A guide to geology / [John Phillips].

Contributors

Phillips, John, 1800-1874.

Publication/Creation

London : Longman, 1835.

Persistent URL

https://wellcomecollection.org/works/sxrbrbff

John Davidson

A

GUIDE TO GEOLOGY.

Prof. Phillip delin.

J.W. Lowry sculp.

GEOLOGICAL VIEW OF THE ISLE OF WIGHT.

h. Hastings sand.– l. Lower green sand.– g. Gault.– u. Upper green sand.– c. Chalk.– t. Tertiary.

A GUIDE TO GEOLOGY.

BY

JOHN PHILLIPS, F.R.S. G.S.,

PROFESSOR OF GEOLOGY IN KING'S COLLEGE, LONDON;

SECRETARY TO THE YORKSHIRE PHILOSOPHICAL SOCIETY;

ASSISTANT SECRETARY TO THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE;

AUTHOR OF ILLUSTRATIONS OF THE GEOLOGY OF YORKSHIRE.

"Et mare contrahitur, siccæque est campus arenæ
Quod modo pontus erat, quosque altum texerat æquor
Existunt montes."—Ov. *Metam.*

SECOND EDITION.

LONDON:

PRINTED FOR

LONGMAN, REES, ORME, BROWN, GREEN, AND LONGMAN.

1835.

PRINTED BY RICHARD TAYLOR,
RED LION COURT, FLEET STREET.

I1

TO THE MEMBERS OF

THE YORKSHIRE PHILOSOPHICAL SOCIETY

THIS VOLUME

IS MOST RESPECTFULLY DEDICATED

BY ONE

WHO HAS LONG LABOURED FOR THEM AND WITH THEM

IN ADVANCING

THE LOVE AND KNOWLEDGE OF NATURE.

PREFACE

TO THE FIRST EDITION.

My object in this work is to answer an inquiry, which has been very often addressed to me,— What are the elementary facts, and admitted generalizations in Geology, which it is requisite to be acquainted with before reading descriptive or theoretical works, or undertaking researches in that science? The really introductory part of geological literature in England is certainly scanty, though several works, both of popular and scientific merit, have greatly animated, and partially directed, the growing desire to unveil the natural history of the earth. The introductory chapter of the 'Geology of England and Wales,' by Mr. Conybeare, has been found of great value in this respect; Mr. Bakewell's Introduction is deservedly popular;

and, as a convenient book of reference, Mr. De la Beche's Manual is unrivalled.

I wish to exclude from this little volume all discussion of theory, and yet to imbody in it those important inferences, once debated, but now established, which give to Geology consistency of reasoning, clearness of description, and an acknowledged place in the circle of inductive science. Among these *inferences* I do not hesitate to admit the distinction of rocks into two classes, according to their igneous or aqueous origin; the existence of internal sources of heat; and the elevation of the present continents and islands from the bed of the ancient sea by subterranean movements. The interesting questions concerning local changes of climate, and successions of races of marine and terrestrial animals and plants, have been cleared of much obscurity, and rescued from the danger of over-generalization; and though on these points we have much to learn, the limited truths which have been established must take their place among the growing mass of elementary geological knowledge.

In the descriptive part of the volume, a method of classifying the subjects of geological research has been adopted in accordance with the elementary views given in the first part, so as to present a considerable body of arranged information in a small compass. It was thought proper to give an illustration, at some length, of the principle upon which to investigate the subject of the diluvial accumulations, because on this the spirit of discussion is still active, and it seemed desirable to furnish the mind of the student with some certain grounds for admitting the comparatively recent movement of tumultuous waters over many parts of the dried and inhabited land. The origin, the conditions, and the effects of these floods are matter for his further research.

A few tables of the relations of the earth to the solar system, simple views concerning the temperature of the surface and interior of the earth, of the air, and of the sea, a short process for calculating barometrical observations, and some other statements, are given at the end, for the purpose of reminding the student of the close and increasing connexion of Geology with Physical Science.

He cannot be reminded too often of this connexion; he cannot strive too much to cultivate it; for it is precisely the application of mathematical, mechanical, and chemical laws which is converting the indigested heap of geological facts into a system of at least partial truths, which harmonize with the general œconomy of nature, and are capable of receiving continual correction and enlargement, until they afford a secure basis for a general theory of the earth.

York, July 1, 1834.

PREFACE

TO THE SECOND EDITION.

SINCE the first appearance of this work, frequent reflection upon the plan and execution of it, aided by the friendly criticism of some eminent geologists, has led me to simplify some explanations, to make others more complete, and to illustrate at greater length some points which appeared to require it. Among the enlargements from this latter cause will be found some sections (§ 33. to 36.) on Physical Geography, others (§ 91. to 100.) on the Structure of Rocks, and (§ 160, 161.) on Mineral Veins.

In the account of the several systems and formations of strata, the lists of organic remains have been amended, characteristic species indicated, the relation to existing genera of the fossils in each system expressed numerically, and many other improvements effected, while the whole has been reduced to a more regular form.

The list of authors placed at the end of the volume will, it is hoped, be found sufficiently extensive, though a large portion of foreign works, and a multitude of controversial, topographical, and other writings, relating to English Geology, are unavoidably omitted. A new plate has been added, of a peculiar kind, for the purpose of showing an example of a mode of drawing, remarkably applicable to geological illustration. The Isle of Wight is indeed singularly adapted for such a drawing, yet there are few districts which may not be usefully represented in a similar manner.

April 22, 1835.

CONTENTS.

PART I.—ELEMENTARY FACTS AND INFERENCES.

PART II.—GENERALIZATIONS.

PART III.—DESCRIPTIVE AND PRACTICAL GEOLOGY.

PART IV.—TABLES, CALCULATIONS, &c.

A

GUIDE TO GEOLOGY.

PART I.

ELEMENTARY FACTS AND INFERENCES.

DEFINITION OF THE SCIENCE.

1. GEOLOGY, founded upon observations of the effects of terrestrial agencies upon a grand scale, admits of being taught, first, by actual demonstration of the phænomena as they are laid open by nature, in mountains and valleys, cliffs and ravines; secondly, by the aid of specimens of natural products, and representations and descriptions of the manner of their occurrence. As we cannot transport a pupil to the summit of the Alps, the glens of the Grampians, or the caverns of the Peak; as we cannot at pleasure show him the bold cliffs of Hastings, Whitby, or Charmouth, the wasting shores of Norfolk, or the extension of new land along the margin of the Adriatic, he must be taught to reason upon these characteristic phænomena by the aid of pictorial or verbal representation. With this view, we found museums of

specimens, publish sections and maps, and models, and endeavour, by lectures on these examples and imitations of geological occurrences, to lead the student to the contemplation of the magnificent objects themselves. Could we dispense with these artificial aids, were it possible to compress into a reasonably short geological tour an actual inspection of the most important facts, much of the technical language which is now found so convenient might be dispensed with; many explanations might be spared; the monuments yet remaining of the changes which the earth has undergone, would tell their own history, and never require the little aid of words. But the writer and the lecturer must have recourse to other methods; and, by a studied arrangement of representations and reasoning, strive to impress the same truths, with equal force of conviction, which are directly gathered from the more vivid though less regular lessons in the glorious theatre of nature.

2. The teacher of geology must suppose himself called upon to answer questions concerning both the facts of the science, and the inferences to be collected from them; and his instructions will be so much the more successful as he takes these questions in the most natural order of their occurrence, and answers them most completely and satisfactorily. In doing this, he is not at liberty to neglect even elementary truths; because if these were passed over in compliment to such as have made progress in the science, those for whose advantage he is specially interested would be called to the unreasonable task of labouring without tools, of reasoning without data.

3. The definition of any physical subject or property, or mathematical abstraction, is a description of something real or representative, and is easy; but the limitation of the several fields of research in which the human intellect may employ itself, demands almost a prophetic spirit: it is not the beginning, but the consummation of the study, and perhaps never can be complete. While the intimate union and close dependence of all the physical sciences become daily more and more evident, the difficulty of rigidly defining any one of them is continually increasing.

Having due regard to these considerations, we may say that it is the province of geology to investigate the ancient natural history of the earth. For this purpose geologists must observe the effects of terrestrial agencies, both organic and inorganic, which are now in progress, in order to understand those which have been performed in earlier periods; they must inquire what changes now take place upon the land and in the sea; whether these be due to mechanical, chemical, or vital agency; and compare these effects with the monuments of more ancient revolutions; and thus endeavour to trace the physical conditions of the globe from the earliest period to the present date, so as to present a correct history of the successive steps by which it has been brought to its actual state, and made fit for the purposes which it now fulfills.

PROGRESS OF THE SCIENCE.

4. It is obvious that for the right and full understanding of the phænomena which come before a geologist, he must often refer to the established results of other branches of physical science. Mineralogy must be his guide in ascertaining the ingredients of rocks; chemistry must teach him their ultimate constitution; he must apply to botany and zoology for the examination of extinct plants and animals; and to astronomy and general physics for correct general data within which to confine his inferences. How clearly does this show us the reason why the universally occurring facts concerning the structure of the globe have only within a few years been submitted to any regular investigation, or reduced to general truths! Generalization in geology can only be based upon the established results of other more limited natural sciences: every discovery of laws in chemistry and zoology widens the foundation of rational geology; and so long as men adhere to the method of philosophy taught by Bacon, geology can never again become a speculative science, never again be an arena for discussing delusive hypothesis and unsubstantial conjecture.

5. Geology is purely a science founded in exact observation and careful induction: it would therefore be not a harsh sentence to refuse this title to the mass of mere opinions and conjectures which for some hundred years before the nineteenth century were pompously designated Theories of the Earth: with much better right may the title of geologists be

conceded to Strabo and the old philosophers who studied the local phænomena of their countries and proposed limited hypotheses, in agreement with their notion of the laws of nature, than to Burnet and Buffon, whose systems of cosmogony have the air of a philosophical romance rather than of a serious generalization of facts. The history of the progress of opinions in geology may be useful as a warning to men advanced in geological inquiries, not to reason upon assumptions while facts remain to be explored, and to repress that impatience of spirit which ever seeks to anticipate observation by the efforts of invention; but the student should, if possible, be kept in impartial ignorance of these conflicting hypotheses, which are too apt to fascinate the young and imaginative mind. For this reason we shall pass silently over the whole subject of the history of theoretical geology, and shall proceed at once to record the real discoveries in the science.

6. There is no reason to apprehend that a science founded on interesting facts, which meet us in our daily walks, and are brought to our recollection by the artist, the voyager, and historian,—a science which links itself with every investigation into the material universe,—will ever want cultivators. Its progress is assured, and all civilized people will contend for the honour of directing its march of discovery. It has been, and still is, the just boast of our country, that in variety of research, in extent of discoveries, and in sound and valuable generalizations, the geologists of Great Britain are second to none. The English system of geology as applied

to secondary rocks has been adopted over all Europe, and the labours of English geologists have still a decisive influence on the progress of the science. Whether this shall be the case in future years must depend upon the industry of succeeding observers. There is, however, no reason to despond on this subject: no region of the earth is more prolific of geological phænomena than the British Islands; no other country offers equal advantages or greater inducements for exploring them. The principal difficulties which impeded the progress of our predecessors have been removed by their perseverance; they have extricated some leading truths, corrected many errors, conquered many prejudices, fixed the science upon a sure basis, and obtained for it universal attention. Undoubtedly vast fields of inquiry are yet unexplored, and many labourers are required to bring them into cultivation; but whoever now commences this study may do so with the advantages of knowing what results have been arrived at, how to direct his researches toward the points which promise the richest harvest of discovery, and where to obtain aid from collateral branches of knowledge.

To place before the student these results in a regular order, and to instruct him in the processes by which they have been obtained, is the aim of the following pages.

MATERIALS OF THE GLOBE.

7. Following the natural current of ideas, we may first treat of the materials which compose the globe.

It is by observing and comparing the mineral substances exposed in mountain sides, cliffs, and ravines, by nature, or discovered in wells, mines, and other excavations for human convenience, that we arrive at a knowledge of the constitution of the exterior parts of the earth. Here we find a great variety of rocks composed of a still greater variety of minerals, which are all resolvable by analysis into fifty-four simple or elementary substances. This gives us an opportunity of marking clear distinctions between geology, mineralogy, and chemistry. The well-known rock, granite, may be an example.

The geologist considers the circumstances under which this rock occurs in mass or in veins, with a view to determine the agencies which were concerned in its production, the period when it was produced, and other important characters. The composition of the stone is so far a matter of study for him as it helps to clear up these problems.

To the mineralogist granite is an object of study, because it is composed of certain minerals which are characterized by certain constant properties. It is not granite that he studies, but its constituent quartz, felspar, and mica. These minerals are investigated by their qualities of geometrical form, specific gravity, hardness, affections for light, electricity, &c., as separate objects.

Finally, the chemist takes these separate minerals, resolves them into their several ingredients, examines the properties and proportions of these, and investigates the laws of their combination.

8. Geologists are not required to be chemists or mineralogists, but they cannot safely be ignorant of

the results of chemistry or mineralogy: for these frequently throw a strong light on the production of rocks, and sometimes remove all obscurity from their origin.

Of fifty-four undecompounded, and therefore called simple or elementary substances, known to chemists, five exist in a separate state only as gases; viz. hydrogen, oxygen, azote, chlorine (fluorine?).

Seven are non-metallic solids and liquids; viz. sulphur, phosphorus, selenium, iodine, bromine, boron, carbon.

Thirteen are metallic, or metalloid bodies, which unite with oxygen to form the earths and alkalies; viz. sodium, potassium, lithium, aluminum, silicium, yttrium, glucinum, thorinum, calcium, magnesium, zirconium, strontium, barium.

Twenty-nine are what are commonly called metals: manganese, zinc, iron, tin, cadmium, arsenic, antimony, copper, molybdenum, uranium, tellurium, chromium, cerium, nickel, vanadium, cobalt, lead, tungstenum, titanium, mercury, columbium, bismuth, osmium, silver, palladium, rhodium, platinum, gold, iridium.

9. Oxygen combines with so many of these, and in such large quantities with the earthy and alkaline metalloids, which are the most predominant ingredients of minerals, that we may venture even to say that one half of the ponderable matter of the exterior parts of the globe is composed of oxygen gas in a state of combination. The speculations to which this conducts, as to the concentration from a gaseous condition of the matter of the planetary system, seem to be in agreement with the astronomical views of Her-

schel and Laplace, but are perhaps beyond the range of geology, which considers not the origin of the globe, but its successive changes of condition.

10. Were the attractive forces tending to bring together these elementary substances (§ 8.) equal between every two of them, there might be as many minerals produced as there are possible combinations of fifty-four dissimilar numbers; and if, besides, they might unite in any proportions, the number of compounds resulting would be incomprehensibly great, and the constitution of minerals would be, in a certain sense, accidental. Nothing like this happens, however; for, in the first place, the affinities between the substances are various in degree; and those which have the stronger attractions for each other unite and exclude feebler combinations; and, secondly, the several substances tend to combine only in certain proportions, according to general and rigorous laws; the consequence is that the number of distinct minerals is not very great, and the constitution of each is exactly adjusted to a chemical formula.

11. Perfectly crystallized minerals have both a regular geometrical form and a certain internal symmetry of arrangement amongst their particles; sometimes the former character fails, and the latter is not to be discovered without refined optical researches; yet, as the constancy of the chemical composition of minerals appears to prove that their particles were aggregated while at liberty to follow their natural tendencies, we must be cautious in affirming that any homogeneous minerals are devoid of a crystalline structure. But, this *theoretical* crystallization being beyond the test of observation, we may with great

convenience, and practical accuracy, distinguish among the mineral productions of the globe two classes; the former containing evidently crystallized rocks and minerals, the latter apparently uncrystallized masses.

When applied to rocks this distinction is more clear and important than in classifying minerals. Rocks consisting of one or several crystallized minerals, which were obviously generated in the very mass where they occur, have a very different geological history, and suggest very different trains of reasoning from others composed of rolled or fragmented minerals, brought together by mechanical agency, such as the force of water. Compare, for instance, crystallized granite with coarse sandstone, the former tells us plainly that it has been generated by chemical forces operating upon matter in a state of fluidity, or under the powerful controul of electricity; but the latter teaches us that not only heat, electricity, and chemical agency have been concerned in the production of the materials of the globe, but that the mechanical agency of water has been of great importance in modifying their results and producing new aggregations. In determining whether rocks are of crystalline or of mechanical origin, some doubtful cases will occur, which experience alone, and this not always, can decide. We shall see reason for this hereafter, § 30.

12. The mean density or specific gravity of the whole mass of minerals near the surface of the earth, is about twice and a half that of water; but astronomical and general physical researches equally prove that the mean density of the whole planet is four or

five times that of water; consequently the matter in the interior of the earth is heavier than that near the surface. This is all we really know of the nature of the nucleus of the earth. Whether the substances of which it consists be of the same kind as some of those near the surface, or of another kind altogether, can only be matter of conjecture. By the aid of mechanical and astronomical considerations, we may indeed proceed so far as to learn the limits of rational theory on the subject. We shall find, for instance, that if the matter of the interior of the globe be compressible in the same degree as some of the substances near the surface, the accumulating pressure toward the centre would condense them far more than is necessary for the data mentioned above, unless there were some counteracting expansive force in the interior, such as heat is known to be. We must therefore allow either that the interior substances of the globe have a totally different mechanical constitution from those which we see near the surface, or that an expansive force of great energy counteracts the compression to which they are subjected.

13. One doubtful step further on this subject we may venture to make, under the guidance of mathematical and physical researches. The spheroidal figure of the earth is a necessary consequence of its rotation on an axis; it could only be acquired by a body whose parts were capable of free relative motion. The theory of the lunar irregularities which depend on the earth's spheroidal figure, appears to teach us that, for at least some considerable distance from the centre of the earth, the materials are arranged in conformity with the elliptical outline of the

surface: hence its interior parts must have been capable of free relative motion, and it may be very reasonably supposed that they have been in a state of fluidity. That such fluidity was occasioned by heat, is a plausible or rather a necessary hypothesis, for no other known agent is adequate to the effect. But our confidence in this hypothesis becomes strengthened when we find that the results of careful experiments, repeated in various parts of the world, agree in demonstrating that the interior parts of the earth, at small depths, are sensibly hotter than the surface, and that this augmentation of heat follows some regular ratio to the depth. If, then, it be probable that in former periods the whole interior of the globe was fluid by heat; if it be at present internally hot; and if, without introducing the consideration of new substances, the expansive force of heat may counterbalance the effect of condensation, it seems by no means a chimerical theory that the nucleus of the globe may even now be partially fluid with heat. It is no objection to this view, that the surface temperature of the earth is regulated by the sun: this cannot be otherwise while a thickness of solid rock over the nucleus conceals and stifles all sensible heating effect from within.

ARRANGEMENT OF MATERIALS.

14. We shall now return, to observe the positions and arrangement of rocks in the exterior and visible parts of our planet; to generalize the phænomena which they present; to examine the history of their included animal and vegetable reliquiæ; and, from

the whole of this evidence, attempt a connected outline of the leading physical changes which have happened to the earth, and have left traces accessible to human scrutiny.

The depth to which it has been found practicable for man to penetrate the crust of the earth, is but a small part of that to the knowledge of which, in some cases, the force of induction has enabled him to attain. The deepest mine in Great Britain descends to little more than three tenths of a mile: the deepest mine in the world (2,764 feet) to little more than half a mile. We shall see hereafter, that owing to the way in which the materials of the globe are arranged, the structure of the crust of our globe is really known, in particular instances, to a far greater depth. (See fig. 1. § 18.) At present, limiting our statements to the extent of actual observation, we shall show what is the arrangement of the materials of the earth, as they are seen in wells, pits and mines, on the sides of rivers, and on the slopes of mountains, and in cliffs against the sea.

15. There is a circumstance to be attended to in the very outset of this inquiry, which it is of much importance to understand properly. The *actual surface* of the earth is occupied by soil, (which is often nothing else than the decomposed substance of the rocks beneath,) by gravel and sand, and particular sorts of clay, which have been drifted by wind and transported by superficial currents of water, and deposited in much confusion upon the solid fabric of rocks. In all the following statements concerning the parts of the globe near the surface, this irregular and variable covering is neglected, and the reader is supposed to

look upon the naked skeleton of the globe, stripped of its fertile soil, and all its softer and looser investments. The soil and other loose materials of the surface of the land are worthy of curious and diligent research, and have, indeed, amply rewarded inquiry; but the study of them belongs to another part of the subject. We learn little concerning the *structure* of the earth from these irregular accumulations, which, in fact, only mask and conceal its original features, though they teach very remarkable truths concerning the revolutions which have affected its surface. (See fig. 2.)

16. There are two principal conditions of arrangement, to which all the minor appearances observable in the crust of the earth are subordinate or dependent.

In the first case, the bounding surfaces of the rock are parallel, or nearly so, and extended to great distances, so as to include between them a tabular mass or layer of rock, which is technically called a bed, or *stratum*. Several such beds or strata may be laid parallel one to another, and thus constitute a stratified *formation*. These strata may be of the same or of different thicknesses, of the same or different chemical qualities; they may include the same or different organic exuviæ, or be wholly devoid of them. All these circumstances are worthy of remark; but the important thing to be attended to in the first instance is, that *the rock is stratified*. (Fig. 3.)

In the second case, no such stratification is observable. Many rocks are columnar in structure; some are formed in large lenticular or spherical concretions; others have a peculiar internal cleavage; others are amorphous. All these and many more circumstances are important; but the first thing to remark is, that *the rock is not stratified.* (Fig. 3.) See §91—100, for a further examination of this subject.

STRATIFIED ROCKS.

17. A useful notion of the leading appearances of stratification is most easily acquired by examining the eastern, southern, and western coasts of England, where the cliffs present what is called *a natural section*, and generally display the edges of more than one kind of stratified rock; sometimes many kinds, as limestone, sandstone, and clay, which are placed one upon another, in a certain order, like the leaves of a book. The order of occurrence which the edges observe in one part of the cliff is found to be the same in another part; so that these strata form a series of terms, whose relative place is known. In other countries, other and quite different rocks may be seen, but these likewise show amongst themselves a settled order of succession. Exactly the same conclusion results from the experience of miners and colliers, wellsinkers and quarrymen: it is confirmed by examination of mountain slopes, and valleys; so that we may state it as a general truth, that the strata, wherever they occur, by the sea-coast or in the interior of the country, are superimposed on one another in a constant order of succession, and compose one regular series.

18. It is observed that the bounding surfaces of the strata, which we shall henceforward designate

planes of stratification, are seldom quite horizontal, but declining into the earth, so that along many lines of coast their edges rise from beneath the water to some height above it. In the interior of a country, in the same manner, the same or other strata decline in some direction, east, west, north, or south, so as in that direction to go deeper and deeper. This declination, or *dip* of the strata, is sometimes at a considerable angle to the horizon, but generally it is so moderate as 1 yard descent in 50 yards length. All the strata in the same district commonly dip in the same direction. The exceptions to this general law arise from particular and well-known, often local, causes. If, then, the circumstances of the country are favourable, we may see in the cliffs of the coast, or along the valleys and hills of the interior, the several strata rise in succession from the deeper parts of the earth, and end at the surface. We can notice their order of succession, measure the thickness of each, and combine our observations into an artificial diagram, which shall represent truly what *would be* the appearance, if we could perform the operation of cutting the earth along the given line to the required depth. Such a diagram is called an *artificial section.* By prosecuting these researches, until we have found the true place of each stratum in the general series, and its thickness, we come to form a *general table* or *section* of the whole series of strata existing together in any one country. Though we may not be able at any one place to see more than a few of these strata exposed, yet by examining them as they successively rise to the surface of the earth, and adding all their thicknesses together, we learn the *aggregate* *thickness* of the whole mass of strata under any region; the depth, in short, which must be sunk in order to penetrate through the whole series, beginning with the uppermost. In England we may call this known thickness 3, 5, or more miles, according to the situation; and the following table shows what is the series of strata.

19. Series of British Strata, beginning at the Surface, from which all Water-moved Gravel and River Sediments are supposed to be removed. (See § 15.)

