculations established upon the laws of heat, to be such as would have taken place, if the globe had progressively cooled to the state at which we now find it. There is thus every reason to believe that the fluidity which the earth possessed before it assumed its spheroidal form, was owing to heat, that it was at first completely fluid, but that in consequence of gradually cooling, its superficial parts being first fixed, formed a solid crust, of which the thickness has increased from without inwards, and which is the true primordial soil. Moreover, we are led to admit that the internal mass of the globe still possesses its original fluidity, and that a temperature capable of holding in a state of fusion most of the known rocks, exists at an inconsiderable depth.

270. Proofs of Fluidity from the Earth's Density. —Another important fact is made known to us by astronomical and physical science, which is, that the earth is denser in its interior than at the surface, that there must be a progressive increase of density in its layers as we proceed inwards, and that the mean density of all the layers is about five times greater than that of water, and consequently nearly double that of the mineral crust, for the stony matters of which rocks are composed have specific gravities varying only from 2 to 3. The internal mass cannot therefore be composed of the same matters as the crust, but may probably be formed of metallic substances, which alone of all those known are much heavier than those of rocks. Besides, the small quantity of metals that occurs accidentally disseminated in the midst of the mineral crust, in the form of veins or nodules, has been visibly carried from below

upwards by the internal agents. Thus we might admit with much probability that the internal mass is to a great extent formed of metallic matters, held in fusion by the high temperature which prevails at that depth, and no doubt disposed in the order of their respective densities. The lightest substances of this nature which we know being the metals of the earths and alkalies, which on account of their avidity for oxygen, oxidize and lose their lustre as soon as they come in contact with water or air, it will be seen that they ought to occur in greatest abundance in the superficial layers, and by their oxidation give rise to the mineral crust, which in fact is composed almost entirely of such substances oxygenated and combined. For a long time there was the insurmountable difficulty of conceiving how the granitic rocks could have been produced by the cooling of a great mass in a state of fusion; but this difficulty no longer exists when, by the aid of fire, chemists have been able to compose of all these substances most of the mineral species which enter into the composition of these rocks.

271. Further Proofs from Eruptions.—The theory of the original fusion of the globe, and the still existing fluidity of its internal parts, is confirmed more and more, when we follow it in its consequences. Thus, the cooling and contraction which the oxidized crust must have gradually undergone, will serve to account for part of the solutions of continuity which are observed among the strata. Moreover, the high temperature to which the fused matters which compose the central mass are submitted, readily enables us to conceive the production and accumulation, beneath the solid envelope, of the gaseous matters whose existence is manifested in volcanic eruptions. Lastly, the pressure exercised against this flexible and unequally resisting envelope, by the gases and fluid matters themselves, explains, in a very plausible manner, the phenomena which precede, accompany, and follow those eruptions, such as earthquakes, the raising of mountains, the dislocations and tiltings of strata, the formation and filling of veins, and that

of those deep cracks, or vast spiracles, through which the lavas escape with violence, to spread out at the exterior.

272. Fluidity consistent with the various Phenomena.—The theory in question also well explains the immense quantity of volcanic products which have been brought from the interior of the earth, the identity of nature of the lavas ejected in the most distant parts of the globe, and the resemblance which they present to the rocks of the deposits which appear to have been formed by elevation. Lastly, it accounts with equal ease for the heat of warm springs, and the similarity of the mineral substances which they contain, to those which exhale from the craters of volcanoes or solfataras. In fact, the hot mineral waters bring to us the temperature of the deep places where they have sojourned: further, they without doubt carry with them the residue of the gaseous emanations, which rise from the bowels of the earth, as from a common reservoir, and of which a part depositing itself, whether on the walls of the cracks of the mineral crust, or in the cavities or basins with which they communicate, give rise to those deposits of ores, which are named veins or nodules.

The above details are sufficient to show the agreement which exists between the different orders of astronomical, physical, and geological facts, and which appears to furnish an irresistible argument in favour of the igneous origin of our planet. We shall add only a single observation, which is, that it appears to result equally from the above hypothesis, and from the researches of geologists, that the temperature at the earth's surface was formerly higher, and at the same time more uniform, than it has been since the commencement of the modern period; that in the now cold or temperate regions, it was at least equal, perhaps superior, to that of the warmest parts of our globe, and that this temperature has gradually diminished, so that the equatorial climate has been, by little and little, thrust back from the poles to within its present limits.

Having spoken of the causes which have operated at the surface of the globe since the commencement of the present order of things, and of those which have acted in its interior at all ages, we have now to indicate some phenomena observed in the intermediate region of the earth's crust, and others which, at its surface, have followed the general convulsions which preceded the present condition of the earth.

RECAPITULATION.

257. Has granite ever been observed in a melted state? Is it traversed by trap veins? Whence has the trap come? —258. What renders it probable that the central parts of the earth are hot? What are M. Cordier's conclusions on this subject? Does the earth continue to cool? With what degree of rapidity?—259. When the earth at first became cooled, with what was it enveloped? How were the primary strata formed? Are they chemical deposits? or have they been mechanical sediments hardened by the central heat? How have they been traversed by the igneous masses?—260. Describe the manner in which the successive strata may be supposed to have been deposited.—261. Can the periods at which igneous eruptions took place be determined?—262. What alterations in the strata are produced by trap veins?—263. What changes are caused by masses of igneous rocks?—264. Have large tracts of country been suddenly elevated? How is it probable that the general crust of granite was formed at one and the same period? Is granite ever elevated into mountain ranges? Who first showed that the granite of the Alps had been raised after the deposition of our uppermost secondary rocks? —265. By what means have the deposits been raised from the ocean? Who has traced several distinct systems of elevation? Mention one of them. How many are indicated in Britain by Mr. Phillips?—266. In what part of the north

of Europe has a gradual elevation of land been observed? Have similar changes been noticed elsewhere?—267. In what respect is the series of igneous rocks the inverse of that of the aqueous? Is it accordant with reason and observation, that the more deeply the igneous rocks are seated, the less extended they should be at the surface?—268. How is a change of climate indicated by organic remains?—269. What are the principal reasons for believing that the earth was originally in a state of igneous fluidity?—270. How does the consideration of the earth's density render this fluidity probable? How is it probable that the internal mass consists chiefly of metals?—271. What proof is derived from volcanic eruptions and earthquakes?—272. What other phenomena may be explained by the theory of igneous fluidity?

CHAPTER IV.