[The marine strata are marked by numerals; the freshwater and estuary beds, by letters. The names of some characteristic fossils are in Italics.]

Tertiary Strata.

A small number of the fossils are identical with existing species.

	Names of Formations.	General Thickness. Yards.	*Remarks.*
	1. Crag	16	A water-drifted mass of marine shells, pebbles, &c. About 40 per cent. of the shells are supposed to be identical with existing species.
	a. Freshwater marls	33	They include a bed of estuary shells. They are peculiar to the Isle of Wight.
2.	London clay	100 to 200	Mass of clay rich in marine shells, of which 3½ per cent. are identical with recent kinds.
	Plastic clay	100 to 400	Variously coloured sands and clays, the latter containing organic remains much allied to those of the London clay.

Secondary Strata.

All the fossils belong to extinct species. They are different from those in the Tertiary Strata.

Cretaceous System.	3. Chalk	200	Of unequal hardness, soft above, marly below, with interstratified flints; extinct Zoophyta, *Ananchytes*, and other Echinodermata, &c.
	4. Greensand	160	Upper greensand, very fossiliferous, in general chalky. Gault, a blue marl or clay, often very fossiliferous, *Belemnites minimus*, &c. Lower greensand or ironsand, very fossiliferous in places.

System	Names of Formations.	General Thickness. Yards.	Remarks.
	b. Wealden	300?	Weald clay, with freshwater shells, Cyprides, &c. Hastings sands, with land plants, bones of *Iguanodon*, &c. Purbeck beds of clay and limestone, with freshwater shells.
Oolitic System.	5. Portland oolite	130	A variable locally oolitic limestone, some beds full of fossils. Kimmeridge clay, with layers of *Ostrea Delta*.
Oolitic System.	6. Oxford oolite	150	Upper calcareous grit. Ammonites, &c. Coralline oolite, with beds and masses of coral, *Echinida*, many shells, &c. Lower calcareous grit. Ammonites *catena*, Pinna *lanceolata*, &c. Oxford clay. Kelloways rock. — *Ammonites Calloviensis*, *Gryphæa dilatata*, &c.
Oolitic System.	7. Bath oolite	130 (Near Bath.)	Cornbrash. Thin, impure, shelly limestone, *Avicula echinata*, &c. Forest marble. Shelly oolite, with concretionary sandy limestones. Bath oolite. In several divisions, shelly, oolitic, compact, and sandy beds, *Megalosaurus*, *Apiocrinus*, &c. Fuller's-earth. A series of calcareous and argillaceous shelly beds. Inferior oolite. Pholadomya, *Trigonia striata*, &c. Sand, with concretionary masses holding shells.
Oolitic System.	8. Lias	350	Upper lias shale. Full of characteristic *Saurians*, of *Ammonites*, *Belemnites*, and other shells. Marlstone. Replete with Terebratula, Pectenida, *Avicula inæquivalvis*, &c. Middle lias shale. Contains Gryphæa, Ammonites, &c. Lias limestones with *Gryphæa incurva*, *Ammonites Conybeari*, &c. Lower lias shale, and coloured marls.
Saliferous, or New Red Sandstone System.	9. New red sandstone	300	Coloured marls, gypsum, and rock salt. Red and white sandstones and marls. Conglomerate and sandstone. — Few or no organic remains.
Saliferous, or New Red Sandstone System.	10. Magnesian limestone	100	Knottingley limestone. A few bivalves in the lower beds. Gypseous red marls. No fossils. Magnesian limestone. Shells, corals, &c. Marl slate. *Fishes* of remarkable forms. Red sandstone. Plants of the coal series occur in it.

System	Names of Formations.	General Thickness. Yards.	*Remarks.*
Carboniferous System.	c. Coal	1000	The subdivisions of the coal series are only locally ascertained. Flagstones, ironstones, and a bed of freshwater limestone are the most remarkable layers. The shells are mostly of fresh-water origin. Abundance of land plants of extinct genera.
	11. Carboniferous limestone	800	Upper series of sandstones, shales, coal, and plants, with thin limestones. Upper belt of limestones. *Crinoidea* in enormous abundance. Limestones, flagstones, coal, &c., and land plants. Lower or scar limestones, with characteristic *Crinoidea, Productæ, Spiriferæ, Orthocerata, Bellerophon, Ammonites,* &c.
	12. Old red sandstone 100 to 3300 yards.		Conglomerates and sandstones. No fossils. Coloured marls and concretionary limestones called 'cornstones'. A few fossils. 'Tilestones' or flagstone beds. A few fishes.

Primary Strata.

All the fossils belong to extinct species, and often to extinct genera and families. They are different from those in the secondary and tertiary strata. It is usual to class the upper systems under the title of Transition Strata, and to confine the name of Primary to the mica schist and gneiss systems.

System	Names of Formations	Yards	Remarks	
Upper Grauwacke or Transition System.	13. Ludlow rocks	660	Sandstones. Species of *Orbicula, Lingula,* Terebratula, Spirifera, &c. Limestone. *Pentamerus, Homonolotus,* &c. Shale.	
	14. Dudley limestone	600	Limestone. Shale.	Corals and Crinoidea in vast abundance. Euomphali, *Producta depressa,* Orthocerata, *Calymene Blumenbachii,* and other Trilobites.
	15. Caradoc sandstones, or May Hill rocks	830	Shelly limestone. Various sandstones.	*Pentamerus,* Terebratula, *Orthis,* Trilobites.
	16. Builth and Llandilo rocks	400	Calcareous flaggy beds, &c., including *Asaphus Buchii* and other Trilobites.	

The stratified rocks below are not sufficiently understood to permit of their division into formations. The three groups which follow, ought to be considered as so many systems of formations.

Names of Formations	Yards	Remarks
Clay slate and grauwacke slate system	3000	In this series it is probable that further researches may enable us to institute subdivisions. In the Cumbrian district there are three divisions of slates; the upper dark, fossiliferous, resting on beds of calcareous schist, with Orbiculæ, corals, &c.; the middle green, without fossils; the lower dark, soft, without fossils.

	General Thickness.	Remarks.
Mica schist system ...	(unknown)	No organic remains. The beds of mica schist, composed of mica and quartz, alternate with gneiss, chlorite schist, talc schist, hornblende schist, clay slate, quartz rock, and primary limestone.
Gneiss system	(unknown)	No organic remains. The gneiss beds, composed of mica, quartz, and felspar, alternate locally with mica schist, quartz rock, primary limestone, &c.

20. A knowledge of the exact series of strata existing in any given district may thus be easily acquired, and it has in fact been possessed by practical men in almost every local district where natural sections can be observed, or mines and collieries are extensively wrought. But until Werner and Smith, independently of each other, compared the stratification of different countries, and discovered laws of accordance in the series of strata over large tracts of the globe, the local knowledge of miners and colliers, for want of combination, was of small geological value, and often led to absurd hypotheses. Any one who possesses this local knowledge is, however, immediately in a state to follow the steps of the great geologists above named. In the first place, he must accustom himself to consider the series of strata, not only as they succeed each other in the earth, but also as they appear on the surface; he must not only draw a section but colour a map. (See, as an example, fig. 4.)

We shall suppose him situated near the sea-coast of Yorkshire, and to have marked on his map the ranges of chalk, Kimmeridge clay, coralline oolite, and lias. The chalk, which is the uppermost term of this series, extends from Flamborough Head through Yorkshire, Lincolnshire, Norfolk, Suffolk, Hertfordshire, Wilts, Dorsetshire, &c. Parallel to it extends also the Kimmeridge clay: the coralline oolite occupies a broken but parallel range. The lias holds an uninterrupted course from the coast near Whitby, through Yorkshire, Lincolnshire, Northamptonshire, Gloucestershire, and Somersetshire, to Dorsetshire. Nor is the range of these strata limited to England, for they cross the Channel, and occupy large spaces, in the same order of succession, on the continent of Europe.

Hence we learn that not only the principle of stratification is very extensively recognised over the globe, but also that some particular sets of strata are continuously traceable over large tracts, preserving the same relative position on the surface and in the interior; so that a general table of their order of superposition may be drawn up, which shall apply, allowing for local peculiarities, with equal truth to every part of their ranges, as, for example, to all Europe. Thus we rise to a general principle of great importance, by which we may hope eventually to connect the results of observations of stratified rocks over the whole globe into one harmonious system.

21. *This continuity of the strata* is not to be understood of every locally observed bed of the series, nor even sometimes of every set of beds of the same kind; for some of these beds are the effect of very limited causes, and all of them are liable to local variation. Hence it happens that in some countries certain strata are wholly wanting, and others are so much altered that certain parts of the series assume totally different characters. No sets of strata are

universally continuous; there are no *universal* stratified rocks; but yet it is true that certain groups of these stratified rocks, consisting, for example, of certain kinds of limestones, sandstones, and clays, or of certain gneiss rocks, mica schist, and clay slate rocks, are so extensively traceable as to give us reason to conclude that very extensive and uniform operations of nature were concerned in their production.

22. The organic exuviæ which are found in the stratified rocks offer a wide field of inquiry, from which already rich and valuable results have been gathered. This is not the place to develop that magnificent subject further than to show *what* these remains are, and how they can be brought to afford evidence of revolutions which the earth has undergone. Both plants and animals have left monuments of their existence and traces of their forms, in the earth. The ligneous, vascular, and sometimes the cellular parts of plants abound in the earth, and the leaves are so perfectly retained than an exact comparison can be instituted between them and recent vegetables. Of animals generally the soft parts are not preserved in the earth; but the bones of reptiles and other vertebrata, the hard coverings of crustacea, the shells of mollusca, the stony and lapidescent* coverings, supports, and cells of zoophyta, are abundant. Generally speaking, the fossil species both of plants and animals are not identical with existing kinds; often they belong to different genera, and sometimes admit of no close resemblance with any living

* This term is applied by Lamarck to several genera of corallines, in which the support of the Polypi is of a nature intermediate between membranaceous and stony.

form. In certain strata of the least ancient date, both plants and animals occur not distinct from existing species. Fossil plants and animals do not exist in all the strata, nor everywhere in equal abundance in the same stratum or set of strata. They are not confined to any particular kind of rock; they are not always present in rocks of a certain kind; nor, except in a few instances, always absent from other rocks. These remarks are sufficient for the present course of argument. See § 60—88.

UNSTRATIFIED ROCKS.

23. The *principle of stratification* is universal; that is to say, in every country of sufficient extent stratified masses occur in a certain consecutive order; and in many very large districts removed from the mountains nothing but stratified rocks are seen. Any one whose notions of the structure of the earth were drawn from observations in south-eastern parts of England would certainly suppose, as Werner did, that all rocks were stratified. On the contrary, the inhabitant of mountainous regions finds a great variety of rocks, such as granite, sienite, porphyry, &c., in which no trace of stratification can be seen,—many others, like gneiss and slate, in which this structure is so anomalous as to convey to his mind a very indistinct notion of its true nature. These insulated observers can therefore hardly understand each other; and it is no wonder if theories based on their observations are found to disagree.

24. In many countries, however, the stratified and unstratified rocks occur together; and it is then seen

that while the former follow a regular arrangement, and lie nearly parallel to the earth's surface, the latter appear in irregular, often unconnected masses beneath all the strata, or protruding through them in insulated peaks, or traversing them in vertical masses called dykes, or penetrating them by veins. Not only have they no constant relation to the stratified rocks, but they have no constant relation to one another, either of position or mode of occurrence; so that it is impossible to form anything like a regular series of them. Hence they are very properly called by D'Halloy *roches hors de série.*

25. Further examination shows that the mineral ingredients of which the stratified and unstratified rocks consist are either very different or in a very different state. For while the stratified rocks, amidst all their variations of colour, hardness, and chemical constitution, can be described as limestone, sandstone, clay, ironstone, coal, &c., the unstratified rocks are wholly different, and consist of minerals of many kinds, variously aggregated together. The former are often composed of attrited grains, the latter of perfect crystals; the former generally contain organic exuviæ, the latter almost never. Whenever the latter appear at the surface, the former are more or less disturbed and confused in position: and the result of comparative examinations upon them is invariably found to be a full belief that they were produced by different causes acting independently, and, in most instances, at different periods. See § 44—50.

We shall now class the phænomena presented by these rocks in such a form as to exhibit their distinctive peculiarities, and put them in comparison with the modern effects of natural agencies upon the globe. In this way we may expect to learn the causes concerned in their production.

ORIGIN OF THE STRATIFIED AND UNSTRATIFIED ROCKS.

26. In the modern system of nature we recognise two great agencies employed in producing changes on the face of the globe,—WATER, which wastes away, grain by grain, the elevated portions of the land, and deposits its spoils in lower situations, thus ever tending to equalize the levels of the surface;—FIRE, which raises matter in masses from the interior of the earth, and thus tends to increase the inequalities of its surface. Both of these agents act chemically; water dissolves, heat fuses; both also act mechanically. The mechanical effects of water depend on the general force of gravitation, and ever tend downwards, so that the lowest part of any aqueous deposit is the oldest; but the mechanical force of heat is independent of gravitation, and ever struggles to overcome it. Water is a tranquillizing,—heat a disturbing, agent.

27. Rocks are formed both by aqueous and igneous agency in the present œconomy of nature, and the products of these agents are in general easily distinguishable. The deposits from water are composed of limestone, which is sometimes a chemical product, sometimes a mechanical or sedimentary deposit, or of sandstone and clay, which are always of sedimentary origin. The accumulations formed in the beds of lakes, at the mouths of rivers, and in gulfs of the sea, are so stratified and composed of

such materials. Moreover, these modern strata inclose remains of freshwater, terrestrial, or marine organic bodies, according as these existed in, or were transported into, the water; and they are deposited in the strata according to the periods when these were formed. In every respect, then, the modern aqueous deposits are exactly similar to the stratified rocks produced in former conditions of the globe. Whether they are equally extensive is another question; but it is clear that processes of the same kind have occasioned all these phænomena.

28. On this determination of the aqueous origin of stratified rocks inclosing organic exuviæ of aquatic animals, rests the doctrine of the relative antiquity of the rocks, according to their relative place in the scale of stratification. In the same manner as we cannot doubt that the lowest layer of the sediment from a pond, lake, river, flood, or inundation of the sea, is the most ancient, and the upper layer is the least ancient of all those which exist together, so in the series of stratified rocks, which were likewise deposited from water, the lowest are the oldest, and the uppermost are the newest. It is not here a question of what periods of time elapsed between the deposition of the oldest and the newest; the general principle only is required to be granted, and it will be left to a future special investigation to draw the proper inferences on the lapse of time during the accumulation of the strata.

There can also be no reasonable doubt on another important topic. As at the present day, (except under special circumstances, as explained in § 96.) so in ancient times, we may be sure that the marine stratified deposits would assume the character of level or nearly level surfaces, because this is the result of the ordinary action of agitated water. In whatever positions these strata are now found, we may always agree that they were at first deposited nearly level. See § 91—98.

29. The rocky accumulations from modern igneous agency are exhibited to us in volcanic regions, where we see that the lava thrown out does not form true strata, except for very limited areas, though, in consequence of successive eruptions, it may be laid in many consecutive stream-like deposits. Even the scoria which is ejected from the volcanic cone, and falls more or less on all sides of it, is accumulated in such a way amongst the streams of lava, and with such a relation to the slopes of the ground, that it does not form true strata. The lava frequently forms dykes and veins. (§ 99.)

The materials of these eruptions are neither limestone, sand, nor clay, but consist chiefly of a variety of crystallized minerals, in which the bases of these rocks are united with other earthy, alkaline, and metallic substances. Finally, they contain of course only by peculiar accidental circumstances any remains of animals or plants. When the melted lavas come in contact with previously solidified rocks, some changes occasionally happen, which may be imitated by artificial heat. In all these particulars the modern products of fire resemble the ancient unstratified rocks. We may further remark, that the most abundant and characteristic mineral substances now obtained from volcanic rocks are equally abundant and characteristic of their older prototypes ; that in both classes these minerals are often found grouped together in the same manner; that some of the most abundant of the older unstratified rocks are not distinguishable from certain modern volcanic rocks; and that there is such a general resemblance between the two classes, and so many analogies of combination and appearance continually observable between them, that we cannot hesitate to pronounce the unstratified rocks generally to be the product of heat. It would not be right to say they were ancient volcanic rocks, for volcanos are only a particular case of the general effect of subterranean heat; and there are various facts connected with the history of the older rocks which do not permit us to assign to them a real volcanic origin. On the contrary, certain differences, almost always existing between these and volcanic rocks, appear sufficiently marked to lead us to a theory of their origin, which shall explain at once their general dependence on subterranean heat, and their particular differences from volcanic products.

30. There are some rocks which appear both stratified and crystallized, as certain limestones; others which are neither stratified nor apparently crystallized, as wacké and some sorts of claystone. Yet even these, and some other cases which on a first view appear to confuse the classification and disturb the inference, are capable of satisfactory solution. It is known by direct experiments that artificial heat is capable, under particular circumstances, of changing sedimentary limestones into crystalline limestone. Thus, Sir J. Hall actually converted chalk into granular limestone. Now the granular or crystalline limestone, above alluded to, sometimes occurs in such

a relation to rocks of igneous origin that its crystalline structure is with much probability referred to the local development of heated rocks in that situation. In other instances we may easily imagine the interior heat to have produced the same phænomenon, though no igneous rocks be actually exhibited in the neighbourhood.

With respect to uncrystallized rocks which are also unstratified, we may remark that though, among the modern effects of volcanic fire, we have selected crystallized rocks as characteristic of these effects, and have noticed the analogy in this particular of the old unstratified and modern igneous rocks, yet neither in one class nor the other is it meant to be understood that such rocks are the only ones that exist. Here, again, we are aided by actual experiment. Mr. G. Watt has shown that the very same mass of chemical substance, perfectly fused and allowed to cool, will become glassy, earthy, or crystallized, according to the rate of its cooling. The same thing happens in volcanic products; the same thing, hardly in a less degree, did happen amongst the ancient igneous rocks. We have, therefore, the means of explaining all the apparent exceptions to the general rules given above, and by a careful study of the cases shall probably in time arrive at a clear understanding of the conditions which occasioned all the phænomena.

PHYSICAL GEOGRAPHY.

31. Having thus arrived at a clear view of the origin and relative position of the rocks composing the

crust of the globe, we must turn our attention to the surface, which, as before observed (§ 18.), is formed upon the edges and surfaces of these rocks (fig. 2.), and inquire what connexion there may be between the physical features of the surface of the globe and the subjacent rocks. Taking the most general view which the subject admits, we may consider the mountainous regions of the globe as rising in the midst of the broad plains and gently undulated regions, like islands in the sea. Some particular plains are surrounded and defined by the chains of elevated ground, as the Plain of Bohemia; but it is a more general fact that the plains spread round and inclose the mountain masses. The depths of the sea appear to balance the ridges on the land. There are in the sea certain lines and certain centres of depression, as on the land are particular chains and peaks of elevation. If we could remove the whole of the enveloping ocean, it is probable that the greatest depths of the basins of the ocean would be found proportioned to the greatest elevations of the land, and equally limited in area. The far greater part of the ocean is of a moderate depth, as the far greater part of the land is of a moderate altitude.

32. Putting out of consideration, for the present, the loose water-moved fragments which cover to a small depth in many parts the actual solid framework of the earth (§ 15. and fig. 2.), we may state as a general truth, that the great plains and moderately undulated regions of the dry land owe their principal features to the quiet deposition of the stratified rocks below them; while the mountainous lands, on the contrary, owe their peculiar features to the elevation

of pyrogenous rocks* along their chains or amidst their groups and peaks. It is a general law, confirmed by most ample evidence, that the interior parts of mountainous regions consist of granite and other pyrogenous rocks rising from below all the strata, and bearing them up to their present elevations. From these elevated points and lines, both the subjacent igneous and the superior stratified rocks descend at various angles towards the plains and more level regions, beneath which they sink and pass for various distances, until they again emerge in some other mountain group having similar characters. In consequence of this arrangement, it happens generally that the oldest strata, those which sink deepest under the plains, rise highest against the mountain slopes; a circumstance easily understood, though sometimes called *a geological paradox* (fig. 5.). The most constant of all the facts connected with this part of the subject is the development of granitic or some other pyrogenous rocks about the centres of the elevated groups, from beneath all the strata there occurring. Very frequently cracks and fissures of the strata are filled by these igneous rocks injected from below, and thus in some cases the proximity of their masses is indicated when they cannot be actually seen.

33. The surface of the earth derives all its diversity of form and products from the originally different nature of its constituent rocks, the variety of positions into which these have been thrown (§ 25.), and the consequent inequality of effect produced upon them by atmospheric and other modifying agencies. Had the stratified rocks remained in their original

* Rocks formed by fire.

nearly level position, all the immense variety of mineral treasures which they contain would have been hidden from the eye of man, and the dry land would have been a monotonous waste, without that picturesque grouping of mountains, that pleasing variety of hill and valley, that ornament of bay and promontory, which we now gladly acknowledge to be a great source of enjoyment and instruction.

And, as we behold how marvellously the animal and vegetable creations are adapted to each other, and both to the local influences of climate, soil, elevation, proximity to the ocean, and other important conditions, produced by geological revolutions, there is no room for doubt that the subterranean movements by which this fundamental diversity of the earth's surface was occasioned, are as much a part of the general plan of creation as the existence of the atmosphere, the proportion of land and sea, or the succession of the seasons.

34. The sea-coast of every country derives its characteristic outlines, its rocky cliffs and alluvial depressions, from the unequal hardness, various direction, and degree of elevation of the rocks. The long horns of Cornwall and Caernarvonshire coincide with axes of convulsion ; Pembrokeshire, like the Isle of Wight, is extended by the operation of similar causes from east to west; Flamborough Head, composed of chalk, projects into a magnificent promontory, round which the currents of the German Ocean turn, with fatal perseverance, to waste the clays and sands of Holderness.

35. The chains of mountains and ranges of hills, and the vales and plains which surround and divide

them, are all occasioned by similar causes. The range of Snowdon is the line of an axis of elevation (§ 45. *et seq.*); the Penine Chain, from Ingleborough to the South Tyne, is formed by a magnificent dislocation, which depresses the strata on the west above 1000 yards; and where this dislocation turns to the east along the Tyne, and to the east and south-east through Craven, it produces, in the midst of a mountain country, two great irregular valleys across the summit of drainage.

36. The form of the individual hills and valleys is occasioned principally by peculiarities in their geological structure. Compare, for instance, the pinnacled primary rocks of the high Alps with the broad swellings of the oolitic Jura; the fantastic cappings of basalt in Scotland with the serrated slate mountains of Cumbria and the green swelling outlines of the English chalk.

How different are the vertical cliffs of mountain limestone, which have been rent asunder in Mendip and the Peak, from those of other rocks! The streams which foam through many channels among the slate rocks of Lowdore, or rush in white lines down the slopes of Skiddaw, give a totally different effect to the scenery of the Cumbrian glens from that which belongs to the lofty cascade of Hardrow, and other less known waterfalls, across the ridges of limestone in the magnificent dales of the North of England.

A general acquaintance with geological truths is therefore absolutely indispensable to an enlarged intellect, which is desirous of forming right general views of the arrangements of existing nature, and especially of physical geography.

GENERAL VIEW OF THE STRUCTURE OF THE EARTH.

37. Leaving the question of the original aggregation and interior arrangement of the matter of the globe (§ 9. 12. 13.) to the astronomer, and the laws of the atomic constitution of minerals (§ 8. 9. 10. 11.) to the philosophical chemist and crystallographer, we may gather from the preceding statements sufficient grounds for a general view of the structure of the exterior crust or shell of the globe. By far the greater portion of the surface of the earth is occupied by rocks, which were deposited by water in the form of strata (§ 16.), more or less approaching to a horizontal position, which succeed one another in a certain order of superposition (§ 17. 18.), are of different antiquity according to this order, and are continuous (§20.21.) for less or greater distances. In these strata multitudes of remains of plants and animals (§ 22.) lie buried, which are for the most part distinct from the plants and animals of the present day, though belonging to the same great divisions, and formed upon the same general plan of terrestrial and aquatic life. This system of stratified rocks extends to a variable depth, not exceeding a few miles (§ 18.), and below it and amongst it (§ 25. to 28.) occurs a set of rocks, which are not stratified, and do not contain organic remains, but consist of such minerals, and occur in such circum-

stances, as to be clearly the result of igneous agency. These pyrogenous rocks are frequently found piercing through the strata in various ways, as if uplifted from below. In some cases, also, the effects of heat are traceable in the stratified rocks themselves (§ 30.), in consequence of which they have partially or generally assumed some of the appearances properly characteristic of the pyrogenous rocks.

38. The dry surface of the earth is formed on the edges and surfaces of the strata and tops of the uplifted pyrogenous rocks, in such a manner that while the great plains and moderately undulated regions consist almost entirely of stratified rocks, the mountainous parts usually contain an axis or nucleus of pyrogenous rocks covered by stratified rocks; both of which groups decline on all hands from the mountain chains, sink below the more level regions to various depths, and pass to various distances. (§ 32.)

Both fire and water have been actively engaged in the construction of the earth. Water has deposited from above, in a settled order of succession, many extensive strata and sets of strata, variously filled with the remains of plants and animals which existed during the several periods; and heat has expanded these strata from below, and thrown up a different set of rocks from the deeper parts of the earth. It is the business of the geologist to trace with accuracy the effects of these agencies, separate and combined; to arrange these effects in a chronological order, and thus to compose a correct if not complete history of the revolutions by which the earth has been brought to its present condition, stored with its present wonderful variety of animal, vegetable, and mineral forms, and made fit for the residence of a being gifted with that human curiosity which prompts him to examine, and that divine reason which enables him to interpret, the works of nature, and through them to hold a sublime communion with the Creator of the universe.

PART II.

GENERALIZATIONS.

SUBAQUEOUS PRODUCTION OF THE DRY LAND.

39. The most important of all the leading truths established by modern geologists was not wholly unperceived by the enlightened philosophers of antiquity. When Ovid ascribes to Pythagoras the opinion that, in the course of the changes of nature, what is now dry land was formerly sea, and the contrary, and illustrates the doctrine by the submersion of cities along the shores of the Mediterranean, and by the occurrence of marine shells far from the sea, it is impossible not to be struck with the force and simplicity of the argument. Ideas of the same kind were distinctly announced by Strabo and others accustomed to the phænomena of earthquakes in Asia Minor. But the poetical notion of changes of land and sea over given regions, suggested by limited phænomena, is distinguishable from the philosophical conclusion, based on universal research, that the whole of the existing continents and islands have been reared out of the bosom of the sea; that all our highest mountains are of comparatively modern date, and that in some former period of the world, the ocean-currents flowed over the yet unborn Alps and

Pyrenees, as well as over the plains of India, Africa, and America.

40. Whether at the time when all our continents were beneath the sea, there were other continents raised above it, is a matter which it is difficult to bring fairly within the scope of inductive science, except in a very limited form, and upon rather doubtful assumptions. The only clear and *certain evidence* for the existence of land in other situations than where it now appears, is to be sought in the history of terrestrial organic exuviæ imbedded in the earth; the only reasonable *presumptive evidence* in favour of such a doctrine, must be founded on mechanical considerations connected with the mass and depth of the waters of the ocean. To conclude that because continents were raised in one quarter others *must* have been depressed elsewhere in a certain proportion, is inadmissible, because it requires us to admit what is perhaps false, viz. that the spaces occupied by the solid and liquid parts of the mass of the globe have always been exactly and invariably in the same proportion to each other as at present. Who can assure us of the truth, or even the probability of such a law? If the temperature of the earth has varied even a little; if there are variable vacuities in the earth; if in the course of heating and cooling, of composition and decomposition, the spaces occupied by material substances change; this law must be rejected.

41. The simple argument of Ovid,

> .... Vidi factas ex æquore terras,
> Et procul a pelago conchæ jacuere marinæ,

will probably never lose its force in convincing mankind that they stand upon the elevated bed of the ancient sea. When we find shells and corals, which beyond all doubt must have lived in the sea, deposited in the interior of solid rocks, with all their delicate ornaments of structure uninjured, lying in these rocks as they usually do on the bed of the sea, we are irresistibly compelled to conclude, not only that these exuviæ were deposited by the ocean, but that the animals actually lived in or near the very spots where their remains are buried, and were there quietly covered up by the ordinary deposits of earthy matter then proceeding. The stratified rocks inclosing these remains were really in succession the bed of the ancient sea; and wherever we find the faithful testimony of marine exuviæ, the conclusion is immediate and unobjectionable, that the ancient bed of the ocean is laid open before us. The extent to which this principle is applicable varies in different countries. In Europe generally, in North America, in India, a large portion of the whole area may thus be proved to have been formerly submerged.

42. As in the present operations of water, strata containing organic remains alternate with others which do not contain them, and yet all the conclusions as to local circumstances apply to both equally, so some strata which contain no exuviæ, alternate with others which do contain them, and by this are proved to have been subject to the same local conditions. Therefore such strata as red sandstone, and many kinds of slate which, in England at least, contain no organic remains, were as certainly formed in the bed of the sea, as the conchiferous limestones above and below them. Moreover, strata which in some countries contain no organic remains, do con-

tain them in others, as, for instance, the red sandstone; and, by combining all these facts together, we arrive at the conclusion that the Ovidian argument, from the presence of marine exuviæ, applies to at least three fourths of the whole area of the solid land, and to the whole series of strata except those which lie at the very bottom; and to all heights above the level of the sea, and to all attainable depths below it. But even if there were no marine exuviæ in the stratified rocks, yet because of their production from water, their regular order of succession, and other characters, they speak for themselves, and show most clearly that they are not to be regarded in any other light than as deposits upon the bed of ancient waters. In this case we make no exception, but include with equal confidence the most ancient primary slates and the most modern tertiary sands.

Thus we arrive at the conclusion that not only all the great plains and all the undulated portions of the land were formerly submerged, but that the flanks and often the very summits of the loftiest mountains were similarly circumstanced, for all these are composed of stratified materials of some kind or other.

43. The same conclusion applies likewise to the pyrogenous rocks which appear about the centres of mountain groups; for, as we have before seen, these rocks appear in such a relation to the strata of the mountains, that, by a large induction of facts, we are led to conclude that they have been thrown up from beneath all these strata, and have, in fact, been upheaved with them from their original situation on the bed of the sea. Therefore it is concluded, as a fundamental maxim in geology, that the whole area now

occupied by dry land was formerly covered by the sea. We may next inquire into the agencies by which the land was redeemed from the waves.

ELEVATION OF LAND.

44. The strata formed upon the bed of the sea could only be laid dry by one of two processes; either the general level of the sea has been lowered, as Werner imagined, or there have been vertical movements in the bed of the sea. The notion of the gradual lowering of the level of the ocean is one of those imprudent suppositions which the constantly increasing connexion of geology with exact science has nearly banished from our systems. It was adopted with the view of accounting for the often observed fact, that the strata which descend to the greatest depth under the plains, and are certainly the oldest, are also found rising to the greatest height along the flanks of the mountains. The Wernerian hypothesis assumed that the great physical features of the globe, its mountains and plains, were aboriginal; it assumed that all the igneous rocks were of aqueous origin; and it was to agree with these fundamental errors that the monstrous notion of the gradual and universal sinking of the water-level, from the summits of the mountains to the shores of the actual sea, was framed. This notion is so contrary to common sense, that it will be instantly rejected by every mind which is not prepared to admit an unlimited variation in the quantity of water upon the globe.

45. No direct collision with natural philosophy

can be chargeable upon the other supposition; we must therefore judge it by comparison with observed facts. The vertical movements may have been elevatory or depressing, or both: they may have been sudden and convulsive, or gradual. In every case of *convulsive* elevation or depression along a line or about a centre, the strata, originally deposited nearly level, must be placed in angular positions with respect to the horizon, and the dips or slopes thus occasioned will be most considerable along the line or about the centre of the disturbance. Thus, in the annexed diagram (fig. 10.), *d* represents a case of depression, and *e* of elevation. Nearly analogous results would follow a *gradual* vertical movement of the strata. If the elevatory or depressing action was exerted over a very broad area, and was gradual, it might happen that no sudden or violent dips should be anywhere traceable, but the effect would be a gradual intumescence or subsidence. These are obvious truths, and they are sufficient for the purpose of examining the question of the desiccation of the land.

It cannot be doubted that both depression and elevation have happened to many parts of the bed of the sea; but when we proceed to those parts of the country which were most affected by these disturbances, we are at once convinced that it is to local elevation of the bed of the sea we must ascribe the existence of mountains. The general fact of the rapid dip of the strata in the proximity of the mountains (fig. 5.), contrasted with their gentle slopes or nearly horizontal position, even at moderate distances, is sufficient proof of this. As nothing can be more certain than the dependence of the figure of continents and islands upon the direction of the ranges of mountains, there is no room to doubt that all our solid land has been *raised* out of the sea, parallel to certain lines, and around certain centres of vertical movement.

The confusion of dip (fig. 6.) so commonly observed in the proximity of mountains, seems to indicate that the elevatory movements were sudden and convulsive; but the full discussion of this subject would lead to theoretical considerations unsuited for an elementary work. Whether depressions in other parts of the globe corresponded to the elevations in these, is a question of the same character.

46. We may, however, advance our conclusions, as to the elevation of land, one step further, by considering the relation of the lines and centres of elevation to the eruption of pyrogenous rocks. The appearance of these rocks along the lines of subterranean movement is so constant and characteristic a phænomenon, that we cannot doubt of the dependence of both upon the same local causes. Some pressure from within, determined to particular points, has evidently upheaved the strata with the subjacent pyrogenous rocks. In some cases it is probable that the pyrogenous rocks were upheaved in a solid form; in others it is demonstrable that they were in a state of igneous fusion, so as to flow into cracks and fissures of the strata. The phænomena may be plausibly explained upon the supposition of the local production of great subterranean heat, or by considering the convulsive movement as a paroxysmal relief to a general pressure upon the internal fluid

nucleus of the globe. Each of these views has able defenders.

47. Nothing is more evident in physical geography than that the extent and direction of the land depend on the ranges of mountains; these have been shown to owe their elevation to subterranean movements; and this is generally thought sufficient proof that the elevation of all the solid land is due to the convulsive rising of the mountains. This is, however, not proved, though we may always justly consider that large breadths of land rose with the mountains. But it is not adequate as a general explanation of the desiccation of the continents, for a very sufficient reason, viz. that many mountains were raised by the convulsions, of which they exhibit traces, *before the strata were formed, which are now laid dry around them.*

48. Persons who are aware of this difficulty propose another view. They say, as the mountains certainly owe their elevation to convulsions centred beneath them, so also probably were all the other parts of the dry surface of the earth raised by other convulsions, suitably posited. This is equally erroneous. There is no ground whatever for applying this hypothesis to the desiccation of the eastern and south-eastern parts of England, the North of Germany, and other large tracts of Europe; for in all these cases no convulsions can be traced at all adequate to the effect.

There remains for these cases, which relate to perhaps half the area of the dry land, only the hypothesis of gradual elevation of large tracts, either by the manifold repetition of small disturbing movements, or some general expansion beneath a whole physical region. Many of the Swedish naturalists believe that such an expansion is at this moment gently raising a great part of the Scandinavian peninsula. Mr. Lyell, from a recent personal examination, has been led to adopt these views, which are also sanctioned by the authority of M. Arago.

RELATIVE ANTIQUITY OF LAND.

49. One of the most interesting of the results to which a careful study of the circumstances of the elevation of mountains has conducted geologists, and at the same time one of the most certain, is the knowledge that the dry land is not all of the same antiquity; in other words, that some mountain ranges, and some large regions, were raised above the sea long before the occurrence of the convulsions which affected the level of other countries, and even before the production of the strata of those countries. For instance, we have no doubt that the Grampian, Lammermuir, and Cumberland mountains were dry land long before the Alps were reared from out of the sea, and while the greater part of the area of Europe was occupied by the ancient ocean.

How is this ascertained? It depends upon the determination of two leading truths: First, That the series of convulsions to which mountain ranges owe their origin, were effected at many different and relatively ascertainable periods. Secondly, That by these convulsions, or some gradual operation, the bed of the sea was not only *relatively* raised in certain parts, but that particular portions of it were uplifted above the level of the surface.

50. The relative age of convulsions is known by observing what strata *are* and what *are not* dislocated by them. If, for instance, as on the borders of Cumberland, the old slate and limestone strata are dislocated in certain directions, while, in the prolongation of these directions, the newer strata of red sandstone are not disturbed, but lie level over the sloping surfaces and edges of the others, we know that the convulsion happened after the formation of the slate and limestone, but before that of the red sandstone (fig. 7.). Again, because on many of the peaks and in many valleys of the Alps tertiary strata are found in a state of dislocation, it is clear that the last dislocations of the Alps were subsequent to the tertiary æra. Always, the age of a convulsion is less than that of the dislocated strata, and greater than that of the strata which lie undisturbed, and unconformable on or against the former.

That certain parts of the bed of the sea were not only raised, in relation to other parts, but absolutely reared above the waters into ranges of high ground, is known by the circumstance, that since the date of the convulsions which can be traced in them, marine strata have been formed around them, and in hollows of their surface, in such a way as to indicate that they stood up like islands, amidst the waters, defining the area over which the sea could form its deposits, and producing the vegetables and other remains of terrestrial beings, which are imbedded in these deposits. Thus the Cumbrian group of mountains was dry land at the time of the deposit of the red sandstone around it; the same was the case with Charnwood Forest; and by continuing researches on the principle of combining the evidence of convulsive movements, and subsequent deposition of marine strata, we may gradually hope to see light break in upon the interesting problem of the ancient hydrography of the earth.

PERMANENCE OF THE LEVEL OF THE OCEAN.

51. It has already been shown that the whole of the dry land was formerly submerged (§ 39—43).

The preceding statements (§ 49, 50.) will probably be admitted as sufficient to prove the justness of the data for our conclusion, that the dry land is not all of equal antiquity, as the strata composing it certainly are not.

We have stated on what grounds geologists conclude that the desiccation of much of this land is a consequence of subterranean movements (§ 45, 46.), and that for the remainder it is preferable to appeal to a more gradual and general change of relative level of land and sea (§ 48.). It has also been stated that the drying of the land by a general subsidence of the ocean level (§ 44.) is a mere delusion, and that the facts can only be explained by internal movements producing locally sudden or gradual change of dimension. Though the Wernerian hypothesis of the gradual subsidence of the ocean, which to suit the phænomenon which it professed to explain must have been to the extent of some miles, is now little regarded, it is necessary to show the line of argument according to which it is allowable for geologists to take for granted the permanence of the level of the ocean, *independently of astronomical vicissitudes.*

52. In this argument the quantity of water upon the globe is supposed to be constant: we have clearly no right to suppose otherwise. Variation of the level of the water may happen in consequence of internal movements and displacements of the parts of the earth, or from a change of the temperature of the globe. *Displacements* of the parts of the globe may cause land to sink or rise, or both. If any part of the bed of the sea sinks into a cavity, or rises out of a cavity, the ocean level will be altered in proportion to the bulk of this cavity. The greater the cavity out of which any part rises, or into which any part sinks, the greater the change of level. If we suppose three fourths of the globe to be covered by water, and imagine a portion of the bed of the sea, equal in cubic content to the land now above the water, to sink into a cavity, the dry land remaining unmoved, the depression of level occasioned over the whole ocean would be something more than one third of the mean height of the land. This we may take at 1000 feet: consequently the depression of the sea upon this enormous sinking would be something more than 333 feet. If the existing land should sink into a cavity, so that it should just be submerged, the level of the sea would remain nearly unaltered.

The converse is true. If the bed of the sea should be raised, but not to the surface, and thus an internal cavity be produced, there will be a general elevation of the ocean level proportioned to the cavity; if any portion of the displaced mass of earth should project into dry land, the level of the ocean will be raised in proportion, first, to the difference of cubic content between the cavity and that quantity of land which projects above the surface, and, secondly, to the alteration of the area of the ocean.

But if we discard the notion of cavities, and suppose the elevation of one part to be compensated by the depression of another, the ocean level will vary merely as the quantity of land above its surface. It will rise by the sinking of the land under it, and the contrary. If we suppose all the dry land to sink till it be submerged, it will cause the ocean to rise about 250 feet. To such a depth then, and no more, could the ocean have sunk upon the rising of this mass of land. If at all times as much land rose above as sunk beneath the surface of the sea, the ocean would remain level.

53. The effect of a general *change of the temperature* of the globe in altering the relative level of land and water cannot be stated, unless we assume some fixed temperature for the water. In this case the change of dimension must go to some hundreds of miles on the radius before the relative level of land and water would be so affected as to account for the emersion of a large part of the land. A change in the mean temperature of the superficial parts of the globe is a very probable geological cause of some fluctuation of the ocean level; but its effect cannot have been considerable.

54. *Astronomical vicissitudes* would for the most part be insensible in altering any of the dimensions of the globe; and unless we take into account a great displacement of the axis of rotation of the earth, we

are forced to admit that the mean level of the ocean is nearly permanent, and that the dry land has been really *raised* out of its bosom by the force of subterranean movements. What was exactly the nature of these is a problem, which must be intrusted to the researches of mathematicians guiding the industry of geologists.

LAPSE OF TIME.

55. The magnificent spectacle of continents rising gradually or suddenly from their parent waves is calculated to impress upon even the least attentive mind a sentiment of respect for the sublime subjects of geological inquiry. It is hardly possible to avoid looking around for indications of the time required for the subaqueous production of such a mass of strata, and for their subsequent elevation. Before involving ourselves in the difficulties which beset the research into the source and prior condition of the materials of stratified rocks, we may proceed to examine what evidence they afford of their relative antiquity, and what inferences they will justify as to the absolute length of time consumed in their production.

As the antiquary, who is required to determine the dates of the successive piles of a ruined city, judges by the style and sculpture and state of preservation of the fragments; so the geologist, by deciphering the characters impressed by nature on the rocks, is able to arrange them according to successive æras. If the antiquary be unable to refer his discoveries to historical records, and thus to learn the absolute intervals from one event to another, he is reduced to nearly the same state as the geologist who desires to ascertain the number of years or cycles of years which elapsed during the formation of the crust of the earth. In both cases certain assumptions must be made before even plausible conjectures can be hazarded. Geology, however, would gain little by even a correct *conjecture* on this subject; and though undoubtedly a vast variety of facts observable in the earth are clearly indicative of definite time, these have been far too little inquired into to give us at present the slightest hope of changing the vague periods of geology into exact terms of years. The following investigation is therefore not intended to accomplish more than to produce a conviction that a long succession of time elapsed during the construction of the visible crust of the globe.

56. In the production of strata which are composed of fragmented materials of any kind, mechanical forces were exerted; for it is chiefly by the influence of waves and currents that sandy and argillaceous matter is brought to the stratified form. When, therefore, we see even a single sandstone rock composed of some hundreds of regular layers of sand and mica, and compare this with deposits from modern rivers or the sea, we shall feel assured that, in assigning to the accumulation of this rock a considerable space of time, we are proceeding in a just spirit of philosophy.

If we consider the common case of alternating clays and sandstones, both of which are mechanical deposits from water, but produced under different circumstances, perhaps brought in different directions, the indications of the progress of time become perhaps more clear and satisfactory.

It is very common to find deposits of limestone, apparently produced by chemical decompositions, lying in frequent alternation with sandstones and clays; and in such a case, by inquiring of the actual system of nature, we receive an answer that such changes of the mode of action in a given place imply cessations and renewals of chemical and mechanical actions which require time.

By reviewing in this manner the whole series of strata, amounting locally to some miles in thickness, and considering the accumulation of each bed, the alternation of beds of different kinds, the excitement, duration, suspension, and resuscitation of mechanical and chemical agencies, we shall be strongly impressed with the folly of setting narrow bounds to the time employed in these operations.

57. Some stratified rocks are composed of fragments of various kinds, united by a general cement of a different nature. These are called brecciated or conglomerate rocks, according as the fragments are angular, or rounded by attrition in water. Here there is proof that before the production of one stratum a previously stratified rock had been consolidated, partially broken up, its fragments agitated in water, and then redeposited. In some cases conglomerated rocks have been again broken up, and their fragments submitted to the same process of attrition and reaggregation.

58. There is another class of phænomena which speaks a language on this subject that can hardly be

misunderstood. We are well assured of the length of time required for the growth and maturity of organic beings; when, therefore, a single bed of stone only a few inches thick is found to contain a given species of shell, in every variety of magnitude, from the embryo to the full-grown or aged individual, all the specimens having evidently been enveloped quietly on the bed of the sea, and no bed either above or below for 100 yards or more containing any such shells, the conclusion seems certain that even for the accumulation of this one bed of stone the lifetime of that species of molluscous animal was required. Such a case occurs in the coal district of Yorkshire, where a bed of shale only a few inches thick, but extending for many miles, contains *Ammonites Listeri* in every stage of its growth; but that shell does not occur above or below, through a great thickness of strata.

In some cases whole rocks are literally composed of zoophytes, so as to resemble a modern coral reef, or of shells of many kinds. The extensive strata of coal are derived entirely from immense accumulations of vegetables, and sometimes no less than fifty consecutively deposited strata of this kind extend over a hundred square miles and more.

Strata which contain certain tribes of organic remains alternate with others which inclose none, or quite different races. Strata full of marine exuviæ are separated by others full of trees swept down from the land; and thus we are furnished with evidence of intermitting activity among the agents of ancient nature.

59. It seems unnecessary to accumulate more evidence in order to obtain an unanimous verdict from all impartial readers that the length of time occu-

pied in the production of the strata, some miles in thickness, which exhibit all this variety of events, was really very great. Whether it may hereafter be found susceptible of some rude approximation will depend upon the knowledge we may be able to gain of the rate of stratification and consolidation, and of the length of life of organic fossils. Is this expectation wholly chimerical?

CHANGES OF CLIMATE.

60. There is reason to believe that during the long periods (§ 59.) expended in the production of the whole great series of stratified rocks (§ 19.), and in the elevation of these out of the sea, the local temperature and other circumstances which influence the growth of plants and animals, both on the land and in the sea, were subject to remarkable changes. In this branch of the subject, the progress made of late years in philosophical botany and zoology is found of great importance. Without some fixed notions of the dependence of organic forms upon the influence of temperature, moisture, and other conditions,—without some clear proofs of the geographical limitation of the existence of species in a natural state, according to definable circumstances, it would be impossible to come to any conclusion respecting ancient climate. Besides this, it is necessary for a good argument on this subject that the fossil organic remains on which we found it should be very carefully compared with existing tribes, and their several degrees of analogy or difference noted. It is evident that any conclusions as to the character of ancient climate drawn

from comparison of fossil plants and animals with those which now inhabit particular regions of the earth, will be more or less binding as the analogies obtained are more or less exact and numerous.

61. In the existing system of nature the forms of life become more numerous toward the equator, and vanish altogether toward either pole. Thus, Humboldt counts only 4000 species of plants in temperate America, and 13,000 in tropical America; 1500 in temperate Asia, and 4500 in equinoctial Asia. In some natural groups of plants, as, for instance, ferns, the species grow to the greatest magnitude in warm regions, and dwindle to the smallest size in colder countries. These instances serve to point out the principle of the investigation of dependence of organic life upon temperature. The results obtained by this process apply accurately to the sea *at small depths*, and to the land *at small elevations*. In the gulfs of the ocean, and on elevated mountains, variations of temperature obtain, which require to be allowed for. Thus, in mountainous regions, the mean temperature of the air diminishes at the rate of about 1° Fahr. for 100 yards' elevation; and the flora of the mountain-slopes varies in a corresponding manner, so that the plants collected from the base of the Alps differ in a nearly constant manner from those at moderate heights. At the greatest heights, where the cold is severe, the plants resemble those which in the northern regions flourish near the level of the sea.