OF VACUITIES IN ROCKS FILLED WITH ORES OR DEPOSITS FROM WATER.—METALLIC DEPOSITS, VEINS, AND THE PREVALENCE OF METALS IN PARTICULAR ROCKS.—CAVERNS AND SUBTERRANEAN CURRENTS.—BOULDERS.—DILUVIAL DEPOSITS.—THE FLOOD.—GENERAL IDEA OF THE FORMATION OF THE GLOBE.

273. Having in the preceding chapters spoken of the causes which have operated at the surface of the globe, since the commencement of the present order of things, and of those which have acted in its interior at all ages, I have now only to indicate some phenomena observed in the intermediate region of the earth's crust, and others, which in its upper parts preceded the modern alluvial deposits. As some remarks on those popular subjects the Flood, and the accord-

ance of geological results with the Mosaic account of the creation, may be expected, I am unwilling to pass over these subjects in silence. Lastly, a brief recapitulation of facts will indicate the prevalent ideas of geologists respecting the formation of the globe. The nature of metallic veins, hot springs, and subterranean waters, requires to be the first alluded to, as connected with phenomena already described.

274. Metallic Deposits.—The substance of rocks is frequently permeated by metallic matters, in grains, or filaments, and the debris or detritus of rocks often contains metals and ores in sufficient quantity to be worked. Sometimes the metallic substances are collected into beds, nodules, irregular plates or veins. Beds or strata of clay iron-ore are common in the Coal-Formation, where they alternate with shale and sandstone. Beds of iron-ore also occur in gneiss and other primary rocks. Such deposits are generally thin, but sometimes they swell out to a great thickness. They are seldom of great extent, but gradually or suddenly contract, and are said to wedge out. Few metals occur pure, they being usually combined with sulphur, oxygen, or acids. In the former state they are called native metals, in the latter ores. Thus we have native gold, silver, and iron, and various ores of lead, tin, and other metals. When either a native metal or an ore is abundantly intermixed with the substance of a bed or stratum, the entire deposit is sometimes worked as an ore. In all these cases, the metallic matter must be supposed to be of contemporaneous origin with the rocks or formations containing it; but the case is different when it is deposited in veins.

275. Metallic Veins.—If we suppose a fissure formed in a rock, or a series of rocks, to be filled with mineral substances of a nature different from the materials of the rock, together with metallic ores, we may obtain a sufficiently correct idea of a vein of this kind. These veins are chiefly found in the primary, and lower, and middle secondary rocks. They vary from an inch, or less, to several yards in width, and sometimes have an extent of many miles. They

are not plates of equal thickness, but swell out and contract at irregular intervals, branch off in various directions, reunite, and often intersect each other. It is not known to what depth they extend, nor has it been ascertained whether they become wider as they descend. In veins of this kind, the walls of the bounding rock are generally covered with a layer of mineral substances, such as quartz, calcareous spar, or fluor spar, upon or amidst which the ores are deposited; and frequently an alternation or intermixture of ores and minerals takes place, until the whole cavity is filled up. Partial vacuities, however, are often met with, in which the finest crystals of the different minerals are found. The ores in a vein which crosses several strata of different rocks often vary. Thus copper-ore, silver-ore, and iron ore, may be found at different depths in the same vein.

276. Formation of Metallic Veins.—Various opinions have been entertained as to the manner in which the fissures have been filled up. As the ores and minerals in veins generally have no relation to the ingredients of the bounding rocks, and as the same vein frequently contains the same ores in a part of its course, which traverses several strata differing in nature, it is obvious that the ores and sparry substances are not always derived by transudation or electric transfusion from the strata. Some, as Hutton and Playfair, have supposed them to have been injected into the fissures from below, in the same manner as the igneous materials of trap veins; while others, as Lehman and Necker, conceive them to have come in a gaseous or sublimated state from the heated regions of the interior, and to have been gradually deposited. Both modes are probable enough; but in cases where masses or nuclei, or imperfect veins, occur in rocks, we cannot admit such an origin. There would seem to have been a separation of particles from the rock, whether by molecular aggregation or electrical transference; and yet these deposits, if not far removed from veins, may have been transferred into cavities from a vein itself by the modes of transfusion mentioned. Whatever may be the

mode in which the cavities have been filled, it at least appears, that the prevalence of metallic veins in a rock is determined by its original condition as to fissures, mountain-limestone, for example, being more productive than shale, because its cracks have been retained open, while those of the latter have crumbled.

277. Prevalence of Metals in particular Rocks.—Metals and ores are found in greater abundance in the older rocks than in the newer, and in mountains or hilly regions than in plains. Thus, in Britain, metallic veins occur in gneiss, killas, mountain-limestone, and the coal-formation; but none of any importance have been found above the New Red Sandstone. This circumstance itself affords an additional probability of the ejection of the matter of veins from beneath. Metals and ores are not confined to such deposits, but are often found in grains or fragments in sand, gravel, or other detritus. The following summary account of the geological localities of metallic ores is from Mr. Bakewell's Introduction:—

"Platina and the recently discovered metals, palladium, rhodium, osmium, and iridium, have chiefly been found in the sands of rivers.

"Gold and silver are found in primary and transition rocks, in porphyry and sienite, and in the lowest sandstone. Gold has been occasionally discovered in coal, and very abundantly in the sands of rivers, and sometimes in volcanic rocks. Silver is very frequently associated with lead, in different proportions, in the lead ores of Great Britain: in some of them the quantity is so considerable, as to be worth the expense of extracting it from the lead, by calcination.

"Mercury is found in slate, in limestone, and in coal-strata.

"Copper, in primary and transition rocks, in porphyry, sienite, and occasionally in sandstone, in coal-strata, and alluvial ground. Masses of native copper, of many thousand pounds weight, are said to be found on the surface, in the interior of North America.

"Iron, in every kind of rock.

"Tin, in granite, gneiss, mica-slate, and slate.

"Lead and zinc, in primary and transition rocks, particularly in the mountain-limestone; also in porphyry and sienite; in the lowest sandstone, and occasionally in coal-strata.

"Antimony, in primary and transition mountains; it is also found in porphyry and sienite.

"Nickel, bismuth, cobalt, in primary mountains, except limestone, trap, and serpentine. Cobalt and nickel also occur in transition mountains, and in sandstone.

"Arsenic, in primary and transition mountains, and in porphyry.

"Manganese, in primary and transition mountains, and occasionally in the lower stratified rocks.