62. The relation of bulk and temperature in water is of a remarkable kind. At a temperature a little below 40° Fahr., fresh water is in the highest state of

condensation (under the ordinary pressure of the atmosphere); and therefore in all cases when the temperature of the surface of fresh water sinks to below 40° Fahr., the particles so cooled descend from the surface toward the bottom. If this process be continued till *all the mass of water* is reduced to below 40° Fahr., the surface may begin to freeze, which is the case with most freshwater lakes; but owing to the depth of others they never freeze. The case is different with salt water, which continually grows more heavy as it is cooled, even to the freezing-point, which is several degrees below that of fresh water. The sea may be looked upon as a great lake, which never freezes except in latitudes where the cold is so extreme as to overcome the downward tendency of the cooled surface-water, and convert it into ice, which, being specifically lighter, floats on the surface. In all latitudes the hottest sea water remains at the surface, or tends to rise thereto.

The greatest difference of temperature in the ocean, according to latitude, exists at the surface; the least difference in the deeper parts. We must therefore direct our inquiries, as to the influence of marine temperature upon organic life, to those plants and animals which constantly dwell near the surface of the water.

63. The play of oceanic currents materially diminishes the extremes of even its surface temperature, so that the polar ocean is warmer, and the equatorial ocean is cooler, than the adjacent continents. This uniformity of oceanic temperature is partially communicated to all the islands and shores, so as to constitute a distinct sort of climate, which is

less subject to extremes either of heat or cold than that of the interior of continents, and is more uniformly charged with aqueous vapour. We have therefore the following scale of climates in relation to latitude.

	Mountainous	
	Continental	
Equatorial	Littoral	Polar.
	Marine	
	Pelagian	

In agreement with what was before observed, we need not take into account the animals and plants of the pelagian or deep sea, or those which dwell on the mountains of very cold countries. Of the other climates, we may investigate some of the characteristic organic forms very simply.

64. First, of terrestrial climate as indicated by plants. Humboldt and other scientific voyagers present us with landscapes of the tropical regions, in which the magnificent Palms, the princes of the forest, are surrounded by Bananas, Cycadeæ, arborescent Ferns, Bambusiaceæ, Equisetaceæ, Lycopodiaceæ, Cacti, Euphorbiæ, and Mimosæ. To enjoy the splendid aspect of the tropical plants in the colder zones, we must imitate the tropical climates by hot stoves. In the elevated parts of the tropical continents, which have a climate comparable to that of northern latitudes, occur Cypresses, Pines, and Oaks. It is along the moist shores, and on the small islands of the warm zones of the earth, that arborescent Ferns, and Cycadeæ, and Equisetaceæ grow in the greatest abundance, so that in these situations they form a very large proportion, even to half the total number

of plants. In the drier interior of the continents, on the contrary, arborescent Ferns are less abundant; but Palms, and especially the succulent Cacti, form the characteristic vegetation. If we suppose that by any means the plants of an ancient tropical region of varied surface were buried under marine sediments, and by subsequent revolutions affecting that part of the globe these altered reliquiæ were laid dry and exposed for examination, the ancient character of the climate when and where these plants grew, could be satisfactorily inferred, *provided* that in the actual system of nature plants of analogous tribes were found really limited in their situation by circumstances depending on climate. Now this is precisely what happens in the case of fossil plants: for the most abundant and characteristic forms of ancient vegetation are Ferns, some of them arborescent, Lycopodiaceæ, Equisetaceæ, Cycadeæ, Palms, and Cacteaceæ. With these, or in separate layers, occur coniferous trees, and other plants, apparently indicative of cold regions or elevated land. Upon the whole, it seems the most probable inference, that the abundant vegetation of our coal strata was the produce of a tropical region, varied with plains, and shores, and mountain sides. The state of conservation of the plants, covered with leaves and in a state of considerable perfection, seems to prove that they have not been washed to a great distance; if so, the *places* where they are buried had the same sort of climate as warm regions of the earth in its present state*.

* If the river rolled as far as the Mississipi, cold regions and hot might equally yield reliquiæ to a basin which should be in a

65. If this conclusion be sound, it will be difficult to avoid believing that nearly the same warmth of climate was felt at the same time in those parts of the globe where now are New Holland, Greenland, North America, and Europe; for in all in these countries, plants belonging to the same or very analogous species lie in a deposit of the same geological antiquity—the carboniferous system. Humboldt long ago expressed the necessary consequence of this pervading high temperature, by saying, that in this condition of the world there was properly *no peculiarity* of climate, but a general superficial warmth, depending on the then greater or nearer influence of the interior heat.

66. In the existing œconomy of nature, terrestrial climate is supposed to be in a remarkable manner indicated by the races of vertebral and invertebral animals; but in the application of this principle a difficulty occurs, which is, in a less degree, also experienced in geographical botany. Animals are limited in their distribution by other causes than climate; they are localized between certain chains of mountains, certain breadths of deserts, and particular arms of the sea, and not unfrequently confined even to particular valleys and islands. Moreover, the remains of terrestrial animals are scarce in the earth; and it is perhaps only by a comparison of the forms of reptiles that any trustworthy results can be derived concerning the climate of the land in the

---

temperate zone; or in other ways the inferences might be varied. Currents of the Atlantic bring tropic timber to Ireland and Iceland.

northern zones of the world during any part of the period of stratification. Even here the conclusion is not very applicable to the land, because most of the fossil reptiles were marine. While, however, the ichthyosaurus and plesiosaurus might be littoral, and the crocodiles were probably estuary and river animals, the megalosaurus and iguanodon might live along the margins of primæval lakes; and from the whole series of these gigantic beings, compared with the present saurians and other reptiles, we may be well justified in inferring, that as all large reptile forms are almost peculiar to the warm regions of the globe, so it most probably was in the older time.

67. The geographical existence of zoophytic animals is subjected, in a very decided manner, to the influence of warmth at small depths in the ocean, and therefore (§ 57.) these will furnish the best possible evidence for the temperature of the ancient sea. If we confine our attention to the polypiferous and spongiform zoophyta, we shall find that the stony corals generally, including the madrepores, millepores, and tubipores of old writers, belong to warm seas, as the West Indies, East Indies, the South Pacific, Red Sea, Mediterranean, &c., and hardly appear abundant in any part of the ocean beyond the 33rd parallel of latitude (except along the south-east coast of Australia). The older calcareous strata are so full of remains of stony corals, that they have been considered by most geologists as coral reefs, analogous to those which, in shallow parts of the seas, grow up, like the Bermudas, a mingled mass of coral, shells, and calcareous mud derived from the comminution of these materials in the currents of the sea.

The *corticiferous corallines*, like Gorgonia, Isis, &c., appear equally determined in their general distribution to the warm shores of the sea, but their number in a fossil state is too inconsiderable to serve as the basis of analogical reasoning.

The *celluliferous corallines*, like Flustra, Sertularia, and Cellaria, appear, on the contrary, most abundant in the temperate and colder zones as far north as 60°; but they are of comparatively rare occurrence in a fossil state. Sponges give us some curious results. These half-animalized beings contain, in their durable parts, spiculæ of calcareous or siliceous matter, with more or less of a horny substance. In proportion as the horny matter increases in quantity, and ramifies and anastomoses* into network, the sponges are more flexible and more useful: those which consist principally of earthy fibres are too harsh for use. The horny sponges belong to warm seas, and especially to southern seas, where, as on the shores of New Holland, they grow even in temperate latitudes. The siliceous and calcareous sponges are plentiful along the coasts of Great Britain, even to the northern parts. Fossil sponges are much more analogous to the horny than to the earthy kinds.

68. There would be little advantage in extending this investigation to the Mollusca, Crustacea, or fishes which dwell in the sea; because these animals inhabit various depths in the water, sometimes migrate periodically to the shores, and are not sufficiently characteristic of climate, except by analysis of the families too minute for our argument.

* A term frequently used by anatomists to express the opening of vessels into one another.

69. We have thus found (after limiting our investigations to such organic races as are eminently and in large groups characteristic of climate in the actual œconomy of nature, and are also plentiful in a fossil state,) clear indications (§ 60. to 68.) that the ancient climate on the land was such, over a great portion of the globe, as to nourish plants of tropical forms; that the water of the ocean in the same regions, at small depths, was of such temperature as to permit the growth of coral reefs, and the existence of large reptiles. And as these conclusions will not admit of explanation without calling in astronomical causes, which probably have not acted, such as the displacement of the earth's axis, change of the earth's distance from the sun, &c.; or, allowing that the superficial warmth of the earth was nearly independent of the solar rays, and regulated by the communication of heat from within; in agreement with inferences from other considerations (§ 13.), we cannot hesitate to adopt the latter alternative, and to view the globe as now cooled at the surface, owing to the accumulation of nonconducting solid rocks over an ignited nucleus, and governed in its temperature by the external influence of the sun.

EARLY RACES OF ORGANIC BEINGS.

70. Were one who was completely ignorant of geological science required to consider the question whether this globe had been tenanted in some ancient periods by races of animals and plants different from those which now inhabit it, he would perhaps be surprised at the novelty of the idea, but would find

himself unable to answer. History, it is evident, can tell us nothing of those times which preceded the existence of man: there is nothing in the Mosaic records of the creation of man, and the present forms of organic life, which in any manner defines the earlier condition of the globe, further than by affirming that it was formerly in a different state, especially as to its enrichment with living beings, from that which it exhibits to us at present. This latter consideration is too little present to the minds of many sincere readers of the Bible; and, in consequence, a very unhappy conflict has been sometimes occasioned by comparing those results of geology which relate to periods left wholly undefined in the Scriptural narrative, with the successive works of creation which are in that narrative distinctly marked. If we take the first verse of Genesis as affirming the eternal superintendence of God over all the prior conditions of the world, from the epoch of its original creation until he saw fit to give it its present character, and to call into being its present races of man, animals, and plants, and compare this with geological inferences relating to periods anterior to man, we shall find two conclusions inevitable; first, that there is no word in the Scriptural narrative which limits in any way the inferences or even the speculations of geology, with reference to these periods; secondly, that nothing can ever be learned about those periods by human labour, except in the way of geological induction. This is sufficient for the purpose of the present inquiry, which relates to races of animals and plants, not only anterior to man, but even to the elevation of most parts of our continents from beneath the waters of the ocean.

71. Recurring to the observations concerning the lapse of time (§ 55—59.) which took place during the formation of the stratified crust of the globe, we shall be prepared to enter on a more extended inquiry concerning the races of animals and plants than was necessary in a former section (§ 22.).

The number of species of plants and animals at present in existence is not known even nearly to accuracy, but the following estimate may perhaps be accepted as affording a useful notion of the *relative* proportions. The numerical statements of organic remains actually known are chiefly taken from the *Encyclopædia Metropolitana* (Art. GEOLOGY). All organic remains found only in gravel, caverns, &c., are excluded.

	Living.		*Fossil.*
Plants	60,000	......	600
Zoophyta	1,000	......	770
Mollusca	6,000	......	4,800
Articulosa	110,000	......	400
Fishes	5,500	......	500
Reptiles	2,000	......	60
Birds	5,000	......	10
Mammalia	1,200	......	60
	190,700	......	7,200
	26	to	1

72. The actual system of organic beings is adjusted to terrestrial and aquatic life; and of aquatic animals, some live in the sea, others in fresh water. The following Table gives a comparative estimate of

recent and fossil plants and animals according to these conditions:

		Recent.		Fossil.
Terrestrial.—	Plants	59,000 +	......	500
	Mollusca ...	600 +	......	50
	Articulosa..	107,000 +	......	200
	Reptiles ...	1,800	......	10
	Birds	5,000	......	10
	Mammalia .	1,100	......	60
		174,500	......	830
		210	to	1
Freshwater.—	Plants	100	......	40
	Zoophyta ..	10		
	Mollusca ...	400	......	150
	Articulosa..	2,500	......	50
	Fishes	500	......	20
	Reptiles ...	100	......	40
	Mammalia .	50	......	?
		3,660	......	300
		12	to	1
Marine.—	Plants	1,000	......	40
	Zoophyta ..	1,050 +	......	770
	Mollusca ...	5,000	......	4,600
	Articulosa..	500	......	185
	Fishes	5,000	......	500
	Reptiles ...	100	......	10
	Mammalia..	100	......	?
		12,750	......	6,100
		21	to	10

From these comparisons it is immediately evident that by far the larger relative proportion of fossil organic remains belongs to the marine division, that the fewest of all are the terrestrial races. This might have been foreseen, for as we are looking upon the bed of the ancient sea we ought to expect marine remains abundant, and terrestrial reliquiæ very rare. At the present day, only a very small proportion of animals and plants, inhabitants of the land, is carried down to the sea, or even deposited in freshwater lakes.

73. It has not been found necessary, in discussing the history of fossil plants and animals, to constitute a single new class; they all fall naturally into the same great sections as the existing forms. Thus, among plants, both recent and fossil, occur the same leading classes, founded on the cellular or vascular structure, and on the floral and seminal parts of the plant; among Zoophyta, we distinguish recent and fossil Polyparia and Radiaria; among Mollusca occur all the divisions of Conchifera, Gasteropoda, Pteropoda, and Cephalopoda; among Articulosa we find Crustacea, Insecta, Annulosa, &c.; and among vertebral animals, Fishes, Reptiles, Birds, Mammalia. Moreover, on analysing these classes, and comparing the subdivisions, families, and genera, we find very often, especially in the marine tribes, that the same characters will apply equally well to both the recent and fossil races. Thus, among conchiferous mollusca we have both recent and fossil shells with two lateral muscles (Plagymyona), shells with one (principal) subcentral muscle (Mesomyona), and shells of a particular and still different construction (Brachiopoda). Again, in Plagymyona some have many teeth at the hinge (Arca, &c.); others striated hinge teeth (Trigonia); some large ligamental teeth (Mya); some gape at the ends (Lutraria); some bore holes in

rocks (Pholas, Lithodomus), &c. All these and many more characteristic forms and habits occur in both recent and fossil shells. Now as these divisions are all founded upon important points of structure, we are warranted in concluding that the older organic creations were formed upon the same general plan as at present. They cannot, therefore, be correctly described as entirely different systems of nature, but should rather be viewed as corresponding systems composed of different details.

The difference of these details arises mostly from minute specific distinctions ; but sometimes, especially among terrestrial plants, certain crustacea, and reptiles, the differences are of a more general nature, and it is not possible to refer the fossil tribes to any known recent genus, or even family. Thus we find the problem of the resemblance of recent and fossil organic beings to resolve itself into a general analogy of system, frequent agreement in important points, but almost universal distinction of minute organization. Of 7000 fossil species tabulated above, not more than two or three hundreds are *identical* with living species. Of above 600 genera which include those species, more than half are peculiar to the fossil state.

GEOLOGICAL DISTRIBUTION OF ORGANIC REMAINS.

74. Remembering (§ 41.) that each set of stratified rocks was successively the bed of the sea, and that the organic exuviæ which lie in these rocks are those of animals and plants then living in the sea or on the

land, we shall be able to compare the organic beings of the several periods of the stratification of the earth's crust, with each other as well as with existing tribes. The series of strata, taken in general terms (§ 19.), may be conveniently arranged in six groups or systems, as under, beginning with the least ancient.

Tertiary system.
Cretaceous system.
Oolitic system.
Saliferous system.
Carboniferous system.
Primary system.

We shall first consider the numerical relations of the organic fossils which have been found in these several groups in various parts of the world; and, for the sake of perspicuity, separate the marine from the fluviatile and terrestrial reliquiæ.

75. The first Table relates to marine tribes.

	Plants.	Zoophyta.	Mollusca.	Articulosa.	Vertebrata.	Totals.	General Thicknesses of Strata.	Number of Species to 100 feet thickness.
Living	1,000	1,050	5,000	500	5,200	12,750		
Tertiary.........	13	{26 +23}	2,728	5	26	2,921	2,000	146
Cretaceous ...	14	{140 +95}	500	13	15	777	1,100	70·7
Oolitic	4	{180 +95}	771	22	70	1,142	2,500	45·6
Saliferous	6	{7 +8}	118	1	24	164	2,000	8·2
Carboniferous.	?	{30 +27}	237	7	10	311	{5,000 to 15,000}	3·1
Primary.........	4	{87 +35}	349	65	?	544	{20,000 or more}	2·7 or less

This Table shows, in a very striking manner, the fact of the far greater abundance of marine organic exuviæ in the newer than in the older strata, and seems to add a strong argument in favour of the old opinion, that the lowest of all the primary strata were formed in a period when the ocean was devoid of living beings. If this conclusion be correct, the archives of nature are almost completely preserved to us, and the history of fossils is that of nearly the whole series of living beings which have successively inhabited the ocean.

76. Let us now turn our attention to the terrestrial reliquiæ, which are less abundantly diffused through the same systems of strata. We shall confine ourselves to plants of undoubtedly terrestrial and lacustrine origin.

	No. of Species.	Thickness.	Number of Species to 100 feet thickness.
Tertiary	156	2,000	7·8
Cretaceous	7	1,100	0·7
Oolitic	76	2,500	3·0
Saliferous	40	2,000	2·0
Carboniferous	274	10,000	2·7
Primary	10?	20,000	0·05

For various reasons, we cannot venture to draw any inferences from these data as to the relative numbers of plants really existing on the land during these periods. The principal difficulty arises from the obvious fact that the occurrence of terrestrial reliquiæ at all in the marine deposits is *accidental*.

77. We may now advance to another view of the subject of the distribution of organic remains in the earth. We may inquire whether the fossils which occur in all these great systems of strata, and which differ more or less completely from existing forms, be indefinitely distributed through the different groups of strata, or whether the series of fossils in each system of strata be distinguishable from those

in the other systems. To this the reply is short and decisive. Wherever examined, the several systems of strata above enumerated contain wholly distinct suites of organic remains, by which, in every limited district hitherto explored, they may be respectively characterized. As the fossils are distinguishable from recent beings, for the most part by minute differences of organization, but sometimes by whole genera and families, so the several systems of fossils locally observed differ from one another in the same manner. The primary strata, for instance, may be distinguished from the carboniferous system by minute yet clear distinctions in the several species of shells belonging to the same genera of Orthoceras, Producta, Spirifera, &c.; from the saliferous system, by the absence in this latter of Trilobites, Orthocerata, and whole groups of corals; and from the oolitic system, by the presence of new forms of Ammonites, Gryphææ, Trigoniæ, Pholadomyæ, &c.

78. On this subject, two propositions may be adopted; first, The amount of the differences observable between the fossils of any two systems of strata is greatest in those systems which are the furthest removed, as, for instance, between the primary and the tertiary systems; secondly, The amount of the differences observable between the fossils of any system of strata and those at present in existence is greatest in the oldest system of strata, and least in the newest. Thus, on placing together primary fossils and recent shells or Zoophyta, the difference is striking and total; but on comparing tertiary and living forms, it is the resemblance which arrests our attention. In one case we see at a glance the most obvious

and complete discordance; in the other it requires careful scrutiny to assure ourselves that they are not identical. Viewed in this manner, the whole living and fossil world of existence, as far as relates to the inferior, and especially marine tribes, seems to be almost united into one vast chain of being, which has derived from the same Creator in all past times the same fundamental laws of relation to the conditions of the world, but which shows itself in various forms, because these conditions were made to change. What a lofty view of the superintending care and providence of God through *all* periods of past time is thus opened to our minds! How heedless of plain truths must they be who can ever disconnect geological inquiries from reverential thoughts of the divine Lawgiver of Nature!

79. The conclusions above stated as to the entire distinctness of the organic remains in the several systems of strata apply with certainty to every limited region; that is to say, in whatever part of the world primary, carboniferous, saliferous, oolitic, cretaceous, and tertiary systems have yet been seen together, the fossils which they respectively contain are different from one another. In every country yet examined it is *locally* true that the systems of strata of different age contain distinct races of organic remains. But inquiries of equal importance now present themselves. Do strata of the same age uniformly contain fossils of the same species? Do they contain fossils of analogous species? Or are the fossils which any rocks contain merely of local occurrence, so that in distant parts of the world strata of the same age contain wholly different organic remains?

This is a mere question of fact: it must not be answered by reasoning upon existing phænomena, or by hasty generalization from limited data. On this subject we have yet much to learn: the following, however, are ascertained truths.

80. The same groups of fossils which are in a very eminent degree characteristic of certain systems (§ 77.) in one country, are also found under the same relations to those systems, not only in adjacent, but in far removed tracts, sometimes even to the distance of thousands of miles. Thus, for example, of the extinct crustaceous animals called Trilobites, the far greater portion of those found in England belongs to the primary strata; they also appertain in the same nearly exclusive manner to the same system of strata through Norway, Russia, the Harz, Britanny, &c. They also characterize the primary system of North America.

Again, the extinct plants called Lepidodendra characterize, almost absolutely, as a group, the coal strata of Great Britain: they have exactly the same relations to the coal of France, Belgium, Silesia, and North America.

Certain groups of Ammonites belong exclusively to the oolitic system of England: they are equally characteristic of this system in France and Germany, and come to us from the Himalayan mountains associated with other oolitic fossils.

Peculiar forms of Echini mark the cretaceous strata of England, and the same occur in France, Poland, and along the shores of the Baltic.

Whole families of shells, such as Volutes, Cones, Cerithia, &c., may be viewed as distinguishing the tertiary strata from those below them, in all parts of the world.

81. Instances are known of certain peculiar species of fossils occurring in the same series of strata in almost every region where those strata are known. Thus, the Dudley Trilobite (*Calymene Blumenbachii*) is found in Shropshire, Herefordshire, and Gloucestershire; it also occurs in Norway, in the Eifel, and in North America, but only in the same part of the primary series of strata. *Calamites Suckovii* occurs in the English coal-fields, and in those of Liege, Anzin, Pennsylvania, and Virginia, but not in any deposit of a different age.

The general aspect and character of series of fossils derived from the same system of strata in very distant quarters of the globe are often extremely similar; very generally the same characteristic forms are repeated at all points in the ranges of the same strata; but there are also local differences always observable, which become the more considerable and obvious the greater the distance between the localities.

82. From all these considerations, we may conclude satisfactorily that the organic remains found in any one system of strata are of the same general character wherever those strata occur; that many *local* distinctions derived from organic remains between successive systems of strata disappear when the facts are viewed on a great scale; but that, as far as our experience at present goes, each system of strata may be identified through its whole course, and discriminated from the older and more recent systems, by a judicious examination of a sufficient

number of its organic contents. It is thus made evident that there have been many races of marine animals and terrestrial plants which have been successively called into existence in the same regions of the globe to suit its altered condition, and we may be well assured that these successions of organic beings, well understood, will afford a secure and unchangeable scale of geological chronology. What the periods are which this scale of successive creations indicates, we may perhaps never know. There is but one mode of approximation to even a plausible estimate of these periods—a knowledge of the length of life of the different sorts of marine animals. If this mode should be found impracticable, we fear the problem must be despaired of. See *Encyclopædia Metropolitana*, Art. Geology.

83. It would be impossible, even if it were suitable to the object, to give in an elementary work anything like an extended exemplification of the principles above announced. Fortunately, however, some illustrations can be presented in a tabular form, which will sufficiently evince the truth of these views. If we put in one table some of those genera which in the present system of nature are most rich in species, and in another those which were most prolific in forms in the older periods, we shall see very clearly what analogy or difference may exist. Also, by selecting other genera and families, we may shew through what ranges of strata, that is to say, through what geological periods, they existed, and at what periods they were most numerous. Thus, Trilobites existed during the primary and carboniferous epochs, but are never known in the more recent strata, nor

do they exist at present; Productæ pass through the primary and carboniferous epochs, and end in the saliferous; Spiriferæ pass through all these epochs, and end in the oolites; Ammonites pass through all these periods, and end in the chalk; Terebratulæ existed through all these periods, and also through the tertiary system, and are still in being. On the other hand, certain tribes began to exist at later periods, as the Belemnite, many genera of Echini, &c., and ended their races before the dawn of the tertiary period. This will serve to render intelligible the following Tables.

TABLES OF THE GEOLOGICAL DISTRIBUTION OF FOSSILS.

84. Table I. *Genera containing many living species.* (*Gasteropoda.*)

	Cypræa.	Conus.	Voluta.	Strombus.	Murex.	Fusus.	Cerithium.	Mitra.	Pleurotoma.
Living Species	135	181	66	45	75	67	87	112	71
In Tertiary Strata	19	49	32	9	89	111	220	66	156
In Cretaceous System	...	...	2	1	2	...	1		
In Oolitic System	...	...	...	...	1				
In Saliferous System									
In Carboniferous System									
In Fossiliferous Primary Strata									

The numbers of living species and those of the fossil species in tertiary strata are taken from Deshayes (Lyell, 1st edition, vol. iii.); those in the other systems of strata from the *Encyclopædia Metropolitana* (Art. GEOLOGY). In this Table, the strong analogy of the tertiary and living forms of animals, and their distinctness from all those of earlier date, are very decided.

85. Table II. *Genera containing many fossil species.* (*Conchifera.*)

	Producta.	Spirifera.	Terebratula.	Trigonia.	Pholadomya.	Plagiostoma.	Inoceramus.	Gryphæa.
Living Species	...	...	15	1	1	...	...	1
In Tertiary Strata	...	...	18	...	1	...	...	3
In Cretaceous System	...	...	57	12	1	13	19	7
In Oolitic System	...	6	49	14	16	17	1	17
In Saliferous System	7	5	14	7	...	8	...	1?
Ir. Carboniferous System	26	23	16	...	1	...	1	
In Fossiliferous Primaries	21	37	30	3	1			

This Table suggests curious remarks concerning the duration of existence of certain genera; the periods of their greatest fecundity in species; the consequent distinction of particular sets of strata, by the presence or absence of whole groups of shells, and by the extraordinary plenty of others.

86. Table III. *Genera of Cephalopoda.*

	Bellerophon.	Orthoceras.	Belemnites.	Nautilus.	Ammonites.	Hamites.	Scaphites.	Baculites.	Nummulites.
Living Species	...	...	...	2					
In Tertiary Strata	...	...	...	4	?				10?
In Cretaceous System	...	...	8	9	57	28	4	5	3
In Oolitic System	...	...	75	13	164	2			
In Saliferous System	...	...	...	2	3				
In Carboniferous System	13	17	...	18	7+				
In Primary Strata	11	29	...	3	17				

In the above Table I have followed the usual nomenclature, and considered the Ammonites as a genus. The next gives the geological distribution of the several sections of Ammonites proposed by Von Buch.

87. Table IV. *Subgenera of Ammonites.*

	Goniatites.	Ceratites.	Arietes.	Falciferi.	Amalthei.	Capricorni.	Planulati.	Dorsati.	Coronarii.	Macrocephali.	Armati.	Dentati.	Ornati.	Flexuosi.
Living Species	—	—	—	—	—	—	—	—	—	—	—	—	—	—
In Tertiary Strata	—	—	—	—	—	—	—	—	—	—	—	—	—	—
In Cretaceous System	...	...	...	2	4	...	...	...	...	9	14	13	2	3
In Oolitic System	...	...	12	22	27	12	26	5	11	11	11	4	5	3
In Saliferous System	...	3												
In Carboniferous System	7													
In Primary Strata	17													

It is easy to see how important, in questions concerning the relative antiquity of stratified rocks, is a knowledge of Ammonites, since whole sections of them are characteristic of certain systems of rocks.

88. The last Table will show that particular species of fossils are generally confined to one system of strata. The stars indicate in what strata the species named occur.

Table V. *Species of Shells, Corals, &c.*

	Plagiostoma spinosum.	Plagiostoma duplicatum.	Terebratula Wilsoni.	T. sacculus.	T. tetraëdra.	T. plicata.	Clypeus sinuatus.	Spatangus Cor anguinum.	Sp. ovalis.	Galerites albogalerus.	Gal. depressus.
Tertiary Strata											
Cretaceous System	*	...	...	...	...	*	...	*	...	*	
Oolitic System	...	*	...	...	*	...	*	...	*	...	*
Saliferous System											
CarboniferousSystem	...	...	...	*							
Primary Strata	...	...	*								

PART III.

DESCRIPTIVE AND PRACTICAL GEOLOGY.

CONSTITUENT INGREDIENTS OF ROCKS.

89. It has already been stated, that notwithstanding the immense variety of rocks which solicit the attention of a geologist, a correct knowledge of only a limited number of mineral substances is sufficient to enable him to trace and recognise these rocks, and describe them satisfactorily to others. The following short list includes those that appear most essential for this purpose. It is hardly necessary to observe that the student will do well to endeavour to familiarize himself with these minerals, by considering the variation of their appearance and modes of combination with one another, and examining them in a crystallized, amorphous, and decomposed state. For this end he should often contemplate arranged cabinets of minerals, and collect fragments of compound rocks. A little practice will give him a notion of their characteristic forms, hardness, specific gravity, and ordinary optical characters.

1. Quartz.	9. Schorl.	17. Carbonate of magnesia.
2. Felspar.	10. Chiastolite.	18. Sulphate of lime.
3. Mica.	11. Chlorite.	19. Muriate of soda.
4. Hornblende.	12. Green earth.	20. Bitumen.
5. Actinolite.	13. Talc.	21. Iron, Oxide of.
6. Augite.	14. Steatite.	22. —— Sulphuret of.
7. Hypersthene.	15. Garnet.	
8. Diallage.	16. Carbonate of lime.	

Those geologists who have occasion to examine into the history of mineral veins, must, in addition, make themselves acquainted with metals, alloys of metals, and combinations of metal with sulphur, selenium, carbon, oxygen, and acids.

90. To assist in the acquisition of the requisite knowledge of these minerals, the following statement of some of the modes of their occurrence in a considerable number of rocks may be found useful. (See also Macculloch's Treatise on Rocks.)

Quartz. Crystallized in double six-sided pyramids in the substance of granitic, porphyritic, and other igneous rocks; in six-sided prisms terminated by six-sided pyramids in mineral veins and in cavities in granite; compact in veins; nodular in amygdaloidal traps: rolled masses in old red conglomerate, millstone grit, and grauwacke: worn grains in sandstones, clays, certain quartz rocks, and coarse clay slates.

Felspar. Primary rhomboidal crystals in granite, porphyry, trachyte, and basalt: composite crystals in cavities of granite, and veins: disturbed crystals in gneiss: rolled crystals in conglomerate: decomposed to porcelain clay in some granites and sandstones.

Mica. Crystallized in hexagonal plates in granite, porphyry, lava, and primary limestone; disturbed crystals in gneiss and mica schist; fragmentary scales in sandstone, sand, shale, and clay.

Hornblende. Crystallized with felspar, &c., in syenite, greenstone, basalt, and lava; also in hornblende slate.

Actinolite. In hornblende slate, in veins.

Augite, or *Pyroxene.* Crystallized with felspar in augitic greenstone, augitic basalt, melaphyre, lava; also in primary limestone.

Hypersthene. Crystallized with felspar in hypersthene rock, hypersthenic syenite, hypersthenic granite, hypersthenic greenstone.

Diallage. Crystallized with felspar in gabbro or diallage rock; obscurely crystallized in serpentine; fine-grained in serpentine.

Schorl. Crystallized with quartz in the "cockle" rock of Cornwall.

Chiastolite. Crystallized in the clay slate of Cumberland, Spain, Ireland.

Chlorite. Crystallized in veins, and granite; amorphous in chloritic mica schists, and clay slates.

Green Earth. Amorphous, pulverulent, or compact in amygdaloidal porphyries, basalts, and wackes.

Talc. Crystallized in some granites. Amorphous and earthy, in veins, talcose schists, and primary limestone.

Steatite. Amorphous in serpentine, granite, clay slate, and veins.

Garnet. Crystallized in granite, gneiss, mica schist, clay slate, primary limestone; near trap dykes; in veins.

Carbonate of Lime. Crystallized in veins, cavities of calcareous rocks, shells, primary limestone, and stalactites; amorphous in limestone rocks; concretionary in oolites; fibrous in certain limestones, and shells; nodular in amygdaloidal traps; laminar in shells, and corals; pulverulent in rock marls, chalk, &c.

Carbonate of Magnesia. Crystallized in veins; amorphous in certain clays; combined with carbonate of lime in dolomite, magnesian limestone.

Sulphate of Lime. Crystallized (selenite) in clays; fibrous, compact, pulverulent (gypsum) in clays, &c.

Muriate of Soda. Crystallized in rock salt; invisibly disseminated in most rocks; in lava.

Bitumen. Concrete or liquid in certain limestone rocks, shells, and veins; disseminated invisibly through the mass of many shales and limestones.

Oxide of Iron. Crystallized in lava, syenite, hypersthene rock, and veins; minutely disseminated in sandstones, clays, ironstones, ochre, &c. &c.

Sulphuret of Iron. Crystallized in clay slates, primary limestones, near trap dykes, in chalk, clays, argillaceous limestones; in artificial products, both of aqueous and igneous origin.

STRUCTURE OF ROCKS.

91. It has been already remarked (§ 16.) that the most important distinction in the structure of rocks is that of their being stratified or unstratified. The fundamental idea of a stratum of rock is that of a widely extended mass of matter, which settled to rest, while in an incoherent state, under the influence of gravitation, with or without any lateral impulse. According to this view we may imagine strata to

have been formed by the falling or drifting of sand in the air; by the deposition of particles in a calm or agitated liquid; and by the solidification of a fluid mass.

92. Let us examine these cases in succession. The ashes thrown up from a volcanic crater fall around it, and collect in concentric laminæ sloping on all sides from the centre. (See pl. ii. fig. 9.) This may be called conical lamination; it is, in general, easily distinguishable from a case of conically uplifted stratified rocks, by the irregularity and discontinuity of the layers.

93. Sand, drifted by the wind, collects into particular forms, according to the nature of the obstacles to its progress. It is heaped against the old temples of Egypt; accumulated into irregular hills on the sea-coast, round the roots and stems of *Elymus arenarius* and *Arundo arenaria*; but on the wide plains of Western Norfolk, and on a greater scale in the African deserts, it is scattered in a more equable manner. Where a river impedes its progress, the sand often fills up the stream on one side with a shallow projection, and causes it to excavate the opposite bank. Similar phænomena happen on the seaside. No true strata are formed by such irregular and accidental causes.

94. Particles minutely disseminated in a quiet liquid, whether by chemical decomposition or mechanical disturbance, produce, when they fall therein, strata proportioned in thickness to the quantity of matter suspended above; that is, generally, proportioned to the depth of the water. Hence, in the freshwater lakes of central France, it has been

observed that the calcareous strata grow thinner toward the edges of the basins. The same happens to the very fine clays which, under the name of warp, are deposited on the low lands adjacent to the tide-rivers of the North of England.

95. But the matter which falls from an agitated liquid partakes, in its arrangement, of the lateral influence of the currents and eddies. From the stormy waters of the Arve falls abundance of sediment, full of oblique and crossing laminæ which indicate the variable direction of the currents. The same structure is often noticed in sandstone strata, as in the cliffs under Nottingham Castle and Knaresborough Castle. For such cases the term oblique lamination is conveniently employed.

96. A different result happens when a rapid stream delivers coarse detritus into a deep and quiet lake; the Rhone, for example, falling into the Lake of Geneva, communicates to the sediment a horizontal force, which, combined with the influence of gravitation, causes the particles to describe curves in the calm water. Parallel to these curves, which deviate more and more from the horizontal as the particles descend lower, the matter accumulates round the point where the river enters, and thus a peculiar concentric lamination is occasioned. In the deeper parts of the water the curves of descent are too steep for the matter to lie at rest, and consequently the laminæ are found to follow nearly conical slopes. (See Mr. Yates's paper on this subject, Edin. Phil. Journal, 1831.)

97. It is evident that the most extensive and uniform strata are produced from a corresponding dif-

fusion in water of substances which slowly and equally settle on its bed. The regularity of the strata of limestone, shale, and coal is very remarkable; the irregularity and discontinuity of coarse conglomerates are no less striking: both these results are in conformity with effects daily produced on a smaller scale. The ocean is to be viewed as an unquiet lake, receiving sediments of various kinds under different conditions. The restless agitation of its surface-waters tends to diffuse far and wide the lighter matter contributed by rivers, or obtained by its own warfare with the coasts, while the coarser and heavier matter remains near the shore, and thus the materials are sorted, and transported to various distances, till they quietly settle in extended strata, which tend more and more to become horizontal, the further from shore and the more tardy the deposition.

98. In this way, we may see the means of distinguishing the truly oceanic from the truly littoral portions of old stratified formations: the former may in general be known by the regular and continuous stratification of the limestones and shales; the latter by the irregular mixture of local conglomerates, coarse shales, and debased and attenuated limestones.

99. The last cause of stratiform accumulation, viz. the solidification of a fluid mass, is exemplified in modern lava, and in old plutonic rocks of several kinds. Modern lava has generally been consolidated in air, but the older igneous products most frequently under the pressure of water or a great thickness of incumbent rocks. The form assumed by lava, which has flowed and been indurated in the air, depends almost wholly on the shape of the ground. Round a

volcanic cone the basaltic lavas are in the form of narrow irregular streams, directed down the slope, and thickest toward their base: in the valleys of Iceland, almost lakes of liquid rock have congealed, with all possible irregularity, owing to the cooling of the surface before the flowing of the under current ceased. Even when successive lava-streams have been laid one on another, hardly the least character of stratification is produced.

Some of the older plutonic rocks which were poured out on the bed of the sea, have, indeed, on one surface a stratiform aspect, because they take the shape of the stratified rock beneath them; but their upper surface has those irregular bosses and protuberances which must inevitably result from the cooling of a partially fluid mass. Igneous rocks, which have been forced between strata of other materials, assume a tabular form, which might mislead a beginner uninstructed in the history of such irruptions. Many such *interposed beds*, as they are termed, occur in the Island of Arran. (See also § 146.)

100. Besides the stratified structure, which is coeval with the deposition of certain rocks, there is another pervading *all* rocks, which has met with less attention than it deserves. All rocks are traversed by certain divisional surfaces, commonly called *joints*, which in basalt occasion vertical prisms, in clay-slate parallel tables, in shale rhomboidal faces, in limestone cuboidal blocks. There are many kinds of joints:—

Cracks, which in general do not pass through even one bed of stone. Some of these minute internal fissures are empty, others filled with carbonate of lime or small veins of metallic substances; some have their surfaces marked with a beautiful radiated crystallization of oxide of iron or manganese, like delicate plants. These are often called *dry cracks* by the workmen. All these substances have, no doubt, been transferred through the pores of the rocks by electrical or other subtle agency; that they are not contemporaneous with the rocks is proved by the fact that, whether empty, sparry, or metalliferous, the cracks sometimes pass through shells, fishes, plants, and even divide the pebbles of conglomerate rocks.

Joints go through a whole bed, or several beds of the same description.

Fissures pass through a great variety of strata, though of different nature, as sandstone, limestone, shale, and coal. They even divide strata belonging to different formations. They are either empty, partially lined, or entirely filled with crystals of carbonate of lime, metallic oxides, &c.

There is amongst the great fissures in a given district of stratified rocks a remarkable parallelism, and a tendency to particular directions, which, at least in some instances, coincide with the lines of convulsion. The minor joints seem to be characteristic of the different sorts of rocks by their relative number, closeness, parallelism, and angles of intersection. In slate rocks the joints and fissures intersect one another with almost geometrical regularity; they are very symmetrically arranged in laminated shales; but in thick sandstones only the great fissures hold any regular course.

In unstratified rocks the joints have been little attended to, except when they appeared to produce a prismatic arrangement, analogous to that of basalt.

The production of joints in rocks may be referred to the condensation of their mass from an aqueous or igneous expansion; but the symmetry of their arrangement can only be referred to some kind of crystalline action; and the parallelism of the great joints over large tracts of country (§ 161.) seems the effect either of electrical currents controlling that action, or of peculiar, perhaps undulatory, movements affecting large parts of the crust of the globe.

CLASSIFICATION OF ROCKS.

101. The following classifications of the stony and earthy deposits (often called indiscriminately by the term 'rocks,' for want of a better,) are founded upon the principles contained in a former portion of this treatise (§ 23. to 30.). The first and leading distinction is purely geological. Rocks are divided into Hydrogenous, or of watery origin; and Pyrogenous, or originating from heat. Under the former head are placed, 1. All aqueous deposits from streams, local and general floods, lakes, &c.; 2. Those stratified rocks which were produced under the sea. In this latter division it has been necessary to include a few alternations of freshwater deposits. Under the head of pyrogenous rocks come, 1. The volcanic products ejected, in the state of ashes, into the air, or under water; 2. Melted rocks, poured into the air, into water, or solidified in subterranean situations; 3. Mineral veins, and other metallic deposits.

CLASS I.—HYDROGENOUS DEPOSITS.

Section 1.—SUPERFICIAL ACCUMULATIONS.

(SYNONYMS. *Alluvial and Diluvial Deposits* of English Authors; *Terrains Alluviens, Lysiens, Clysmiens,* Brongn.)

VALLEY SEDIMENTS.

102. In all valleys through which continuous streams, or periodical or accidental inundations pass, the effects of their mechanical action remain more or less distinctly marked. The erosive power of the currents is conspicuous in all the steeper parts of the sloping valley, which, originating generally in a convulsive displacement of rocks, has received, in most cases, its peculiar character from the action of water. According to the nature of the rocks the features of the valley vary. In all the lower parts of the valley, and especially towards the meeting of the freshes and the tide, the sediment brought down from the uplands is deposited on the now level surfaces of the marshes and meadows, in floods, or on the bed of the river in the ordinary state of the waters, or carried out to sea.

In many cases, the sedimentary deposits in valleys seem to have little relation to the actual stream. For instance, in the valley of the Rhine, between Strasburgh and Bingen, the deposit called *löss* is found at the height of some hundreds of feet above the river, and seems to have been a very extensive mass, through which, in some cases, the Rhine now works its way. The remarkable terrace-heaps of gravel and sand at the mouth of Glen Roy, and along many other Highland and Cumbrian valleys, is a phænomenon apparently of a similar nature. It seems to prove that these valleys are of high geological antiquity, and that currents of water formerly passed down them, under different circumstances as to level, outlet, and dynamical action from the present.

In some cases the action of rivers, in accumulating sediment, is so regular as to permit the layers to be counted for terms of years. This is observed on the slopes of the Alps to depend on the periodical melting of the snows.

The organic remains in valley deposits are of such land animals and plants as, lying on the surface, were exposed to the inundation. Land shells are very abundant in the löss of the Rhine valley; along the rivers of Yorkshire, hazel-nuts and trees, bones of stags, land and freshwater shells, &c., occur, and in some instances have undergone petrifaction.

LACUSTRINE SEDIMENTS.

103. Deposits are formed in lakes from several causes: 1. from the growth of shells; 2. from springs containing carbonate of lime; 3. from mechanical admixtures of sand and clay, and vegetable remains derived from inundations or rivers. Some of these may be of very high geological antiquity; for we may believe lacustrine deposits to have been produced upon the land as soon as it was raised above the sea; and this has been shown (§ 49. 50.) to have happened at many different periods. The right way of investigating their antiquity is to study and compare the organic remains imbedded. Thus studied,

it is found that all the known *superficial* lacustrine deposits are posterior to the chalk, though many large tracts of land were elevated long before the production of that rock. In England they are nearly all subsequent to the æra when the mammoth existed in northern regions.

Mr. Lyell has described the production of shell marl in Bakie Loch, Forfarshire, as depending on calcareous springs, and the growth of Limneæ, Cyclades, &c. It contains seeds of Chara, horns of stags, &c. Almost every trace of shells is sometimes obliterated. Certain springs, especially in the volcanic regions of Italy and Auvergne, deposit in lakes a great quantity of carbonate of lime. (Geol. Trans., vol. ii., N. S.) The accumulation of fine clay in ponds and lakes may be universally observed. Inclined laminæ of pebbles and sand are swept into the lake of Geneva by the stormy waters of the Rhone (§ 96.). In some lakes all these processes go on simultaneously.

It is not easy to point out the real or even the relative antiquity of the various lacustrine deposits not associated with marine deposits now known to geologists. The following attempt is offered with much hesitation. The most recent are placed at the top.

1. Now in progress in many lakes. Italy; Scotland.

2. Old lakes, nearly contemporaneous with submarine forests, containing the bones of the beaver, the wolf, the red deer, and other existing species of animals, and the extinct Irish elk. Holderness; Berwickshire.

3. Lakes of the elephantoidal æra, containing bones of the fossil elephant, fossil urus, *Felis spelæa*, *Ursus spelæus*, fox, lagomys, rat, chæropotamus, &c. Weighton in Yorkshire ; Gmünd ? ; Oeningen ?

4. Lakes of the palæotherian period ; lakes of the Cantal, &c. The extinct genera palæotherium, anoplotherium, and lophiodon, seem to mark a determinate terrestrial geological period, and to establish some points of comparison between this and the ordinary scale of geological chronology, depending on the succession of marine strata and organic remains.

TURF MOORS, SUBMARINE FORESTS, &c.

104. In most cases the submarine forests, as they are termed, lie along the course and near the mouths of great rivers, and are often, perhaps generally, at a level between high- and low-water mark, and in a situation where the river sediment, or silt from the tide, has partially covered them. Along the Yorkshire rivers the trees lie generally in a mass of vegetable remains called turf, which occurs at all levels, from about high-water mark to a depth of 30 or more feet beneath it. This surprising spectacle of ancient oaks and firs buried in the earth, in situations where they could not now be made to vegetate, except by the aid of artificial drainage, has not often been carefully described by geological eye-witnesses, and the workmen commonly give but a very confused account of what they have seen. It is by no means certain that in all instances the trees grow where they now appear ; the geological æra of their growth is

sometimes extremely dubious; the ancient condition of the drainage of this country, in relation to the tide-opening of the estuary, is seldom ascertainable: for these reasons the subject is yet in some obscurity.

In one case, near the Humber, the phænomena are not irreconcileable with a probable view of the ancient state of drainage of Yorkshire, without any intervention of subterranean movements: how far this mode of explanation will apply to other cases, may be a subject of further inquiry. In the mean time we may perhaps believe, from the occurrence of peat-beds in the old lakes on the Yorkshire coast, from the certainty of the drifting of peat and timber in other parts, and from the great analogy of the vegetable deposits, that some very general agency was concerned in the prostration and inhumation, and perhaps drifting, of the trees, whether accompanied by a change of level or not. The trees are oak, birch, fir, hazel, alder, yew, &c. With them lie acorns, fir-cones, hazel-nuts, bones of the horse, ox, stag, fallow deer, sheep, &c. (Phil. Mag. 1834.)

CLYSMIC, OR DILUVIAL, ACCUMULATIONS.

(SYN. *Diluvium: Terrain de Transport: Boulders*, &c.)

105. It is a general fact, that the above-mentioned valley and lake deposits, and buried forests, rest upon more ancient water-moved gravel, sand, boulders, and clay, such as are generally termed diluvial deposits. This term was adopted by modern geologists (Smith, Buckland,) to express the inference, that the phænomena in question were due to an ex-

tensive deluge, or succession of analogous deluges, sweeping over the dry land after the completion of the stratified rocks; and it was the more readily received, because it seemed to offer a satisfactory coincidence with the Noachian or historical deluge. On this point it will be proper to use a more guarded logic than was thought necessary twenty years ago. If it should be generally admitted by theologians that the Noachian flood, though general with respect to the limited area over which the early races of mankind had spread, was not an *universal* deluge, some one of the repeated geological deluges, which could not be universal, though some of them were very extensive, may perhaps be successfully compared with that event. At present the use of the term diluvial is to be justified only on the ground of its fitness and utility. It is not the presence of any particular earthy materials, such as boulders, gravel, &c., but the mode of their geographical distribution, and the occurrence in them of the remains of certain tribes of extinct Mammalia, which define the diluvial products. The relation of the deposits to the physical geography of any region marks the condition of the watery action concerned; and the anatomical history of the organic remains determines the relative date of the diluvial operations.