"Molybdena and tungsten, uranium, and titanium, in granite, gneiss, mica-slate, and slate. The latter metals, with chromium, columbium, cerium, and tellurium, are very rare in nature, and can only be reduced to the metallic state with great difficulty."

278. Caverns.—It appears that the great limestone deposits of all ages abound in cavities of irregular form and varied extent. At the present day, caves of every variety of form are produced in rocks along the sea-shore by the action of the waves, which crumble down the stony masses; but these primeval caverns are often found in the heart of solid masses of rock, without any communication with the exterior, their existence having been discovered in the course of mining. One of the most celebrated of these caves is that discovered by some workmen at Kirkdale in Yorkshire, in 1821, and subsequently examined by Dr. Buckland. It is 240 feet in length, 14 feet high, and from 3 to 7 in breadth. The floor was covered with a coat of mud or loam, about a foot thick, in which were found bones of hyenas, tigers, bears, elephants, rhinoceroses, and other quadrupeds, together with those of some birds. From the appearances exhibited, it was inferred that the cave had been for a long

series of years a den of hyenas, and that these animals had dragged into it the limbs of others, the bones of which were found gnawed. Another celebrated cavern is that of Gaylenreuth, in Franconia, consisting of several chambers, in the mud deposited in the bottom of which were found bones of bears, hyenas, foxes, and other animals, including some of the tiger and elephant. In the south of France, similar caves have been found, containing bones of animals, and some even with human bones and fragments of pottery. Various conjectures have been offered respecting the manner in which these organic remains were introduced, such as subterranean currents of water, and the rushing of animals into them to avoid convulsions or floods. The human bones, however, are in no case supposed to be contemporaneous with the rest. Dr. Lund has recently examined eighty-eight caves in Brazil, which he thinks have been formed on the shores of an ancient lake or sea. They are all partially filled with a kind of soil similar to that covering the surface of the country, and the floor is usually of stalagmite.

279. Subterranean Currents.—There is little doubt, that many of the caverns in limestone districts have been formed by the action of subterranean rivulets gradually wearing away the rock in the course of fissures. In the Speedwell mine, in Derbyshire, the miners, in blasting a tunnel, discovered a large cave in which a torrent fell with a roaring noise; and, in like manner, a cavern with a lake was found in the middle of the mountain called Matlock High Tor. Many instances are known of rivulets disappearing entirely by sinking into the earth, and others of their reappearing at the distance of several miles. In limestone districts the surface is sometimes covered with deep hollows, which have resulted from the falling in of the roofs of caverns or passages thus formed by currents of water. The existence of vast quantities of water at various depths, is especially rendered apparent by the practice of boring Artesian wells, so common in France, by which an abundant supply of pure water may be obtained in a district

otherwise almost destitute of it. In a well of this kind sunk at Tours, in 1829, to the depth of 330 feet, the water brought up fragments of thorns, seeds of marsh plants, together with land and fresh-water shells, unchanged; and at Reinke, near Bochum, in Westphalia, a well having been sunk to the depth of 143 feet, brought up small fishes from three to four inches in length. Hence Mr. Bakewell argues, that subterranean currents may have frequently deposited the remains of animals found in caverns.

280. Erratic Blocks or Boulders.—The powerful action of currents of water at the surface is exhibited by the prodigious quantities of blocks and stones that are found scattered over extensive tracts of country, and at vast distances from fixed rocks of the same mineralogical character. Some of these masses are so large, and so little rounded, that they are supposed to have been transported by ice. Great mountain-chains in general, and the Alps in particular, present on their declivities, vast quantities of transported blocks, which may be traced to similar masses of solid rock in the central parts of the chain. On the two slopes of the Alps are seen blocks of granite, protogene, gneiss, and hornblende; on the western side great numbers have crossed the deep valleys which separate the Alps from the Jura, on the declivities of which they have ascended to a great height. Some of them are also found in the Lake of Geneva, in which they must have been deposited subsequently to the formation of its basin. The only reasonable way of accounting for the present position of these blocks seems to be their transportation by glaciers, which in former times have been of much greater extent than now. On the vast plains of Lower Germany, Russia, and the countries bordering the Baltic, are observed similar blocks of granite, gneiss, porphyry, and others, which are met with in sites in the Scandinivian peninsula, whence they may have been floated on ice. The conglomerates of the old red sandstone and other secondary formations shew, that great floods had taken place at intervals during the progress of these de-

posits; and the diluvial strata of the newer tertiary period testify to violent cataclysms of the same nature, by which masses of rock were carried to vast distances.

These transportations have by many been attributed to the Deluge of the Scriptures; but others, with more reason, have assigned them to convulsive movements antecedent to that catastrophe.

281. THE MOSAIC DELUGE.—Over a large portion of Europe the diluvial detritus is said to indicate a current proceeding southward; in various parts of Britain there are indications of a direction from west to east; in the Alps the boulders have proceeded in various directions from the central masses, often following the valleys. During this period it would appear that the denudations took place which have excavated, grooved, and broken up, the upper parts of the previously deposited strata, so as to produce many of the inequalities of the earth's surface. It has been supposed by M. Elie de Beaumont, that the great revolution thus produced, by which myriads of the ancient inhabitants of the globe were destroyed, was caused by the protrusion of the igneous masses of the Andes. However this may be, there is little reason for considering the Mosaic Deluge the same as that which produced the diluvial deposits. Remains of the human species have not hitherto been found in them, and those of the animals which they contain are of species generally different from those now existing. The history of the Flood given in the Scriptures is that of a gradual rise and subsidence of waters, such as would probably have left no remarkable traces of its brief existence. At all events, the deposits left by the waters disclose no phenomena satisfactorily referrible to that deluge, which probably was but partial, its object having been the destruction of the human race, which at that time inhabited only a limited portion of the globe.

282. GENERAL IDEA OF THE FORMATION OF THE GLOBE. —"In the beginning God created the Heaven and the Earth." It is not very probable that the ingenuity of man

will ever enable him to discover when or how this creation took place. Was the earth formed of pre-existing materials? Was it a fragment of the sun, or a concretion of particles existing in space? Was it originally a comet, a meteorite, or an aqueous mass? The history of its formation, and of the successive creations by which it was fitted for the habitation of the human species, is briefly given in the Scriptures, but only as introductory to the history of man. If we peruse the Mosaic record without any regard to geological science, we find that, when first called into existence, the earth was destitute of arrangement, without inhabitants, and involved in darkness. In six days it was reduced to order, and covered with vegetables and animals. On the first day, God dispersed the darkness; on the second, He formed the atmosphere; on the third, He gathered the waters together, caused the dry land to appear, and made the earth bring forth the various tribes of vegetables, from the most tender cryptogamic plant to the noblest fruit-bearing tree; on the fourth day, He caused the sun, the moon, and the stars, previously formed, to shed their light upon the earth; on the fifth, He created the various classes of animals which inhabit the waters, and that of birds; on the sixth, He brought into existence the mammalia, and perhaps reptiles, if they had not been formed on the preceding day, perhaps also all the other animals that inhabit the land. Lastly, He created a man and a woman, to whom He gave a dominion over the creatures, which their descendants have retained to the present day.

Various interpretations have been given of the Mosaic history of the creation; and some few ignorantly-wise persons considering our geological knowledge in many respects perfect, and conceiving that it contradicts the Scriptures, have judged the latter to be untrue, reasoning thus:—The world is the work of God, the Scriptures are said to be His also; now we have examined the world thoroughly, and understand it perfectly, and, as the doctrines inferred from its phenomena are not in accordance with the scriptural account, we cannot hesitate a moment in rejecting the latter as spurious. But our knowledge of the world is different now from what it was a few years ago when these men so spoke; what to them was truth is clearly in our eyes error, and we know that they misinterpreted the Book of Nature. Wise as we are, then, we have learned just enough to shew us, that our interpretations of nature cannot yet be brought fairly to bear upon the Bible, however anxious some of us may be to demonstrate the falsehood of its doctrines. We are not even agreed as to the precise meaning of the first chapter of Genesis. But we may all be very well persuaded, that as the Scriptures disclose to us truths, such as we could never have possibly discovered of ourselves, but which we yet know to be truths, and as they are consistent throughout, they must have emanated from the fountain of truth. "Let God then be true, and every man a liar."

As to the ideas regarding the earth prevalent at the present day, but liable, in the progress of observation, to be materially altered, they appear to be somewhat as follows:—The globe was originally a fluid mass, probably in a state of fusion. It gradually cooled by the radiation of its heat into space. A solid crust was then formed, probably of granite; its atmosphere became condensed; and a mass of water enveloped it. Either from this water the primary rocks were deposited in a crystalline form, or the waters corroded the granitic crust and formed layers, which were consolidated successively by the central heat. Convulsive actions took place, by which the primary layers were variously broken up, and matter protruded from within. Some plants and animals were formed now, or at a previous period. Agitations of the waters wore down the rocks, and carried off the vegetation. Successive layers of mineral matter were formed at the bottom of the sea, then partially consolidated, then raised to the surface in patches. New tribes of plants and animals were formed, lived, died, and were buried in the ever-forming strata, which at one time were covered deep by the ocean, and at another elevated. The crust of the earth was repeatedly broken through, and cracks produced in it were filled by melted matter from the interior, which when consolidated formed veins, and expansions of unstratified rocks. Successive races of vegetables and animals were created, successive depositions took place, the bed of the ocean varied continually, elevations and subsidences were produced. Each successive creation of animals and plants approached nearer to the present creation. The igneous matters, instead of flowing at great depths under the pressure of the ocean, began to be erupted in the open air in the form of volcanoes. The deposits of rocky substances, carbonized plants, and extinct animals, were at length, by what might seem a series of irregular and confused formations and convulsions, reduced to a condition favourable to the existence of a higher order of beings than had hitherto appeared, for the progressive advancement of which in number and intelligence, prospective provision had thus been made. Man was then created, and although changes have taken place since the period of his first appearance upon the earth, the atmospheric and subterranean agents acting as before, a comparative stability has taken place. How long this state of things may continue cannot be conjectured; but, judging from analogy, we may infer that a grand catastrophe will one day involve in destruction the present inhabitants of the globe.

The general and partial theories by which phenomena are attempted to be explained, will be found in the numerous geological treatises, to which the present will serve as an introduction. It is conceived that the student having carefully perused the statements here given, and acquired a practical knowledge of the various rocks, and of the simple minerals of which they are composed, will find himself sufficiently advanced to be able to observe in nature for himself, and to comprehend the details and reasonings presented in books. If such be the case, the author has accomplished his task.

RECAPITULATION.

274. How are metallic substances disposed? Do many metals occur pure?—275. What is the nature of metallic veins? Are they extensive? To what depth do they extend?—276. How have the cracks containing metallic substances been filled?—277. Are metals equally dispersed through all rocks? Mention the rocks in which each metal occurs.—278. In what rocks are caverns most common? Mention a few remarkable caves.—279. Are there subterranean currents of water? May they have formed caves?—280. How have large blocks and rolled stones been dispersed?—281. What mountains are supposed to have been elevated at the period when they were scattered? Can the effects of the Mosaic deluge be traced?—282. What general idea have you formed of the manner in which the crust of the globe has been deposited and arranged?


OUTLINE GEOLOGICAL MAP
OF THE
BRITISH ISLANDS
Trap
Tertiary Rocks
Chalk
Oolite
New Red Sandstone
Coal Formation
Old Red Sandstone
Greywacke &c.
Gneiss &c.
Granite
ORKNEY ISLANDS
OUTER HEBRIDES
Frith of Forth
Berwick
Sunderland
Whitby
Whitehaven
Flamborough Hd.
York
Leeds
Liverpool
Manchester
Chester
Lincoln
Nottingham
Derby
Stafford
Warwick
Northampton
Cambridge
Ipswich
Yarmouth
Norwich
The Wash
Carnarvon
Harlech
Montgomery
Cardigan
Caermarthen
Milford Haven
Bristol Channel
Gloucester
Oxford
Reading
London
Margate
Dover
Maidstone
Salisbury
Winchester
Southampton
Chichester
Brighton
Beachy Head
Dungeness
Dorchester
Portland Isle
Isle of Wight
Launceston
Plymouth
Falmouth
Start Pt.
Londonderry
Carrickfergus
Downpatrick
Armagh
Dublin
Wicklow
Wexford
Waterford
Cork
Galway
Limerick
Ennis
Kirkcudbright
Dumfries
Carlisle
Peebles
Selkirk
Aberdeen
Banff
Inverness
FRANCE

GLOSSARY.

ACICULAR. Needle-like, or very slender. *Acus*, a needle.

ACOTYLEDONOUS. Plants having seeds or reproductive germs destitute of cotyledons or seed-lobes. A, not; κοτυληδων, cotyledon.