106. When deposits, like those of the diluvial æra, lie in valleys, we ought to examine carefully before deciding as to their origin; but when over wide plains, on hill slopes, and on ranges of high ground we find a collection of rock fragments, and rolled but not river gravel—materials unknown *in situ* in the vicinity,—in situations to which no existing

streams could carry them,—where no imagined lakes could leave them,—where, by no conceivable combination of conditions, consistent with the geological history of the country, either ancient streams or lakes could transport them, we are compelled to infer that some other agency has been employed. This was the course of reasoning applied by Smith forty years ago to some facts near Bath, and soon generalized by his extensive researches in England; by Buckland, Conybeare, and Sedgwick, to a large class of impressive phænomena in the North of England, in the midland counties, and in the valley of the Thames; by Saussure and De Luc to the scattered blocks of the Alps; by Brongniart and others to the travelled boulders of the North of Germany. A case in the North of England appears decisive of the truth of the principle.

107. The accompanying section (fig. 8.) is intended to show the nature of the country along a line E.S.E. from Shap Fell in Cumberland, to Flamborough Head in Yorkshire, a distance, in a straight line, of $107\frac{1}{2}$ miles; but by this rather bending course, of 110 miles. Shap Fells, elevated about 1500 feet above the sea, consist of porphyritic granite, enveloped in schistose rocks. The slope from these fells, eastward, is soon stopped by a bold escarpment of the lower mountain limestone series, which rises to about 800 feet in height, and slopes eastward under the flat narrow valley of the Eden, running N.N.W., which is full of red sandstone, at the bottom of which are certain conglomerate beds. Immediately above, on the east, is an escarpment of the same lower mountain limestone, thrown up to a great

height, and surmounted by other rocks of the same formation to an altitude, in Cross Fell, of 2901 feet; in Shunnor Fell, of 2329 feet; Water Crag, 2186 feet; &c. The lowest part of this ridge *which opens directly to the west*, is the Pass of Stainmoor, which is about level with Shap Fells: from hence the slope is almost uniform to the Vale of York, which runs north and south. Beyond rises the oolitic ridge of the eastern moorlands 300 to 1485 feet; then follows the Vale of Pickering, 100 feet above the sea; and the section crosses over the chalk wolds 500 to 800 feet, and ends at Flamborough Head, 150 feet above the sea.

It is found that blocks of the Shap granite have travelled down the slope of their native mountains, over the limestone ridge of Orton, across the Vale of Eden, over the limestone ridge of Stainmoor, down and athwart the whole Vale of York, over the oolitic ridge,—not at the highest points,—and over the chalk hills to Flamborough Head*.

The Valley of the Eden is an ancient submarine valley, defined by the ancient elevations of the limestone and slate on either side; the Vale of York has served for the passage of vast bodies of water, which have removed much of its stratified red sandstone, so that the physical features of the country were much the same during the transport of the blocks as at present.

108. The difficulty of distinguishing between dilu-

* For details on this and many other instances, read Buckland, Reliq. Diluv.; Conyb. and Phill., Geology of England, Encyclop. Metrop.; &c.

vial and old alluvial accumulations may, in general, be removed by attention to these points: 1st. The rock fragments, or boulders, and smaller masses in diluvial deposits have been generally removed great distances, so that often no rocks of the same kind occur in the drainage of the district, and in directions different from those of existing streams. 2nd. The gravel of these deposits is generally somewhat different in its aspect and manner of attrition from that of old river-courses: it often lies in clay. 3rd. Bones of elephants, oxen, horses, deer, &c., are not unfrequently found in the gravel and clay.

109. There is good geological evidence that the diluvial accumulations are not all contemporaneous—not all the result of one great current, but of currents varying in force and direction, and transporting different materials—clay and pebbles, gravel and sand, in several alternations. But there is such a conformity among the organic remains in these deposits, that we are entitled to say the diluvial deposits mark, over large regions, the termination of a certain geological period, defined by the existence, on the dry land, of peculiar, chiefly extinct, races of quadrupeds.

The most remarkable of these remains in England are those of the mammoth, *Elephas primigenius*, (several varieties, or perhaps species,) *Hippopotamus major*, *Rhinoceros tichorhinus*, *Felis spelæa*, *Hyæna spelæa*, wolf, horse (large and small species), ox, extinct urus, Irish elk, stag.

CAVERN-DEPOSITS, &c.

(SYN. *Cavernes à ossemens. Knockenhöhlen. Brèches osseuses. Spaltausfüllungen.*)

110. From various causes some of the caverns and fissures naturally existing in thick limestone rocks have been partially filled by a mass of materials holding bones of the above-mentioned and other races of animals. In some cases the animals are conjectured to have entered the caves for the mere purpose of dying in quiet (bear-caves of Franconia); into others, hyænas have been the instruments of dragging the carcases of elephants, rhinoceroses, deer, &c. (Kirkdale, Kent's Hole). Grazing quadrupeds have fallen into others (Mendip caves, the ossiferous fissures of Nice, Gibraltar, &c.); and currents of water have contributed to carry the bones into particular repositories, or to move them along the passage of a cave. The extent of the earth's surface over which ossiferous caves and fissures have been discovered is prodigious. In the North and South of England, in Ireland, South and South-east of France, the Ardennes, the Harz, Franconia, Wirtemburg, Switzerland, and along the Mediterranean shores and islands, are the most remarkable localities in Europe. Bone-caves occur in India, North America, South America, and Australia.

Upon the whole the animal remains are analogous in all these situations; but there is much local diversity. It is probable that they are nearly all of one geological period, contemporaneous with the fossil elephant, but posterior to the period when Palæotheria, and some other extinct genera of land animals, lived on some parts of the surface of Europe. No doubt into a cave full of old and extinct quadrupeds, others in more modern times might enter, fall, or be driven to die; and thus a mixture of existing and extinct races be occasioned. Still more probable is the event of man, in an early and uncivilized state, or in a state of war and oppression, occupying a cave formerly tenanted by wild beasts, and there leaving traces of human art. Apparently this is the right view of most of the cases of human remains found mixed among, or buried in, or lying upon the heaps of older bones. The caves in the South of France and in Belgium, where human remains and rude pottery occur, may perhaps be found to admit of this explanation; but the matter is yet undecided.

111. The following animals are frequent in the cavern deposits: most of them are found in the diluvium of the same countries; several of them also occur in lacustrine deposits, of various antiquity. (§ 103.)

Ursus spelæus.	Megatherium Cuvierii.
—— arctoideus.	Megalonyx Jeffersonii.
—— cultridens.	Elephas primigenius.
Gulo spelæus.	Hippopotamus major.
Wolf.	Rhinoceros tichorhinus.
Fox.	——— minutus.
Hyæna spelæa.	Horse.
Felis spelæa.	Boar.
Hare.	Cervus megaceros.
Rabbit.	——— elaphus.
Water Rat.	Bos primigenius.
Beaver.	—— priscus.

The remarkable elephantoidal genus *Mastodon* occurs in diluvium in Europe, and in superficial sediments in America and Ava, but not in caverns.

Authors.—Cuvier, *Ossemens Fossiles*; Buckland, *Reliquiæ Diluvianæ*; Herman von Meyer, *Palæologica*, &c.

Museums.—British Museum; Royal Institution; Geological Society; Dr. Buckland; Sir Philip Egerton, Bart., Oulton Park, Cheshire; Mr. Gibson, of Stratford, Essex; Yorkshire Museum; Bonn; Darmstadt; Count Munster.

Section 2.—Submarine Deposits.

Subsection 1.—Modern Accumulations.

CORAL-REEFS, SHELL-BEDS, &c.

112. The growth of coral in the warm tropical waters, and along the Australian shores, is one of the most important agencies now at work in altering the face of the globe. Coral-reefs are not formed at such enormous depths as was once imagined, but they rise from submarine mountain ridges, from the peaks of old submarine volcanos, along the coasts, and around the islands. In these accumulations the lamelliferous corals bear the largest share; but many shells, fragments of other coral, drifted sand, and many other substances lodged in the reef are enveloped in its growing mass; and thus islands of living rock slowly emerge from the middle of the ocean, gradually become heightened by the heaping up of the materials broken from their edges or drifted by the sea,

covered by trees, and inhabited by birds and a few other animals. The coral-reefs of the Bermudas are described as partly a mass of chalky or granular carbonate of lime, derived from comminuted and decomposed coral, and as taking a form depending partly on the currents of the sea. The elevation above the sea which some West Indian coral-islands assume, is ascribed to volcanic action. We have already noticed the opinion, which is gradually gaining ground among geologists, that several of the limestone strata are locally to be regarded as magnificent coral-reefs. (§ 58.)

In particular parts of the sea the currents drift shells and fishes' teeth, so as to make the seamen remark the fact in their soundings. This is analogous to many cases of the accumulation of shells and shelly fragments in particular parts of the ancient strata.

COAST-SEDIMENTS.

113. The materials brought into the sea by rivers, and obtained from the incessant wasting of cliffs, are not all carried down to the depths, but in a great measure restored to the land, where the coastward currents cease their movements. This happens generally along some low shore, which only just rises above the gradually deepening waters, in some landlocked bay or estuary. The most rapid growths of new land certainly adjoin, or are influenced by, the mouths of great rivers; but many considerable tracts are only remotely dependent on such influence. It is not so much by the mud which descends with the

Ouse, the Dun, and the Trent, that the coast of Lincolnshire has been extended, as by the materials brought from the ruined cliffs of Holderness; neither have the sluggish streams which meander through the fens of Cambridgeshire yielded that mass of matter which, since the Roman sway in Britain, has been added to the coast, to the extent of miles, beyond their line of embankment. The case is different along the shore of the Adriatic, where the torrents from the Alps bring such loads of sediment as to promise the eventual conversion of all the northern end of that sea into marsh land. The flatness of these *foreshores* corresponds with the degree of quiescence of the water, and the laminæ, which cover one another successively, are not quite horizontal, but form long inclined planes, sloping seaward.

Storms, or varying circumstances, may produce a temporary derangement of the laminæ, or spread layers of pebbles, or scatter shells over the surfaces. A variety of marine worms may leave their traces, or marine reptiles the prints of their feet; but generally, remains of such animals, of shells, and plants, are very rare in marsh lands formed under shallow waters. In this manner we may conceive some sandstones of the old strata to have originated; and account for many of their peculiar appearances. The pebble beaches along some parts of the English coast may remind us of the appearance of some conglomerates.

SAND-BANKS.

114. The agitation of the ocean is so unequal, even on the same line of coast, that in some parts

sand, in other parts fine clay, in others pebbles, are accumulated, according to the moving force of the water. Generally, the materials which fall from sea-cliffs are sorted by the tide: pebbles drop quickly near their original sites; sand moves further; fine clay is transported for leagues along the coast. The sand-banks along many parts of the coast are either stationary or moving, augmenting or decreasing, according to the circumstances of the oceanic currents. Along the east coast of England especially, but everywhere more or less, the submarine sand-banks are cut through by real channels, which would be perhaps not very improperly called tidal valleys.

This fact is perhaps analogous to the well-known irregularity of the extent and thickness of many of the ancient stratified sandstones.

Certain modern sand-banks are occupied by weeds, cockles, oysters, or fishes; others not. This is also to be compared with the very irregular distribution of organic remains in the sandstone rocks.

The geologist must on no account think it out of the bounds of his legitimate province to examine with care and interest into the history of the processes now performed in the ocean and on the land; for it is only by discrimination and generalization of these that we can hope to draw satisfactory inferences concerning the force and direction of the agencies formerly exerted in earlier oceans, and on earlier continents.

Subsection 2.—ANCIENT SERIES OF SUBMARINE STRATA, AND OF FRESHWATER BEDS ALTERNATING WITH THEM.

ORDER III.—TERTIARY STRATA.

(SYN. *Superior Order* of Conybeare. *Pleiocene, Meiocene, and Eocene* Deposits* of Lyell. Ger. *Tertiärgebilde*, Fr. *Terrain de Sédiment supérieur.*)

115. Tertiary deposits, formed since the ocean became much divided into arms and gulfs, have so much of local character and independent origin, as to render it almost impossible to refer these dissociated and interrupted strata to one general series. It is only by employing intermediate analogies, and the evidence of organic remains, that we can form to ourselves a proper general view of the order of antiquity of the deposits in different districts. On this account it is always best to describe the tertiary strata according to the natural regions in which they were formed: the English tertiaries are one series; the Parisian another, and very analogous one; the Subapennine a third; the Danubian a fourth. There are many others in Europe, Asia, and America.

The notices in the text will be confined to the English tertiaries, and notes will be appended to mark some of the probable relations of these to well-known foreign tertiaries of like or unlike characters, and equal or different antiquity. According to Deshayes and Lyell, the tertiary series of Europe may admit of being ranked in three leading groups, ac-

* These terms are derived from a Greek word (καινος) signifying *recent*, combined with others signifying *more*, *less*, and *the dawn*.

cording to the relation of the organic remains with existing species of shells. The upper group (Pleiocene) includes, *a.* Sicilian tertiaries; *b.* crag, Subapennine marls: the middle group (Meiocene), tertiaries of the Danube, Rhine, Loire, and Garonne: the lower group (Eocene), *a.* Calcaire grossier of France, London clay; *b.* Plastic clays of England.

116. CRAG FORMATION.

Mineral Character. It resembles almost exactly a shingle- or pebble-beach, with layers of sand and shells, being composed of pebbles of various sorts, rolled and worn fish-teeth and bones, a few bones of quadrupeds, also worn; many shells, sometimes worn, sometimes not; parts of Crustacea, Polypifers, &c. The whole has an ochreous aspect, from the admixture of oxide of iron. In one situation a coralline limestone of the same age occurs, and includes several of the same shells.

Physical Geography. The crag deposit is found in low ground, along the east coast of England, resting in a few places upon the London clay. It may be perhaps rightly viewed as an ancient beach of the German Ocean.

Localities. Norfolk, Suffolk, Essex. Very analogous, but perhaps not contemporaneous, deposits occur along the course of the Loire.

Types of Formation. Bramerton near Norwich, Woodbridge, Aldborough, Harwich.

Organic Remains. These are very plentiful: there are above 200 species of Polypifera, Conchifera, and Mollusca in the crag. Of these, about 40 per cent. are said by Deshayes to belong to species which still exist, mostly in the neighbouring seas. *Fusus contrarius, Voluta Lamberti, Buccinum Dalei,* &c., are characteristic.

Authors. Smith, Woodward, R. Taylor.

Museums. Norwich Museum; Geological Society; Yorkshire Museum (200 species of crag fossils); and many others, besides private cabinets in Norfolk, Suffolk, and Essex, and throughout England.

Note.—In Sicily occur stratified marine deposits of shells, even to great heights above the sea, in clay, sand, and solid limestone, which contain 95 per cent. of existing species. These are generally thought to be the least ancient of all the marine tertiary strata; next to these in relation to existing shells comes, according to Deshayes, the English crag, with 40 per cent. of existing species. This point deserves further inquiry.

In the valley of the Loire at several points towards its mouth, and inland, are deposits of pebbles, shells, and vertebral animals, very like the crag, and referred to the same æra by M. Desnoyers (*Annales des Sci. Nat.*). Lyell and Deshayes consider them to be more ancient, and rank them between the crag and the marine deposits of the Paris basin. The Subapennine marl deposits are full of shells, of which 41·8 per cent. belong to existing species. *For this reason* they are supposed to be coeval with the crag. The *lower* Subapennines correspond to the lower Danubian deposits.

117. FRESHWATER FORMATION.

Mineral Character. A series of marls and marly limestones, mostly full of freshwater Limneæ and Planorbes, divided into two series by an interposed mass of marls, holding Potamida and other, probably estuary, shells in great numbers.

Subdivisions. *a.* Upper freshwater; *b.* Intermediate marine; *c.* Lower freshwater.

Localities. Confined, in England, to the northern half of the Isle of Wight, and a portion of the opposite cliffs of Hampshire. In the basin of Paris, near Montpellier, and various parts of France.

Type. Headen Hill, Isle of Wight.

Organic Remains. Chiefly Limneæ and Planorbes, with seeds of Chara, called Gyrogonites; remains of the Anoplotherium have been found at Binstead.

Authors. Webster in Geological Transactions, Brongniart, Lyell, Sedgwick.

Museums. Newport, Isle of Wight; Geological Society; Yorkshire Museum, and others.

Note.—The freshwater deposits in the Paris basin consist of upper and lower; the former characterized by siliceous millstone, the lower composed of marls locally gypseous. In the gypsum lie bones of Palæotheria, Anoplotheria, Didelphis, and many other quadrupeds. The intermediate marine beds are chiefly sands. It is difficult to determine the relative age of the detached tertiary freshwater deposits in other parts of France, Germany, Hungary, &c. Some of them are of much more recent date.

118. MIDDLE TERTIARY FORMATION.

Mineral Character. The series of foreign tertiaries is not continuously complete; but at detached points strata occur which, by the shells imbedded, appear to fill up that remarkable hiatus in the English marine series between the crag and the London clay, the former containing 40 per cent. and the latter only 5 per cent. of living species. The sandy strata of Bordeaux and Dax contain 594 species, of which only 27 occur in the Paris basin, and 136 are still living. In Baden, the tertiaries contain 26 per cent., in the valley of the Danube, the *lower tertiaries* 28 per cent., of living species.

It is almost wholly on the evidence derived from the numbers of existing species that the classification of Mr. Lyell proceeds.

Localities. Bordeaux, Dax, Vienna, Baden, Touraine, Angers, Turin.

Organic Remains. These belong to the same genera, and are often remarkably similar in minute characters to those of the lower Parisian and upper Subapennine marine series. Nothing but very exact and scrupulous conchological knowledge will be of use in discriminating and identifying tertiary shells.

Authors. Lyell (vol. iii.), Deshayes, De Basterot, Marcel de Serres, Brongniart.

119. LOWER TERTIARY FORMATION.

Mineral Character. A series of clays above, and of clays mixed with sands below, without any bands of limestone, but often abundance of Septaria, and an immense number of marine shells.

Subdivisions. *a.* The London clay, resting upon *b.* The Plastic clay series, a mass of coloured sands and pebble beds, with some layers of shelly clays and plastic clays: green sands at the bottom.

Physical Geography. Forms extensive comparatively low countries. Mineral springs.

Localities. In the valley of the Thames; Essex, Kent, Surrey, Sussex, Hampshire, Dorsetshire.

Types. Vicinity of London, Alum Bay.

Organic Remains. These lie in the London clay, and in certain clays below, and in green sands which are near the base of the whole series. They consist of an immense number of shells, chiefly Univalves, as Voluta, Rostellaria, Fusus, Cassidaria, Ancilla, Buccinum, and other existing genera; no Belemnites or Ammonites; very few Terebratulæ or Echinida. Number of species, 239 or more, of which 12 (or 5 per cent.) are still in existence. The greater part are characteristic of the formation.

Authors. Brander, Webster, Buckland.

Museums. Geological Society. Most English museums contain shells from Barton Cliff.

Note.—The calcaire grossier of the Paris basin corresponds in age to the London clay, and the subjacent coloured sands and clays to the plastic clay group of England. There are 1122 species of fossil shells in the Paris basin, of which 38 are living = three and four tenths per cent. The calcaire grossier occurs in Belgium and in the South of France. See Brongniart, Lamarck, Deshayes, Prevost, Marcel de Serres, Omalius d'Halloy, &c.

ORDER II.—SECONDARY STRATA.

120. This whole system of deposits consists of limestone, sand, sandstone, clay, shale, ironstone, coal, gypsum, salt, flint, and chert. The limestones of different ages have generally distinctive mineralogical characters; but the most sure and valuable distinctions arise from the comparison of the organic remains in each, according to the principles of Mr. Smith. In this way it is found, 1. That the fossils in the secondary strata are ALL distinct from living species. 2. Many of them belong to genera and families not known to be living. 3. They are ALL, or nearly all, different from those of the tertiary strata above, and of the primary strata below. 4. Each formation contains locally peculiar species, and often even genera of Plants, Zoophyta, Shells, Crustacea, Fishes, and Reptiles. 5. The fossils are not equally nor universally distributed in any stratum or formation, but have assignable and unequal geographical limits, some being very generally, others very partially or even locally found. 6. Hence arises the difference in the fossils of different districts of the

same formation, and the necessity of choosing several types for each formation.

The proportion of limestone to the other strata is greater in the secondary than in the earlier or later orders of deposits.

CRETACEOUS SYSTEM.

Above 840 species of fossils belong to these strata, and many of them are common to the chalk and greensand formations. Above 300 species, or 40 per cent., belong to genera supposed to be extinct.

121. CHALK FORMATION.

(SYN. *Craie, Craie tufau,* Fr.: *Kreide, Kreidemergel,* Ger.: *Scaglia,* It.)

Mineral Character. Consists principally of carbonate of lime in a finely granular state, imperfectly indurated, and white. The stratification is rendered evident chiefly by layers of flint nodules, which occur at regular intervals in the upper part, or through nearly the whole of the mass.

Subdivisions. a. Upper chalk; *b.* lower chalk; *c.* chalk marl; *d.* red chalk.

Physical Geography. Occupies generally a district of connected green (not woody) hills, with dry valleys; very strong springs at their base; surface covered with flints.

Localities. Counties of York, Lincoln, Norfolk, Suffolk, Bedford, Buckingham, Oxford, Berks, Wilts, Dorset, Hants, (Isle of Wight,) Sussex, Surrey, Kent. Foreign:—Round the tertiary basin of Paris, South-east of France, Belgium, Poland, Isle of Rugen.

Types. Dover Cliffs, Isle of Wight, Wiltshire Downs, Flamborough Head.

Organic Remains. Locally very abundant; species mostly marine. They consist of marine Plants, lamelliferous and celluliferous Corals and Sponges, Asteriidæ, Crinoidea, and Echinida, mesomyonous and brachiopodous Conchifera, phytophagous and cephalopodous Mollusca, Crustacea, Fishes, Mosasaurus, Chelonia. Many of them occur also in the greensand formation.

Characteristic Organic Remains.—Marsupites ornatus, Ananchytes ovatus, Galerites albogalerus, Inoceramus Cuvieri, Plagiostoma spinosum, Terebratula plicatilis, Belemnites mucronatus, B. granulatus, Mosasaurus Hoffmanni.

Authors. Mantell, Smith, Phillips, Woodward, Brongniart, Nilsson, Norwich Museum.

Museums. Geological Society, Yorkshire Museum, Scarborough Museum, Mr. Mantell's Collection at Brighton, Museums at Paris and Maestricht.

122. GREENSAND FORMATION.

(SYN. *Glauconie crayeuse, Glauconie sableuse,* Fr.: *Quadersandstein of Pirna,* Ger.)

Mineral Character. A stratified mass of sands, occasionally pebbly, often cherty, almost always slightly calcareous, and characterized by abundance of green grains in some or all of the beds. In many tracts, the lower sands are very irony and yield ochre. In the midst of the series is a sandy and calcareous fossiliferous clay.

Subdivisions. *a.* Upper greensand, passing below into *b.* gault, which sometimes alternates with *c.* lower green- or iron-sand, inclosing limestone in Kent.

Physical Geography and Localities. In England, generally forms the base of the chalk-hills, but in Blackdown and the Weald of Surrey and Kent rises into separate ranges of hills. North-east of Ireland. On the Continent, extends with the chalk, and is found separate from that rock in Saxony, along the Alps, Carpathians, &c. In New Jersey and other parts of the United States.

Types. Isle of Wight, and the country near Petersfield, for the whole series; upper greensand in Wiltshire; gault at Folkstone and Cambridge; lower greensand in Kent and Surrey.

Organic Remains. Species mostly marine. Marine Plants; celluliferous Corals; Sponges; Asteriidæ; Echinida; Conchifera of all orders; phytophagous, a few zoophagous, and many cephalopodous Mollusca; Crustacea, &c.; often silicified.

Characteristic Fossils. Fuci, Spongiidæ, Corals, *Galerites subuculus*, *Trigonia aliformis*, *Inoceramus sulcatus*, *Pecten quinquecostatus*, *Terebratula biplicata*, *T. pectinata*; many species of Hamites, *Ammonites varicosus*, *Belemnites minimus*.

Authors. Smith, Webster, Brongniart, Murchison, Dr. Fitton, Miss Benett.

Museums. Geological Society, Miss Benett's Collection in Wiltshire, most English Museums.