ACTINOLITE. Raystone. A mineral having fasciculated or radiated slender crystals. Ακτιν, a ray; λιθος, a stone.

ADIPOCERE. A substance resembling hard tallow. *Adeps*, fat; *cera*, wax.

AGATE. A kind of siliceous stone usually found in amygdaloid. Αχατης, a river in Sicily.

AGGREGATED. Formed of collected fragments or individuals. *Aggrego*, to gather.

ALBITE. A kind of felspar. *Albus*, white.

ALGÆ. Sea-weeds. *Alga*, Latin.

ALLUVIUM. Particles or fragments of rocks and other matters carried away by water. *Alluo*, to wash away.

ALUM. Sulphate of alumina. *Alumen*.

ALUM-SHALE. Shale containing iron-pyrites, which on decomposing produces sulphuric acid, the union of which with the alumina of the shale forms alum.

AMBER. Fossil resin.

AMETHYST. A variety of quartz, generally of a violet colour. A, not; μεθυω, to be intoxicated, from its being supposed to prevent intoxication.

AMIANTHUS. A mineral composed of delicate fibres. A, not; μιαινω, to pollute.

AMMONITE. Shell of an extinct molluscous animal, curved so as to have a fancied resemblance to the horns of Jupiter Ammon.

AMORPHOUS. Without determinate form. A, not; μορφη, shape.

AMPHIBIOUS. Living on land and in water. Αμφι, both; βίος, life.

AMYGDALOID. A trap rock in which are imbedded roundish or almond-shaped bodies. Αμυγδαλα, an almond; εἶδος, likeness.

ANOPLOTHERIUM. An extinct quadruped, so named because unarmed. Ανοπλος, unarmed; θηριον, a wild beast.

ANTHRACITE. A kind of coal. Ανθραξ, charcoal.

ANTHRACOTHERIUM. An extinct quadruped, so named because found in lignite. Ανθραξ, coal; θηριον, a wild beast.

ANTISEPTIC. Preventive of putrefaction. Αντι, against; σηπω, to putrefy.

ARBORESCENT. Tree-like. *Arboresco*, to grow like a tree.

ARENACEOUS Sandy. *Arena*, sand.

ARGILLACEOUS. Clayey. *Argilla*, clay.

ARTESIAN WELLS. Wells bored to a great depth, after the manner of the people of Artois. *Artesium*, Artois.

ASBESTUS. A fibrous mineral not injured by fire. Α, not; σβεννυω, to extinguish.

ASTERIAS. Star-fish. Αστηρ, a star.

ATTRITION. Wearing away by friction. *Ad*, to; *tero*, to rub.

AUGITE. A mineral of a dark green or black colour, occurring in trap and volcanic rocks. Αυγη, lustre.

AVALANCHE. A mass of snow or ice falling from a mountain.

AZOTE. Nitrogen. Α, not; ζωη, life, it being injurious to life.

BASALT. A dark coloured rock. *Basaltes*, Latin.

BASIN. A hollow or valley.

BELEMNITE. An extinct genus of mollusca. Βελεμνον, a dart.

BINARY. Of two ingredients. *Binarius*.

BITUMEN. Mineral pitch. Latin.

BITUMINOUS SHALE. Argillaceous shale, impregnated with bitumen.

BLENDE. A metallic ore, sulphuret of zinc. German.

BLUFF. A high precipitous bank.

BOTRYOIDAL. Like a bunch of grapes. Βοτρυς, a grape-bunch.

BOULDERS. Large rounded blocks of stone.

BRANCHIÆ. Gills. Respiratory organs of fishes and other aquatic animals. Βραγχια, gills.

BRECCIA. Angular fragments connected by a cement or paste. Italian.

CALAMITES. Fossil plants allied to Equiseta. *Calamus*, a reed.

CALC SINTER. Travertine. Deposit of carbonate of lime from springs.

CALCAIRE GROSSIER. A tertiary limestone of the Paris basin. *Calcaire*, limestone; *grossier*, coarse.

CALCAREOUS. Of the nature of lime. *Calx*, lime.

CALCEDONY. A siliceous mineral. *Chalcedon*, a city of Bithynia.

CALCIUM. The metallic base of lime.

CAMBRIAN SYSTEM. A series of inferior secondary, or transition rocks. Greywacké. *Cambria*, Wales.

CAPILLARY. Hair-like. *Capillus*, hair.

CARBON. An elementary substance. Charcoal and diamond are chiefly composed of it. *Carbo*, a coal.

CARBONATE OF LIME. Carbonic acid and lime combined. Most limestones are of this substance.

CARBONIC ACID GAS. A natural gas which often issues from the ground. *Carbo*, charcoal; it being obtained from the slow burning of coal.

CARBONIFEROUS. Coal-bearing. Carboniferous System, a series of rocks, including the Coal-Formation. *Carbo*, coal; *fero*, to bear.

CATACLYSM. A deluge. Κατακλυζω, to deluge.

CEPHALOPODOUS MOLLUSCA, having their feet or organs of motion placed around the head. Κεφαλη, the head; πους, a foot.

CETACEA. Animals of the whale kind. *Cete*, a whale.

CHALK. An earthy limestone, the uppermost of the secondary series.

CHERT. A siliceous mineral allied to flint.

CHLORINE. An elementary substance, which supports combustion. Χλωρος, green.

CHLORITE. A simple mineral of a green colour. Χλωρος, green.

CIRRHIPODA. Animals allied to mollusca, having slender appendages. Barnacles. Κιρρος, a tuft; πους, a foot.

CLINKSTONE. Phonolite, a Felspar rock of the trap series, so named on account of its being sonorous when struck.

COLOLITE. Fossil intestines. Κῶλον, intestine; λιθος, stone.

COAL-FORMATION. A series of deposits in the Carboniferous System.

COMMINUTED. Broken into small fragments. *Con*, together; *minuo*, to lessen.

CONCHIFERA. Shell-bearing, two-valved mollusca. *Concha*, a shell; *fero*, to bear.

CONCENTRIC. Having a common centre. *Con*, together; *centrum*, centre.

CONCHOIDAL. Shell-like.

CONCRETION. A union of particles or fragments. *Con*, together; *cresco*, to grow.

CONFORMABLE STRATA. Having their planes parallel.

CONGLOMERATE. Rounded fragments coherent or cemented. *Con*, together; *glomero*, to heap.

CONTORTED. Twisted or waved. *Con*, together; *torqueo*, to bend.

COPROLITE. Fossil excrement. Κοπρος, excrement; λιθος, stone.

CORAL. A general popular name for Madrepores and other calcareous secretions of marine polypi.

CRATER. The funnel-shaped cavity of a volcano. Κρατηρ, a cup or bowl.

CRETACEOUS SYSTEM. Chalk. *Creta*, chalk.

CRINOIDEA. Radiated animals, so named because bearing a fancied resemblance to κρινον, a lily.

CROCODILE. A large aquatic reptile of the lizard family.

CRYSTALLINE. Formed of or resembling crystals.

CRYSTAL. A regular form of a simple mineral. Χρυσταλλος, ice.

CRYPTOGAMIC PLANTS. A great order destitute of seeds, such as sea-weeds, mosses, and lichens. Κρυπτος, concealed; γαμος, marriage.

CUMBRIAN ROCKS. Part of the lower secondary series. *Cumbria*, Cumberland.

CYCADEÆ. An order of plants having a short stem, with primated leaves. Κυκας, a palm.

CYPERACEÆ. Sedges and allied genera.

DEBRIS. Matter abraded from rocks. French.

DELTA. A triangular deposit of alluvia at the mouth of a river, named from the triangular Greek letter Δ.

DENDRITIC. Resembling a tree. Δενδρον, a tree.

DENUDATION. Exposure of rocks by the removal of strata by the action of water. *Denudo*, to lay bare.

DESICCATION. Drying up. *Desicco*, to dry up.
DETRITUS. Matter worn off. *De*, from; *tero*, to rub.
DEVELOPMENT. Growth, increase, or completion.
DICOTYLEDONOUS. Plants of which the seeds have two cotyledons, or seed-lobes. Δις, double; κοτυληδων, cotyledon.
DILUVIUM. A deluge. Also sand, gravel, clay, and other matters transported by deluges. Latin.
DINOTHERIUM. A gigantic herbivorous animal, having two decurved tusks in the lower jaw. Δεινος, terrible; θηριον, a wild beast.
DIP, inclination of strata.
DISINTEGRATE. To wear away, or fall into fragments, or separate into its constituent particles. *De*, from; *integer*, entire.
DOLERITE. Greenstone.
DOLOMITE. Limestone containing magnesia.
DRUSY CAVITY. A hollow space in a rock or mineral, having the walls crusted with crystals. *Druse*, a little swelling.
DOWNS or DUNES. Sand-hills.

ELVAN. A granitic or porphyritic dyke or vein. Term used in Cornwall.
ENCRINITES. Lily-shaped animal. Εν, in, κρινον, a lily.
ENDOGENOUS. Plants the growth of whose stem takes place by additions in the centre. Ενδον, within; γεινναω, to produce.
EOCENE. Mr Lyell's term for the first or most ancient of the four tertiary periods or deposits. Ἠως, dawn; καινος, recent.
EQUISETA. Plants of the Cryptogamic class, growing in water. *Equus*, a horse; *seta*, a hair: Horse-tail.
ERODE. To gnaw away. *E*, from; *rodo*, to gnaw.
ERRATIC BLOCKS. Wandering or travelled stones, transported from a distance. *Erro*, to wander.
ESCARPMENT. A rock, cliff, or abrupt face of land. *Escarper*, to cut steep.
ESTUARY. An inlet or basin, entered by the sea and a river. That part of a river into which the tide flows. *Æstus*, the tide.

EXOGENOUS. Plants of which the stem grows by additions at the surface. Εξω, without; γεννάω, to produce.

EXUVIÆ. Castings, as the skins of snakes and crabs; or shells of mollusca. *Exuo*, to put off.

FÆCES. Excrement. Latin.

FALUNS. Tertiary strata in France, analogous to the Crag.

FAULT or TROUBLE. A dislocation in the strata.

FELSPAR. A simple mineral. *Fels*, a rock. German.

FELSPATHIC. Composed of, or containing Felspar.

FERRUGINOUS. Of the nature of, or containing iron. *Ferrum*, iron.

FILIFORM. Threadlike. *Filum*, a thread.

FLUOR-SPAR. Fluate of lime.

FLUVIATILE. Belonging to rivers. *Fluvium*, a river.

FORMATION. A series of rocks, supposed to have been produced under similar circumstances.

FOSSIL. An animal or vegetable substance embedded in a rock. *Fodio*, to dig.

FRIABLE. Easily reduced to powder.

FUCUS. A sea weed.

GALENA. Lead-glance, sulphuret of lead. Γαλεω, to shine.

GARNET. A simple mineral of a deep red colour. *Granatum*, a pomegranate.

GAULT. Beds of dark coloured clay, in the greensand formation.

GEOLOGY. The science of the earth. Γη, the earth; λογος, doctrine.

GLACIER. An accumulation of ice and snow on mountains. *Glace*, ice. French.

GNEISS. A stratified rock composed of the same materials as granite. Saxon.

GONIOMETER. An instrument for measuring the angles of minerals. Γωνια, an angle; μετρον, a measure.

GRAMINIVOROUS. Grass-eating. *Gramen*, grass; *voro*, to eat.

GRANITE. An unstratified rock, usually composed of felspar, quartz, and mica. *Granum*, a grain.

GRAPHIC. Resembling written characters. Γραφω, to write.

GRAPHITE. Plumbago or black lead. Γραφω, to write.

Greensand. A formation intervening between the upper oolite and the chalk-formations.

Greenstone. A kind of trap rock, composed of augite or felspar and hornblende.

Greywacke'. A transition or lower secondary rock. *Grau*, grey; *wacké*, claystone.

Gymnospermous. Plants whose seeds are bare.

Gypsum. Sulphate of lime, or Paris plaster.

Hackly. Having sharp projecting points.

Hæmatite. An ore of iron. 'Αιμα, blood.

Herbivorous. Eating grass or vegetables. *Herba*, grass; *voro*, to eat.

Hippopotamus. A large animal inhabiting rivers. 'Ιππος, a horse; ποταμος, a river.

Homogeneous. All of one kind. 'Ομος, alike; γενος, a kind.

Hornblende. A simple mineral of a dark green colour. German.

Hornstone. A siliceous mineral approaching to flint.

Hyæna. A genus of carnivorous quadrupeds. 'Υς, a boar.

Hydrogen. An elementary principle, a constituent of water. 'Υδωρ, water; γεννοω, to produce.

Hypersthene. A kind of hornblende. 'Υπερ, above; σθενος, strength.