123. B. WEALDEN FORMATION.

Mineral Character. Variously coloured sands and clays, with interspersed lignites, conglomerates, and calcareous portions in the former, and limestone and ironstone in the latter. The organic remains indicate that it was principally an estuary deposit.

Subdivisions. *a.* Weald clay, alternating below with *b.* Hastings sands; *c.* Purbeck, or Lower Wealden clays.

Physical Geography and Localities. It is almost peculiar to the Weald of Kent and Sussex, and the Isle of Wight, though traces are supposed to occur in the Vale of Wardour (Wilts), on Shotover Hill, and at Beauvais in France. In Sussex the middle sands rise to 805 feet, enveloped by a valley of the Weald clay in an oval ring.

Organic Remains. Wood belonging to the Monocotyledonous division of plants, Ferns, Cyprides, Unionidæ, Paludinæ, (none of the marine tribes of Echinida, Brachiopoda, or Cephalopoda), Fishes, Iguanodon, Hylæosaurus.

Authors. Mantell, Fitton, Lyell, Smith's Section.

Museums. Mr. Mantell's Collection, Geological Society.

OOLITIC SYSTEM.

In the four formations which constitute this system about 1300 species of fossils are known. Many of these are common to two or more formations, but few or none occur in the cretaceous system. About 500 species, or 40 per cent., belong to genera supposed to be extinct.

124. UPPER, OR PORTLAND, OOLITE FORMATION.

(SYN. *Epioolite,* Brongn.: *Upper part of the Jura Kalk,* Ger.)

Mineral Character. A mass of limestone, partly oolitic, partly compact or cretaceous, including nodules and ramifications of chert; green sandy and nodular beds below, resting on a thick blue clay, with lignite and layers of septaria.

Subdivisions. *a.* Portland oolitic rock; *b.* Kimmeridge clay.

Localities. Isle of Portland, Tisbury in Wilts, Swindon, Garsington, Brill, Aylesbury. Upper part of the Jura limestone in France, Germany, and Savoy.

Organic Remains. In the limestone, Cycadeæ, Spongiæ, Conchifera, Ammonites, Cerithia, Trochi, Fishes. They are usually in the state of casts. *Cardium dissimile, Astarte cuneata, Trigonia gibbosa, Pecten lamellosus,* are supposed to be characteristic, but many species of fossils are found in more than one of the oolitic formations. In the clay, many fossils occur at Weymouth and in North Wilts: the most characteristic is *Ostrea deltoidea. Gryphæa virgula* is supposed to mark this clay in the North of France: I found it abundantly at Heddington in 1831.

Authors. Webster, Smith, Buckland, De la Beche.

Museums. Geological Society; Dr. Buckland, Oxford; Miss Benett's Collection in Wiltshire.

125.—MIDDLE OR CORALLINE OOLITE FORMATION.

(SYN. *Middle part of the Jura Kalk,* Ger.)

Mineral Character. Blue or yellow oolite, occasionally of a pisolitic character, locally full of coral; inclosed in a mass of cherty, or calcareous shelly sandstones; a thick blue clay and shelly sandstone.

Subdivisions. *a.* Upper calcareous grit; *b.* Coralline oolite; *c.* Lower calcareous grit; *d.* Oxford clay; *e.* Kelloways rock.

Physical Geography and Localities. Forms a range of dry hills of moderate elevation in England. Yorkshire, Oxfordshire, Berkshire, Wiltshire, Dorsetshire. Middle part of the Jura limestone, North of France, South-east of France, Germany.

Types. Near Helmsley and Scarborough, Calne, Weymouth.

Organic Remains. Species mostly marine; coniferous and monocotyledonous Plants (rare); abundance of lamelliferous Corals; some Crinoidea (rare); many Echinida; many Conchifera of all orders; a few phytophagous and zoophagous, and many cephalopodous Mollusca; Crustacea; Fishes; Ichthyosauri and Crocodiles; generally in a good state of conservation.

Characteristic Fossils. — *Caryophyllia annulata, Astræa tubulifera, Cidaris florigemma, Clypeus dimidiatus, Plagiostoma rigidum, Gryphæa dilatata, Turbo muricatus, Ammonites vertebralis, A. calloviensis.* A considerable proportion of the fossils of this formation is also found in the lower oolites.

Authors. Smith, Young and Bird, Phillips, Lonsdale, Sedgwick.

Museums. Geological Society, Woodwardian Collection, Yorkshire Museum, Scarborough Museum, Hull Museum, Whitby Museum, Mr. Bean's Collection at Scarborough, Miss Benett's Collection in Wiltshire.

126. LOWER OR BATH OOLITE FORMATION.

(SYN. *Lower part of the Jura Kalk*, Ger.)

Mineral Character. White, yellow, or ferruginous oolite, and compact and shelly limestone, variously associated with sands, slaty sandstones, clays, and marls.

Subdivisions. Near Bath, according to Lonsdale. *a.* Cornbrash, coarse limestone. *b.* Forest marble group, composed of coarse shelly oolite, imbedded in sands, nodular sandstones, and clay. *c.* Great oolite. *d.* Fuller's-earth, clays, marls, and limestone. *e.* Inferior oolite. *f.* sand.—In Yorkshire we have a different series. *a.* Cornbrash, shelly. *b.* Sandstones, shales, coal, and plants. *c.* Slaty, calcareous, shelly sandstone beds. *d.* Oolite, shelly. *e.* Sandstone, shale, coal, and plants. *f.* Ferruginous sands, shelly.

Physical Geography and Localities. Forms ranges of dry hills, which overlook the upper and middle oolite hills, surpassing generally the altitude of the chalk, and commanding extensive views over the older formations. Yorkshire, Lincolnshire, Northamptonshire, Rutland, Oxfordshire, Gloucestershire, Wilts, Somerset, Dorset.

Types. The Bath series, more or less complete, is observed in all the southern parts of the range. Bath, Cheltenham. The Yorkshire series may be studied near Scarborough and Whitby; at Brora, in Sutherland. Foreign localities generally resemble the Bath series: Normandy, the Jura, Savoy, Franconia, &c.

Organic Remains. Species mostly marine. Local deposits of Ferns, Cycadeæ, and other land plants; lamelliferous, cellular, and spongoid corals; Stellerida, Crinoidea, Echinida; Conchifera of all orders; phytophagous and cephalopodous Mollusca; Crustacea; Fishes; Ichthyosaurus; Plesiosaurus; Crocodiles; Megalosaurus; DIDELPHOID QUADRUPED!

Five specimens are known; 2 in the hands of Dr. Buckland; 1 of Mr. Broderip; 1 of M. Prevost; 1 in the Yorkshire Museum. Fossils generally in good conservation; often casts and moulds.

Characteristic Fossils.—*Equisetum columnare*; various species of Zamia, Lycopodites, and Ferns; *Apiocrinus rotundus, Terebratula maxillata, T. coarctata, Belemnites ellipticus.* There is great analogy amongst the fossils of all the oolitic rocks.

Authors. Smith, Conybeare, Lonsdale, Phillips, Buckland, Murchison, Boblaye, De Caumont, Desnoyers, Dufrenoy.

Museums. The Bath series:—Dr. Buckland's Collection, 2 specimens of the Didelphoid Quadruped; Geological Society; Bath Institution; Bristol Institution; Cheltenham Institution; Yorkshire Museum. (*Didelphoid Quadruped.*) The Yorkshire series:—Yorkshire Museum; Scarborough Museum; Whitby Museum; Mr. Bean's Cabinet, at Scarborough.

127. LIAS FORMATION.

Description. Consists principally of blue clay, with much pyrites, some bitumen, ironstone courses, and septaria. In it are beds of sandstone and sandy limestone, and strata of blue and white limestone.

Subdivisions. *a.* Upper lias shale of Yorkshire. *b.* Marlstone. *c.* Lower lias shale of Yorkshire (Upper lias clay of Bath). *d.* Lias limestones, blue and white. *e.* Lower lias marls.

Physical Geography. A characteristic feature of English geology, running in a long, connected course of hill-slopes and low plains beneath the escarpment of the lower oolites, from the Tees to the Exe. Through a great part of this course it is a summit of drainage. Insular hills of oolite diversify it. Yorkshire, Lincolnshire, Northamptonshire, Leicestershire, Gloucestershire, Somersetshire, Dorsetshire, Hebrides, North of France; round the central granites of France; Switzerland; Germany.

Types. Yorkshire coast; Grantham; Belvoir; Rugby; Cheltenham; Bath; Lyme Regis. The lias limestones are well seen at Barrow-on-Soar, near Shipston, near Bath, Lyme Regis.

Organic Remains. Species mostly marine, and littoral. Cycadiform plants, ferns, coniferous wood; Zoophyta rare; Crinoidea common; Stellerida and Echinida rare; Conchifera of all orders; Cephalopoda abundant; other cephalous Mollusca rare; few Crustacea; many fishes; many Saurian reptiles, as Ichthyosaurus, Plesiosaurus, Pterodactylus, Crocodilus, Geosaurus, &c.; Chelonia; fossils often pyritized.

Characteristic Fossils.—Pentacrinus Briareus, Gryphæa incurva, Ammonites Bucklandi, A. Walcottii, A. Conybeari, A. planicostatus, Ichthyosaurus communis, I. tenuirostris, Plesiosaurus dolichodeirus, and many others.

Authors. Smith, Young and Bird, Phillips, Lonsdale, Murchison, De la Beche, Buckland, Conybeare.

Museums. Of Yorkshire generally; Geol. Soc.; Dr. Buckland; Prof. Sedgwick; Lord Cole's Collection at Florence Court, Enniskillen; Mr. Hawkins's Saurian Fossils in the British Museum.

SALIFEROUS SYSTEM.

Of above 200 species of fossils belonging to this system, only 30 or 40 are known in England. Hardly one of them is found in the oolitic rocks. About 40 per cent. belong to genera supposed to be extinct.

128. NEW RED SANDSTONE FORMATION.

(SYN. *Marnes irisées, Calcaire conchylien, and Grès bigarré*, Fr.: *Keuper, Muschelkalk, Bunter Sandstein*, Ger.)

Mineral Character. Clays, sandstones, and sandy conglomerates of various colours, red, white, and greenish, in many alternations. Limestone beds occur in it in Germany, but not in England.

Subdivisions. In England: *a.* Variegated marls and gypsum, and rock salt. *b.* Red and white sandstone. In Nottinghamshire the red sandstone is partly a conglomerate. In Germany: *a.* Variegated marls and sandstones (Keuper), gypsum, salt. *b.* Muschelkalk, a compact limestone, salt. *c.* Red sandstone (Bunter Sandstein).

Geography. Mostly flat, or broadly undulated plains, occupying much of the centre of England, extending from the Tees to the Exe, and from Leamington to Liverpool. Valley of the Tees, Ouse, Trent, Mersey, Severn, Eden, Clwydd, Solway, Annan, &c. Normandy; South of the Ardennes; Westphalia; Wirtemburg.

Types. Dorsetshire coast; Cheshire; Nottingham.

Organic Remains. In England none. In Germany, the Keuper contains plants, shells, Chelonida, Saurians. In Germany and France, the Muschelkalk contains Encrinites, shells, Saurian remains. *Encri-*

nites moniliformis, Avicula socialis, Ammonites nodosus, characterize the muschelkalk. Many plants, especially Voltzia, belong to the Bunter Sandstein. Several others, especially species of Pterophyllum, belong to the Keuper.

Authors. Elie De Beaumont; Voltz; Jäger; Dr. Holland.

Museum. The Strasburgh Museum.

129.—MAGNESIAN LIMESTONE FORMATION.

(SYN. *Zechstein, Rotheliegende, &c.,* Ger.)

Mineral Character. Composed of limestones, sandstones, clays, gypsum. The limestones which compose the greater part of this formation are very variable in all respects; white, yellow, reddish, grey, purple; compact, powdery, oolitic, crystalline, with strings and nests of calc spar; highly magnesian, or purely calcareous. The sandstones and sands are red, purple, yellow: the clays red, white, often gypseous.

Subdivisions. In England: *a.* Grey laminated limestone, with little magnesia and very few fossils; *b.* red and white clay and gypsum; *c.* yellow magnesian limestone; *d.* marl slate; *e.* lower red, purple, or yellow sandstone. In Germany: *a.* Stinkstein, Rauchwacke; *b.* coloured marls; *c.* Zechstein; *d.* Kupferschiefer; *e.* Rotheliegende.

Localities. The North of England, in a line from the Tyne to the Trent; detached parts in Westmoreland, Cumberland, Shropshire, near Bristol. The Thuringerwald.

Types. Sunderland, Ferrybridge, Doncaster, Mansfield. The Thuringerwald, Mansfeldt.

Organic Remains. In England very few, *increasing in number northward* from Nottingham. In Germany, a few mostly marine plants; two Crinoidea; several Brachiopoda, but few other Conchifera; few Mollusca; several fishes; Monitor.

Characteristic Fossils. The most important are the Fishes, belonging to the remarkable genus Palæoniscus of Agassiz.

Authors. Sedgwick, Hutton, Freiesleben, Hoffmann.

Museums. Bonn, Strasburgh, Newcastle, York.

CARBONIFEROUS SYSTEM.

About 600 species of fossils are known in this system. Very few of them occur in any other strata. Of the marine tribes about 150 species, or about 50 per cent., and nearly all the terrestrial species (plants) belong to extinct genera.

130.—C. COAL FORMATION.

(Syn. *Terrain houiller*, Fr.: *Steinkohlengebirge*, Ger.)

Mineral Character. Strata of sandstone, shale, clay, coal, and, very rarely, limestone; layers of ironstone nodules, admixtures of pyrites. The sandstones are generally micaceous, and either very coarse, or fine-grained, in thick beds, or thinly laminated, often alternating with the shales. These are generally dark and bituminous, sometimes black, laminated in various degrees: some of the clays are white.

The *general section* consists of a vast number of repeated alternations of sandstone, shale, coal, and ironstone. The several parts of the series are not easily distinguishable, except for small tracts of country; the coals are the most regular strata. Of these, in some cases, are forty or fifty seams or beds, from less than an inch to more than a fathom in thickness. In a few places, the coming together of several seams makes one enormously thick bed of coal, as in Staffordshire and Ayrshire.

Localities. The coal formation is generally found in limited patches, sometimes correctly called basins. The principal are those of the Forth and Clyde, Newcastle, Durham, Cumberland, Yorkshire, Derbyshire, Nottingham, Lancashire, Ashby in Leicestershire, Coventry, Dudley, Shropshire, North Wales, South Wales, Kingswood in Gloucestershire, Somersetshire. Almost all the central counties of Ireland. France: near Boulogne, Mons, St. Etienne. Belgium: Namur, Liege. Germany: near Elberfeld, Bingen, Silesia, Moravia, Poland, the Carpathians.

Organic Remains. Abundance of *land Plants*, as Ferns, Lepidodendra, Sigillariæ, Equisetaceæ, &c.; no Zoophyta; no Radiaria; fluviatile Conchifera: (no Productæ, Terebratulæ, &c.;) scaly Fishes; *in a particular bed* in Yorkshire occur *Ammonites Listeri*, Orthoceras, *Pecten papyraceus* and Fishes. A freshwater bed of limestone occurs in one of the Shropshire coal-fields.

Coal is nothing else than a compressed and chemically altered mass of vegetables.

Nearly all the species of fossils are *characteristic.*

Authors. Boué, Conybeare, Buckland, Martin, Farey, Phillips, Winch, Buddle, Hutton, Forster, Wood, Lindley, Witham, Ad. Brongniart, Steinhauer, Sternberg, Griffith, Weaver, Murchison, Prestwich.

Museums. Geological Society, British Museum, Yorkshire Museum, Newcastle Collections, Leeds, Halifax, Barnsley, &c. Mr. Hutton's Cabinet at Newcastle.

131. CARBONIFEROUS OR MOUNTAIN LIMESTONE.

(SYN. *Calcaire carbonifère, &c.*, Fr.: *Kohlenkalkstein, Bergkalkstein*, Ger.)

Mineral Character. Beds of limestone, chert, sandstone, shale, and coal; layers of ironstone nodules.

The limestones are nearly white, yellowish, grey, blue, black; compact, oolitic, crystalline, or crinoidal: the chert black, or light-coloured: the sandstones coarse and pebbly, or fine-grained, in thick beds, or thin laminæ; micaceous, or not: the shales mostly dark-coloured, fissile, and bituminous. The coal is generally sulphureous, and of inferior quality.

The general section consists, in the North of England, of alternations of all the above: but in the southern parts the base of the system is wholly calcareous; the upper parts wholly argillaceous and sandy. This latter is the character of the Belgian series.

Localities. South-east of Scotland; Berwick, Northumberland, Durham, Cumberland, Westmoreland, Lancashire, Yorkshire, Derbyshire, Flint, Denbigh, Shropshire, Gloucestershire, Glamorganshire, Caermarthenshire, Pembrokeshire, Somersetshire; a large portion of the central counties of Ireland; the valley of the Meuse.

Types. The mountains near Cross Fell; Ingleborough; Pendle Hill; Peak of Derby; Mendip; Dean Forest; north side of the South Wales coal-field.

Organic Remains. Coniferous and other plants in the alternating shales and sandstones; lamelliferous and celluliferous corals; Crinoidea (one species of Echinida); Conchifera of all orders, but chiefly Brachiopoda of extinct genera; Mollusca, both Gasteropoda and Cephalopoda; Sauroid and other fishes. The fossils are generally in excellent preservation, sometimes silicified.

Characteristic Fossils. Many corals; most of the Crinoidea, Brachiopoda, and Cephalopoda.

Authors. Whitehurst, Martin, Farey, Sedgwick, Miller, Winch, Forster, Hibbert.

Museums. Mr. Gilbertson, of Preston: Geological Society; Bristol Institution; Yorkshire Museum; Mr. Watson, of Bakewell; Royal Society of Edinburgh.

132. OLD RED SANDSTONE.

(SYN. *Vieux grès rouge*, Fr.: *Alter rother Sandstein*, Ger.)

Mineral Character. Beds of sandstone, conglomerate, clay, and concretionary limestone of various colours, but mostly red.

In Herefordshire and Monmouthshire, where this formation is most fully developed, it is composed of a triple or quadruple series.

Subdivisions. *a.* Quartzose conglomerates and sandstones. *b.* Coloured marls and concretionary limestones ('cornstones'). *c.* Tilestone or Flagstone series. *d.* Coloured marls, &c., at Monmouth. The limestones of this series are unknown in the North of England and in Scotland.

Localities. Caermarthenshire, Brecknockshire, Shropshire, Herefordshire, &c.

Types. The Kymin Hill, near Monmouth; the Vans of Brecknock and Radnor; Kirby Lonsdale; south-east border of the Grampians.

Organic Remains. Several noticed in Herefordshire by Mr. Murchison (especially the singular fish *Cephalaspis*, Agass.) occur also in Scotland; fishes of Caithness.

Authors. Murchison, Jameson, Sedgwick, Fleming, Boué, Traill.

Museums. Geological Society; Prof. Jameson.

Order I.—PRIMARY STRATA.

133. The term PRIMITIVE ROCKS, once so common, and supposed to be so well understood, has gradually fallen into disuse, since the comparatively modern date of many of the most remarkable of the rocks so named is perfectly ascertained, and since it is clear that among the older rocks, as among the newer, two entirely distinct classes occur, viz. pyrogenous and hydrogenous deposits. The older strata are now very generally called primary; and an indefinite upper group or portion of them is, by many geologists, called the Transition Series, as marking a passage from the primary to the secondary strata. This is, perhaps, needless; for such passages are not thought necessary to be marked in other instances. Our knowledge of the upper primary (transition) strata of England and Wales has been very much augmented by the recent labours of Mr. Murchison, who is preparing a large work on the subject. A comparison of the results of his researches with those of foreign geologists would greatly benefit the science.

The primary strata are defined above by the old red sandstone; and when that is absent, by the carboniferous limestone: below they usually rest, but sometimes unconformably, upon granite. They consist, in a great measure, of mechanical aggregates, comparable with sandstones and clays, but yet generally distinguishable by superior hardness, and somewhat of a crystalline structure in mass, or texture in detail, from the secondary rocks. Limestone is interstratified with both the argillaceous portions and those rocks more analogous to sandstone; but it is far less abundant than in the secondary system, and lies in irregular, often detached masses. It is chiefly near and in these limestones that the organic remains abound. These remains belong all to extinct species, by far the greater part to extinct genera, and even families; they are, indeed, so wholly different from existing races, that it is often very difficult to point out any definite analogy between them and modern plants, Zoophyta, Mollusca, or Crustacea.

UPPER GRAUWACKE OR TRANSITION SYSTEM.

About 600 species of fossils are already known. They are mostly peculiar to these rocks, though some occur also in the carboniferous system. They are nearly all marine, and probably 400, or 66 per cent., belong to genera supposed to be extinct.

134. LUDLOW ROCKS.

Mineral Character. Beds of sandstone, shale, and limestone.

The sandstones and shales constitute by far the greater part of the formation: the former are slightly micaceous, grey, or dark-coloured, and laminated; the latter are liver- or dark-coloured. The limestone is grey or blue, argillaceous and subcrystalline.

Subdivisions. a. Laminated sandstone (Upper Ludlow rock). *b,* Limestone (Aymestry limestone). *c.* Sandy shale and flag, with concretions of earthy limestone (Lower Ludlow rock).

Localities. Shropshire, Herefordshire, Worcestershire, Staffordshire, Gloucestershire, Radnorshire, Brecknockshire, Montgomeryshire, Glamorganshire, Caermarthenshire.

Types. Ludlow Castle; Aymestry; Sedgley; Woolhope; west side of the Abberley and Malvern Hills.

Organic Remains occur in each of the three groups. They consist of a few corals, Terebratula, Leptæna, Orthis, *Pentamerus Knightii*, Lingula, Orbicula, Orthocerata, Bellerophon, *Homonolotus Knightii*, &c.

Author. Murchison (Proceedings of the Geological Society, 1833-4).

Museums. Geological Society; Ludlow Society.

Possibly the sandy slates which cap the slate formation of Westmoreland may be contemporaneous with these rocks. *Orbicula rugata* occurs in the former beds at Kirby Lonsdale, and in the latter near Ludlow.

135. DUDLEY ROCKS.

Mineral Character. Strata of limestone and shale.

Subdivisions. a. A mass of highly concretionary grey and blue subcrystalline limestone (Wenlock and Dudley limestone). *b.* Argillaceous shale, liver and dark grey coloured, rarely micaceous, with nodules of earthy limestone (Wenlock and Dudley shale).

Localities. In England: Radnorshire, Herefordshire, Worcestershire, Gloucestershire, Glamorganshire, Montgomeryshire, Brecknockshire, Caermarthenshire. In Ireland: the counties of Cork, Clare, &c. Foreign: Eifel, Britanny, Norway, Harz.

Types. Wenlock Edge; Woolhope; Dudley; west side of Abberley and Malvern Hills.

Organic Remains. Corals and Crinoidea in vast abundance. Among the Conchifera are *Producta depressa*, *Spirifera lineata*, Orthis, Lingula. Among the Mollusca are *Euomphalus rugosus*, *E. discors*, *Conularia quadrisulcata*, *Orthoceras annulatum*. The Trilobites are *Calymene Blumenbachii*, *C. variolata*, *Asaphus caudatus*.

Author. Murchison (Proceedings of Geol. Soc. 1833-4.)

Museums. Geological Society; Ludlow Society. Many museums and collections contain Dudley and Shropshire fossils.

136. CARADOC SANDSTONES, OR HORDERLEY AND MAY HILL ROCKS.

Mineral Character. Conglomerates, sandstones, limestones.

Subdivisions. *a.* Thin-bedded, impure, shelly limestone; and finely laminated, slightly micaceous, greenish sandstone. *b.* Thick-bedded, red, purple, green, and white freestones; conglomeritic quartzose grits; sandy and gritty limestones.

Localities. Shropshire, Herefordshire, Worcestershire, Gloucestershire, Montgomeryshire, Caermarthenshire.

Types. Horderley; Woolhope; May Hill.

Organic Remains. A few corals, some Crinoidea, *Pentamerus lævis*, Orthis, Leptæna, Terebratula, Nucula.