Hypogene. A term proposed for granite and other connected rocks. 'Υπο, under; γεννοω, to produce.

Iceberg. A floating mass of ice. *Berg*, a hill. German.

Ichthyodorulite. Fin-bones of fishes. 'Ιχθυς, a fish; δορυ, a spear.

Ichthyosaurus. Fish-lizard. A genus of fossil Saurian animals. 'Ιχθυς, a fish; Σαυρος, a lizard.

Igneous. Formed by fire. *Ignum*, fire.

Iguanodon. A fossil lizard. *Iguana*, a kind of lizard; 'οδων, a tooth.

Indurated. Hardened. *Durus*, hard.

Injected Rocks. Thrown in among or through others. Trap rocks. *Injicio*, to throw in.

Invertebrate Animals. Those destitute of internal skeleton.

JASPER. A hard mineral of the quartz family.
JET. A hard compact lignite.
JURA LIMESTONE. Oolitic limestone.

KAOLIN. Porcelain clay.
KATACLYSM. A deluge. Κατακλυσμος, a deluge.
KELLOWAY ROCK. A member of the oolitic group.
KILLAS. Clay-slate and greywacké series, so named in Cornwall.
KIMMERIDGE CLAY. A member of the oolitic group.

LACUSTRINE. Formed in lakes. *Lacus*, a lake.
LANDSLIP. A portion of land or rock that has slidden down.
LAVA. Melted matter ejected from a volcano.
LEPIDODENDRON. A genus of fossil plants, of which the stems are covered with scars like scales. Λεπις, a scale; δενδρον, a tree.
LEUCITE. A simple mineral, of a whitish colour, found in volcanic rocks. Λευκος, white.
LIAS. A series of clays, shales, and limestones, belonging to the oolitic system.
LIGNITE. Fossil wood partially converted into coal. *Lignum*, wood.
LOAM. Fine soil.
LOLIGO. Cuttle-fish.
LONDON-CLAY. Clay and sand of the tertiary series, equivalent to the Calcaire grossier of the Paris basin.
LOPHIODON. A genus of extinct pachydermata. Λοφος, a crest; οδων, a tooth.
LUDLOW ROCK. A member of the upper part of the greywacké series.
LYCOPODIACEÆ. Plants allied to the genus Lycopodium, or club-moss.
LYDIAN STONE. A quartzose mineral of a grey or black colour.

MADREPORE. A genus of corals.
MAGNESIAN LIMESTONE. A series lying above the coal-formation.
MAMMALIA. Animals bearing mammæ or teats. *Mamma*.

Mammifera. Animals bearing Mammæ or teats. *Mamma.*
Mammilla. A nipple-like prominence.
Mammoth. An extinct species of elephant.
Marl. A mixture of clay and lime.
Marsupial Animals. Having a pouch in which they carry their young. *Marsupium*, a pouch.
Mastodon. A genus of extinct quadrupeds allied to the elephants. Μαστος, a nipple; ὀδων, a tooth; the grinders having conical prominences.
Medusæ. A tribe of marine radiated animals.
Megalonyx. A fossil animal of vast size. Μεγας, large; ὀνυξ, claw.
Megalosaurus. A fossil animal of the saurian family. Μεγας, large: σαυρος, a lizard.
Megatherium. A gigantic fossil quadruped resembling a sloth. Μεγας, large; θηριον, a wild beast.
Mesotype. A simple mineral of the zeolite family, common in some trap rocks.
Meteorite. A mineral mass formed in the atmosphere.
Mica. A simple mineral. *Mico*, to shine.
Mica-Slate. A slaty rock, composed of mica and quartz.
Miocene. One of Mr. Lyell's four tertiary epochs. Μειων, less; καινος, new.
Molar Teeth. Grinders, or back teeth. *Mola*, a mill.
Molluscous. Soft animals, as cuttle-fish and oysters. *Mollis*, soft.
Monitor. A kind of lizard.
Monocotyledonous. Plants whose seeds have a single cotyledon or seed-lobe. Μονος, single; κοτυληδων, a seed-lobe.
Mountain Limestone. Carboniferous limestone. A series of strata lying below the coal-formation.
Multilocular. Shells having many cavities. *Multus*, many; *loculus*, a partition.
Multivalve. Shells of more than two pieces. *Multus*, many; *valva*, a door.
Muschelkalk. Shell Limestone.

New Red Sandstone. Variegated sandstone. A series lying over the magnesian limestone.
Nickel. A metal which occurs in meteoric iron.

NITROGEN. Azote. An elementary substance. Νιτρον, nitre; γεννάω, to produce.

NORMAL. Regular. *Norma*, a rule.

NUMMULITE. A fossil shell, so named on account of its form. *Nummus*, money; λιθος, a stone.

OBSIDIAN. Volcanic glass or vitreous lava.

OLD RED SANDSTONE. A formation lying below the mountain limestone.

OLIVINE. A simple mineral of a greenish colour, common in basalt and lava.

OOLITE. A limestone often exhibiting small round particles or grains, somewhat resembling the roe of a fish. Ωον, an egg; λιθος, a stone.

ORGANIC REMAINS. Fossil remains of animals and plants.

ORTHOCERATITE. A long conical straight shell with numerous dissepiments. Ορθος, straight; κερας, a horn.

OSMIUM. An elementary metallic substance. Οσμη, smell.

OSSEOUS. Bony. Containing or composed of bones. *Os*, a bone.

OSSIFEROUS. Containing bones. *Os*, a bone; *fero*, to bear.

OXFORD CLAY. A member of the oolitic series.

OXIDE. The combination of a metal with oxygen. Οξυς, acid.

OXYGEN. A gaseous principle. Οξυς, acid; γενναω, to produce.

PALÆONTOLOGY. The science of fossil remains. Παλαιος, ancient; οντα, beings; λογος, doctrine.

PALÆOTHERIUM. An extinct pachydermatous quadruped. Παλαιος, ancient; θηριον, a wild beast.

PEPERINO. A volcanic tufa, of which the particles are compared to pepper.

PERCOLATE. To filter through. *Per*, through; *colo*, to strain.

PERMEATE. To pass through or penetrate.

PETRIFACTION. A substance converted into stone. *Petra*, a rock; *facio*, to make.

PHANEROGAMOUS. Plants producing flowers and seeds. Φανερος, evident; γαμος, marriage.

PHONOLITE. Clinkstone. Φωνη, a sound or voice; λιθος, a stone.

PISOLITE. Peastone. A variety of Oolite. Πισον, a pea; λιθος, a stone.
PITCHSTONE. A mineral substance somewhat resembling hard pitch, and allied to obsidian.
PLASTIC CLAY. Clay so named because easily moulded. A member of the Tertiary Series. Πλασσω, to fashion.
PLATINA. A metal. Plata, silver, Spanish.
PLESIOSAURUS. A fossil animal allied to the crocodile family. Πλησιον, near to; σαυρος, a lizard.
PLIOCENE. One of the tertiary periods. Πλειων, more; καινος, new.
PLUTONIC ROCKS. Igneous rocks. *Pluto*, the fabled god of the infernal regions.
POLYPI. An order of radiated animals. Πολυς, many; πους, a foot.
PORPHYRY. An igneous rock containing distinct crystals in a homogeneous or crystalline base. Πορφυρα, purple.
PORTLAND OOLITE. A series of Oolitic beds.
PRECIPITATE. A substance thrown down or deposited from a chemical solution. *Præcipito*, to throw headlong.
PRIMARY. First in order.
PROTOGENE. A kind of granite containing talc or steatite. Πρωτος, first; γεννaω, to produce.
PTERODACTYLUS. A winged reptile. Πτερον, a wing; δακτυλον, a finger.
PUDDING-STONE. Conglomerate.
PUMICE. A spongy lava. *Pumex*.
PURBECK LIMESTONE. Part of the Wealden formation.
PYRITES. Sulphuret of iron or copper. Firestone. Πυρ, fire.
PYROGENOUS. Igneous, Plutonic, or trap rocks. Πυρ, fire; γενναῶ, to produce.

QUARTZ. A simple mineral, composed of silica. German.

RADIATED. Rayed; composed of fibres, or of members emanating from a common centre. *Radius*, a ray.
RED SANDSTONE. So named from its colour. Old Red, below; and New Red, above the Coal-formation.
ROCK. Geologically, a mineral deposit of any degree of hardness or aggregation.

ROESTONE. Oolite.

RUMINATING ANIMALS. Oxen, sheep, deer, and others, which chew their food a second time.

SALIENT ANGLE. A projecting angle.

SANDSTONE. Concrete particles of sand.

SAURIAN REMAINS. Those of animals of the lizard or crocodile family. Σαυρος, a lizard.

SCHIST. Slate. Σχιζω, to split.

SCHORL. A black variety of Tourmaline.

SCORIÆ. Cinders.

SEAM. The separation of two layers or strata.

SECONDARY. Second in order.

SEDIMENTARY. Thrown down from a state of mechanical suspension in water. *Sedeo*, to settle down.

SELENITE. Crystallized gypsum. Σεληνη, the moon.

SEPIA. Cuttle-fish.

SEPTARIA. Fossils divided by partitions. *Septum*, a partition.

SERPENTINE. A rock so named because often variegated like the skin of some serpents.

SHALE. Slate-clay.

SHINGLE. Pebbles or stones worn round by water.

SIGILLARIA. A genus of fossil plants of which the surface seems as if impressed with a seal. *Sigillum*, a seal.

SILICA. One of the earths. *Silex*, flint.

SILICEOUS. Composed of Silica.

SILICIFIED. Converted into flint. *Silex*, flint; *fio*, to become.

SILURIAN. A system of transition or lower secondary rocks, so named by Mr. Murchison. *Silures*, ancient inhabitants of part of Wales.

SIMPLE MINERALS. Minerals.

SIMPLE ROCKS. Composed of a simple mineral species.

SOLFATARA. A half-extinct volcano, emitting sulphurous exhalations.

SPECULAR IRON-ORE. A variety of iron-ore with polished shining surfaces. *Speculum*, a looking-glass.

STALACTITE. Carbonate of lime formed like icicles on the roofs of caves. Σταλαγμα, a drop.

STALAGMITE. Carbonate of lime forming expanded layers on the bottoms of caves. Σταλαγμα, a drop.

STEATITE. Soapstone. A magnesian mineral.

STIGMARIA. A genus of fossil plants, of which the stem is marked with small tubercles. Στιγμα, a mark burnt in.

STILBITE. A mineral of the zeolite family.

STRATUM. A bed or layer of rock. *Stratum*, a bed.

STRATIFIED. Disposed in layers.

SYENITE. A variety of granite, having hornblende as an ingredient. *Syene*, a town in Upper Egypt.

TALUS. A sloping heap of debris at the foot of a rock.

TERTIARY STRATA. A series of sedimentary rocks, the third in order.

TESTACEOUS MOLLUSCA. Shell-fish. *Testa*, a shell.

THERMAL WATERS. Hot waters. Θερμη, heat.

TITANIUM. A metal.

TRACHYTE. A kind of lava. Τραχυς, rough.

TRANSITION ROCKS. Those intermediate between the primary and secondary, or passing from the former to the latter. *Transeo*, to pass over.

TRAP. Igneous rocks. *Trappa*, a stair, Swedish.

TRAVERTINE. A limestone deposited from water holding carbonate of lime in solution. Calcareous tufa.

TRILOBITE. A crustaceous animal found in the older secondary rocks. Τρεις, three; λοβος, a lobe.

TUBERCLE. A small knob. *Tuberculum.*

TUFA, CALCAREOUS. Carbonate of lime deposited from water.

TUFA, VOLCANIC. A volcanic rock of earthy texture.

TUFA, TRAP. Conglomerate of trap rocks.

UNIVALVE SHELL. Composed of one piece. *Unus*, one; *valva*, a door.

URANIUM. A metal

VALLEY OF ELEVATION. Originating in a fracture of the strata, and an upward movement of the fractured part.

VALLEY OF EXCAVATION. Originating in a depression.

VANADIUM. A metal. *Vanadis*, a Scandinavian deity.

VASCULAR. Full of vessels. *Vasculum*, a little vessel.

VEIN. A plate of mineral matter intersecting a rock or series of rocks.

VERTEBRATED ANIMALS. Those having an internal skeleton.

VERTICAL. Perpendicular. *Vertex*, the crown of the head.

VITRIFIED. Converted into glass. *Vitrum*, glass.

VOLCANIC. Produced by volcanoes.

VOLCANO. A vent for the escape of ignited matters, and gas from the interior.

WACKE'. A somewhat soft and earthy variety of trap rock.

WEALDEN FORMATION. A series of rocks lying beneath the Greensand. Weald of Sussex.

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FINIS.

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