Author. Murchison (Proceedings of Geol. Soc. 1833-4).

Museum. Geological Society.

137. BUILTH AND LLANDEILO FLAGS.

Mineral Character. Beds of dark-coloured flags, mostly calcareous, with some sandstone and schist.

Localities. Near Shelve, Shropshire; near Builth; Llandeilo; Norway.

Organic Remains. Several Trilobites, especially *Asaphus Buchii*, Agnostus.

Author. Murchison (Proceedings of Geol. Soc. 1833-4).

Museums. Asaphus Buchii is frequent in collections.

Possibly the limestone of the Cumbrian lakes may be related to these beds.

138. CLAY SLATE AND GRAUWACKE SLATE SYSTEM.

Mineral Character. Argillaceous, indurated, fissile rocks, compact, fine-grained, or coarse and sandy; conglomerates; limestone bands.

Stratification. Often difficult to trace in the slate rocks, except by the alternation of the coarse, gritty, and conglomerate rocks, and by bands of colour.

Cleavage. The fine slaty rocks cleave vertically; the micaceous and sandy kinds split horizontally, like common flagstone; the system of joints has an almost geometrical regularity.

Subdivisions. As observed § 19, this is a great system of formations; but the paucity of organic remains, and other difficulties, make it prudent at present to avoid the attempt to constitute formations. In Cumberland: *a*. Dark flag-like slates (Coniston). *b*. Dark flag-like limestone. *c*. Green slate, and fragmentary rocks (Langdale). *d*. Dark soft slate (Skiddaw).

Localities. The southern borders of the Highlands; Lammermuir ranges; Cumbrian lakes; Yorkshire; much of North Wales; parts of South Wales; Charnwood Forest; Devonshire; Cornwall.

Types. The Cumbrian district; Snowdon; Devon and Cornwall.

Organic Remains. At Tintagel, in Cornwall; in Snowdon; both in deep parts of the slate. Corals, Brachiopoda, occur in *b*. in Westmoreland, and in sandy rocks above the dark slates, *a*.; but the relative antiquity of these beds (*a*. and *b*.) to the Builth and Ludlow rocks is not yet ascertained.

Authors. Otley, Sedgwick, Smith, Horner, De la Beche, Phillips, Boase, M'Culloch, J. Conybeare, Buckland, Boué, &c. The admirable researches of Sedgwick are yet only partially published.

Museums. The organic remains of Snowdon are generally known; those of Westmoreland were collected by Mr. Smith and the Author.

139. MICA SCHIST SYSTEM.

Mineral Character. Beds of mica schist, consisting of quartz and mica, with or without felspar and garnets; of quartz and chlorite; of quartz rock; rocks passing to clay slate, with laminæ of mica, chlorite, talc, hornblende, &c. Limited beds of limestone, iron ore, &c.

Stratification. A minutely undulated character of lamination belongs generally to the mica schist system: it is least evident in the limestones, and most striking in the chloritic varieties of schist.

Subdivisions. It is generally found that those schists which most resemble argillaceous slate lie in the upper part of the system; the most quartzose and felspathic portions lie toward the bottom; the limestone occurs in detached masses along certain planes in the mica schist.

Localities. The Highlands of Scotland; north-west of Ireland.

Organic Remains. None in the British Isles.

Authors. Jameson, Boué, M'Culloch, Necker.

Collections of specimens of the rocks of Scotland may be obtained in Edinburgh.

140. GNEISS SYSTEM.

Mineral Character. Beds of gneiss, consisting of laminæ of quartz, felspar, and mica; beds of mica schist, quartz rock, limestone, hornblende schist, and clay slate.

Stratification. Irregular; the laminæ generally contorted, undulated. The series of gneiss rocks, with the admixtures noticed above, hardly admits of any clear subdivisions. In several foreign countries the alternations of members of the gneiss, mica schist, and clay slate systems are frequent. In the Highlands, gneiss, mica schist, and hornblende schist quartz rock, and limestone, are variously associated. (See M'Culloch on Rocks.)

Localities. The western isles of Scotland; the northern and north-western parts of the Highlands.

Organic Remains. In the British dominions none, unless in the primary limestone of Sutherland. (M'Culloch.)

Authors. M'Culloch, Jameson, Boué, Necker. Collections of Scotch rocks are very instructive.

Class II.—PYROGENOUS ROCKS.

Section 1.—Ejected in the state of Ashes.

SUBAERIAL VOLCANIC ACCUMULATIONS.

141. These are either blown into the air by the explosive gases and vapours which accompany a volcanic eruption, and fall as dust, ashes, scoria, and stones; or poured out in a stream of melted rock from the summit, or more generally the flanks, of the volcano. In consequence of the explosive force being directed nearly vertically, and the ashes falling on all sides equally round the aperture, the hills of scoriæ, ashes, &c., accumulated round a volcanic vent, are always conical. Whether lava currents issue from the apex or the side, they merely cause a slight irregularity in the figure; but a new explosive vent opening toward the base of the mountain may throw up a new hill. Thus several cones on the flanks of Ætna have been thrown up.

SUBAQUEOUS VOLCANIC ACCUMULATIONS.

142. Heavy rains often accompany volcanic eruptions. These may sweep down the falling clouds of ashes to some plain or other repository in enormous quantities: thus, probably, the city of Herculaneum

was buried, while Pompeii and Stabiæ were overwhelmed with dry ashes. The volcanic ashes deposited in lakes and hollows form what is called volcanic tuff; at Naples, puzzolana; on the Rhine, trass. The loose stones, scoriæ, ashes, &c., thrown into the air by a volcano, are generally of the same mineral composition as the lava currents, and are probably derived from the melted rocks within the crater, acted on by steam and gaseous expansion. It is evident that such ejections may happen from beneath the sea, or lakes, but the depth of the ocean and other circumstances seldom permit their appearance. The short-lived island of Sciacca on the Sicilian coast (1832) threw up a vast heap of scoriæ, &c., probably from only a small depth in the sea. These loose materials, subsequently agitated in the water, and collected on the bed of the sea into irregular strata, will, probably, constitute a marine puzzolana, or volcanic sandstone, which may or may not contain marine shells.

Section 2.—Melted Rocks.

SUBAERIAL ACCUMULATIONS.

143. The lava currents (*coulées*) which issue from a burning mountain are completely fluid mineral compounds, which, according to circumstances affecting them after their eruption, solidify into glassy, cellular, compact, or crystalline rocks. Rapid cooling of lava leaves it a glass; slow cooling, a crystalline rock; gaseous extrications make it a cellular mass. It is found that lava solidified under water, that is, under the *pressure* of water, is less cellular and more

dense than parts of the same current which were indurated in the air. Hence we see that the *rate of cooling* and the *degree of pressure* control in a remarkable degree the condensation of lava, and determine some of its most general characters.

The chemical composition of lava is generally such as to give origin to abundance of glassy felspar, or of augite with felspar. The former is composed of silica, 63—69; alumina, 15—17; potash, 13—15. The latter of 50 silica, 24 lime, 12 to 28 oxide of iron, &c. As an intermediate case, the compact lava of Catania and Calabria yields 51 silica, 19 alumina, 10 lime, 4 soda, 14 oxide of iron, 1 muriatic acid. Basalt is an augitic lava, generally consisting of 46 silica, 16·5 alumina, 9 lime, 20 oxide of iron, and 3 or 4 soda. Trachyte is a felspathic rock. Between trachyte and basalt are innumerable varieties, depending on the proportions of augite and felspar, and on the admixture of olivine, oxide of iron, hornblende, quartz, and many other minerals.

Many volcanos have yielded, as superficial products, both basalt and trachytic lava; but the far greater portion of basaltic rocks has been formed as subterranean or subaqueous lava, and subsequently elevated with the strata; the same is supposed by some writers to be the case with the trachytes of the Puy de Dôme and some other localities.

144. SITUATIONS OF ACTIVE VOLCANOS.

In European Islands. Ætna, Vesuvius, Stromboli, Vulcano; several in Iceland; Jan Mayen, Santorino.

In African Islands. Teneriffe, Lanzerote, Cape Verd Isles, Azores, Isle of Bourbon, Madagascar.

In Asia. On the Continent: Demavend, Kamschatka. In the Islands: Zibbel Teir (Red Sea), an Island in the Sea of Azof, Aleutian Islands, Kurile Islands, Japan, Loo Choo, Formosa, Lucon, Fugo, Mindanao, Celebes, Ternate, Fidore, Sumbawa, Java, Sumatra, Barren Island, Banda, New Guinea, New Britain, New Ireland, Friendly Islands, Society Islands, Ladrone Islands.

In America. The Continent: North California, Mexico, Nicaragua, Guatemala, Colombia, Peru, Chili. Islands: West Indian Islands, Galapagos.

145. PRINCIPAL CIRCUMSTANCES OF VOLCANIC ACCUMULATIONS.

1. Volcanic ashes, scoriæ, and ejected stones, forming the cone of the crater.

2. Volcanic ashes, and other rejectamenta, accumulated by rivers and in lakes.

3. Lava currents solidified on land, in lakes in the sea.

These deposits may alternate.

On the subject of volcanic phænomena consult Daubeny's General Treatise on Volcanos, Scrope on Volcanos, and the works of Von Buch, Humboldt, Cordier, De Beaumont, Necker, and Lyell.

HYPOPYROGENOUS, OR PLUTONIC, ROCKS.

146. The rising of new islands out of the sea, composed of lava or scoria, seems to leave no doubt of the propriety of admitting amongst the products of active volcanos submarine currents of lava, spreading over limited breadths of the ocean bed according

to the conditions of the efflux. Observation of such effects is not, indeed, to be attempted, but from noticing the appearance assumed by lava which has flowed along the ground, and solidified under sea water, we learn some of the essential characters impressed upon these rocks by the contact and pressure of water. These characters, conjoined with direct observations on the relations of certain ancient igneous rocks to the adjoining strata, enable us to determine that they were really poured out on the bed of the sea, at intervals during the period occupied in the deposition of those strata.

The occurrence of certain igneous rocks in the fissures of the mass of a volcanic cone, suggests another principal condition of solidification of melted rock; viz. while surrounded by previously consolidated materials. Among the ancient stratified rocks, igneous rocks occur in the state of dykes, filling fissures, and masses interposed between the strata; and by careful study of the circumstances, no doubt remains that in many instances the fissures were filled by injections of melted rock, and the preconsolidated strata violently separated, so as to admit between them fluid masses of greater or less extent, which have subsequently been consolidated into beds more or less conformable to the original strata.

Hence we have submarine and subterranean pyrogenous rocks, which, as they have both been subject to the influence of pressure, are not always certainly and easily distinguishable.

147. There is a considerable variety of subaerial volcanic rocks produced at the present day, notwithstanding the general similarity of the circumstances

of their extrication; but a far greater variety of mineral aggregates was formerly produced under the sea, or forced into the openings of older strata. It is scarcely possible to arrange these products in the order of antiquity, except in very limited districts; and different districts compared in this point of view present very slight analogies. Generally we may, perhaps, admit the greater antiquity of granite, and the more modern date of basalt, and assign an intermediate period for porphyry and syenite. But these and other igneous rocks have been again and again reproduced at different geological eras. On this account it will be most useful to class the igneous rocks with reference chiefly to their composition and aggregation.

Mineral veins and beds present so many points of agreement with dykes and beds of pyrogenous rock, and so many facts harmonizing with the view that they are gradual or sudden effects of heat, that it is probable geologists will at last almost universally agree in regarding them as produced by injection of fluid masses, or by sublimation, or electrical transfer of metallic and mineral particles. For veins of segregation the latter view seems by far the most satisfactory. (See § 160, 161.)

148. GRANITE, PORPHYRITIC GRANITE.

Composition. Essentially contains crystallized felspar, with variable proportions of quartz and mica. The mica is sometimes replaced by talc, or chlorite, and partially by hornblende: in this last case it graduates to syenite.

Some varieties, having large included crystals of felspar, are called porphyritic; others, composed of felspar with angular masses of quartz, are called graphic granite. There is great diversity in the magnitude and colour of the felspar and mica. The quartz is usually grey. Some granite is full of cavities, in which the constituent minerals crystallize in various forms.

Occurrence. In immense masses below all the strata; in interposed beds, or expansions among gneiss and other primary strata; in uplifted masses in contact with ancient and modern strata; in veins ramifying from the great masses into the adjoining rocks.

Localities in Great Britain. Ben Nevis, Glen Tilt, Cairn Gorum, various points in the Highlands; Arran; Base of Skiddaw and upper part of Shapfells in Cumberland; Dartmoor; Cornwall; Isle of Man; Mourne Mountains.

149. FELSPAR ROCK, FELSPAR PORPHYRY, EURITE.

Composition. A basis of uncrystallized felspar, in which crystals of that mineral, with or without crystals of quartz, and rarely mica, are imbedded. Colours, red, grey, green, &c. Some varieties inclose nodules, sometimes almond-shaped, rather than crystals, and are then called amygdaloidal.

Occurrence. In overlying and interposed masses, sometimes columnar, and dykes.

Localities. Glencoe, Ben Cruachan, and other points in the Highlands; Arran; St. John's Vale, Cumberland; Cornwall; North Wales.

150. CLAYSTONE, CLAYSTONE PORPHYRY.

Composition. A basis of uncrystallized, almost earthy felspar, with or without crystals of glassy felspar, quartz, and rarely mica imbedded. Colour, red, yellow, grey.

Occurrence. In interposed masses and dykes; a prismatic structure prevails in both.

Localities. The Pentland Hills; Arran.

151. HORNSTONE, HORNSTONE PORPHYRY.

Composition. The difference between this group and that above is in the less fusibility of the basis. It is not common.

Occurrence. In dykes, associated with pitchstone.

Locality. In the Isle of Arran.

152. PITCHSTONE, PITCHSTONE PORPHYRY.

Composition. A glassy felspathic rock, with or without crystals of felspar and small spherulitic concretions. Colour, green, black, reddish.

Occurrence. In interposed columnar beds and dykes, generally exhibiting a prismatic structure.

Localities. Scuir of Egg; Arran.

153. SYENITE.

Composition. Felspar more or less crystallized, with crystallized hornblende, and admixtures of mica, quartz, augite, oxidulous iron, &c. Colour of the felspar, red, white, (rarely green).

Occurrence. In overlying masses, and rarely dykes.

Localities. Isle of Skye; Isle of Arran; Charnwood Forest; Carrockfell in Cumberland; Malvern Hills.

154. HYPERSTHENE ROCK, HYPERSTHENIC SYENITE.

Composition. Felspar more or less crystallized with crystallized hypersthene. Colour of felspar, white, red; of the hypersthene, green, purple.

Occurrence. In connexion with granite, uplifted masses, and, rarely, dykes.

Localities. Valteline; Isle of Skye; Carrockfell in Cumberland; Radnorshire; Cornwall.

155. DIALLAGE ROCK, SERPENTINE.

Composition. Felspar and diallage: when crystallized, it is diallage or gabbro; when fine-grained and soft, with indistinct traces of crystallization, serpentine. Colours various, with metallic reflections.

Occurrence. In overlying masses and dykes.

Localities. Apennines, Pyrenees, Corsica, Cornwall, Scotland.

156. GREENSTONE, AMYGDALOIDAL GREENSTONE.

Composition. Compact felspar and hornblende or augite, aggregated together with various degrees of distinctness, from a largely granular to an almost earthy state; sulphuret of iron occurs in it. Colour, green, greyish green, black. Occasionally, nodules of agate, chalcedony, or carbonate of lime, give it an amygdaloidal character. When the felspar is crystallized it is undistinguishable from syenite. The compounds of augite and compact felspar are called augite rock by M'Culloch; of augite and crystallized felspar, mimose by M. Haüy.

Occurrence. In interposed masses, often rudely columnar; in dykes.

Localities. In Scotland, especially about Edinburgh; Keswick; Derbyshire, (toadstone); North Wales; North-east of Ireland.

157. BASALT, AMYGDALOIDAL BASALT.

Composition. Basis of augite (or hornblende) and felspar, and often titaniferous iron; a dense compact hornblende or augitic mass, which yet shows crystallizations of felspar. Olivine often occurs in it; chlorophœite, agate, large crystals of felspar, and nodules of carbonate of lime diversify its aspect. In this way, basalt passes to a state of amygdaloid; when the felspathic parts are distinct, it passes to greenstone.

Occurrence. In vast overlying plateaux, and interposed stratiform masses, often associated with greenstone; in dykes. A columnar jointed structure belongs very generally to this rock. Some dykes of basalt in the North of England are from 30 to 60 miles long.

Localities. The North-east of Ireland; Scotland, especially near Edinburgh; North of England, especially Teesdale, Durham, and Northumberland; near Dudley.

158. MELAPHYRE, BLACK PORPHYRY.

Composition. Basis of black augite, with crystals of felspar.

Occurrence. In uplifted masses.

Localities. Along the southern flanks of the Alps.

159. WACKE'.

This rock resembles decomposed basalt or claystone; and in some cases may really be of aqueous aggregation. It is usually traversed by strings of calcareous spar, holds nodules of calcareous spar, chalcedony, quartz, &c. It then becomes the ordinary amygdaloid.

Occurrence. In overlying masses and interposed beds.

Locality. Calton Hill, Edinburgh.

160. METALLIC DEPOSITS.

Composition. Almost indefinite. In particular tracts of country certain metals occur abundantly, either native, alloyed, or united with sulphur, oxygen, and acids; and singly, or in connexion with other metals. Certain associations of metallic substances are known; as of iron and copper, lead and zinc, tin and copper. It generally happens that sulphurets occur together; carbonates, phosphates, arseniates, &c. together.

It is seldom that metallic matters occur unmixed with rock minerals: these are sometimes characteristically associated with certain metals.

Occurrence. Very rarely in anything like beds. (This happens to ironstone, which is an aqueous deposit of carbonate of iron.) Most commonly in veins which fill far-extended vertical or inclined fissures of the preconsolidated rocks, and in other veins which are contemporaneous with the rocks. In some veins (rake veins) the metallic substances, mixed with various rock minerals, all crystallized more or less distinctly, form vertical plates more or less regular, the different ingredients alternating. In other veins (pipes) the metallic and rocky substances are vertical or nearly so, but restricted to narrow angular spaces, not fissures, in the rocks. The particular rock minerals associated with metallic substances in veins, receive the name of matrix or veinstuff: they vary, perhaps, in some real relation to the period of their production, and to the nature of the containing rocks, but a certain independence of local character seems always to be recognised. In Cornwall, and the slate districts of Wales and Cumberland, quartz is a common matrix; in the limestone tracts of Derbyshire and Alston Moor, carbonate and sulphate of barytes, and fluor spar, abound; the metallic substances sometimes lie in soft earthy veinstuff, as at Greenhow Hill, Yorkshire, and in Cornwall.

Metallic veins are not confined to any particular tracts of country or any particular age of rocks, but yet they are by far most abundant along the lines and about the centres of mountain elevations, and in strata of high geological antiquity. No metallic vein has yet been worked in the British islands in strata above the saliferous system. In almost every instance their origin is somehow related to convulsive movements within the earth, and to the development of igneous rocks. In the Pyrenees and Central France, the metallic veins are chiefly confined to a narrow zone round the granitic and other pyrogenous rocks, and are there produced in strata of various antiquity. Rock dykes and metallic veins differ only in the nature of their contents; they have great analogies of origin, but it is rare to find the rock dykes yield metallic treasures.

161. There is a remarkable general fact concerning mineral veins, viz. that the most prevalent direction of those which are productive of metallic treasures is from west to east nearly. This obtains in the North of England, in Wales, Cornwall, Saxony, and most parts of Europe, and in Mexico. Other directions are also characteristic, as from north to south; but veins in these lines are often less productive, and generally admitted to be of less ancient date, because they *cut through* the east and west veins. These latter are called right-running veins, the former cross-courses.

In the North of England, the cross-courses are parallel to the dislocations along the Penine chain; the right-running veins are nearly parallel to the two great faults which pass from that chain to the east along the river Tyne and through Craven. Between these two lines of faults, one set of great fissures (§ 100.) runs about east and west, and another still more constantly about north by west. We may, perhaps, correctly admit that the directions of mineral veins are closely related to those of the great non-metalliferous fissures in the district, which, with the minor joints, compose an essential part of the structure of all rocks.

Metallic matters are often found in the substance of the rocks bordering a vein, in sparry nests and cavities, and in the hollows of shells. These facts, combined with analogous results of operations still in progress, indicate a transfer of the metallic substances by electrical or other subtle agency, even through a considerable mass of rock.

Electricity, probably excited by unequal temperature or chemical action, circulates along many mineral veins. See *Philosophical Transactions* for 1830, for Mr. Fox's experiments hereon.

Localities. Common in the primary rocks of the Highlands, Cumberland, Westmoreland, North Wales, Cornwall, Wicklow, Mourne Mountains, Isle of Man, &c. In the carboniferous limestone of Scotland, Northumberland, Durham, Cumberland, Lancashire, Yorkshire, Derbyshire, North Wales, South Wales, Somersetshire. Rarely in the magnesian limestone of Northumberland, Yorkshire, and Nottinghamshire.

Authors. Werner on Veins; Playfair's Illustrations; Carne, Hawkins, Boase, and Henwood on Cornish Veins; J. Taylor's Report to the British Association, 1833; W. Phillips, in Geological Transactions; Professor Phillips, in *Encyclopædia Metropolitana*; Westgarth Forster; Farey; Williams's Mineral Kingdom; Dufrenoy.

Museums. British Museum, Edinburgh Museum, Mr. Heuland's Collection, The Allan Collection, Geological Society, Yorkshire Museum, Museums of Newcastle, Bristol, Manchester, Liverpool, Leeds, Hull, Mr. Watson of Bakewell, many collections in Cornwall, and other parts of England.

PART IV.

TABLES AND CALCULATIONS.

PHYSICAL RELATIONS OF THE GLOBE AS A PART OF THE SOLAR SYSTEM.

162. THE EARTH AND THE SUN.

Figure of the Earth, a spheroid of revolution, with diameters as 298 : 299.

Equatorial diameter...	7925·648 miles.	Difference, commonly called the compression .... = 26·478
Polar diameter	7899·170	

Mean distance from the Sun, 95,000,000 miles.

Obliquity of ecliptic, 23° 28′.

	d	h	m	s		d.
Time in which the Sun returns to the equinox, called the Equinoctial, or Tropical, or Civil Year	365	5	48	51·6	or	365·242264
Annual precession of the equinox, ∠50″·1 = in time	0	0	20	19·9		0·014119
Sidereal Year	365	6	9	11·5		365·256383
Annual precession of the apogee, ∠11″·8 = in time.........................	0	0	4	47·3	or	0·003325
Anomalistic Year.........................	365	6	13	58·8		365·259708

163. THE EARTH AND THE MOON.

Mean distance of the Moon from the Earth, 59·9643 equatorial radii of the Earth:

An equatorial radius = 3962·824 miles. Hence, distance of the Moon's centre from that of the Earth = 237628 miles nearly.

Diameter of the Moon	2160 miles.
The mass of the Earth being..	1·0000000
That of the Moon is...	0·0125172
Mean sidereal revolution of the Moon.........	27·321661418 days.
Mean synodical revolution of the Moon......	29·530588715 days.
Excentricity of orbit	0·054844200
Mean inclination of orbit	5° 8′ 47″·9

164. THE EARTH AND THE OTHER PLANETS.

Planets' Names.	Mean distance from the Sun.	Mean Sidereal Period in Mean Days.	Excentricity in parts of the mean Distance.	Inclination of the Orbit to the Ecliptic.	Mass in billionths of the Sun's.	Equatorial Diameter, the Sun's being 111·454.
Mercury .	0·387	87·969	0·2055	7° 0′ 9″·1	493628	0·398
Venus	0·723	224·700	0·0068	3 23 28·5	2463836	0·975
Earth	1·000	365·256	0·0167	——	2817409	1·000
Mars	1·523	686·979	0·0933	1 51 6·2	392735	0·517
Vesta......	2·367	1325·743	0·0891	7 8 9·0	——	——
Juno	2·669	1592·660	0·2578	13 4 9·7	——	——
Ceres......	2·767	1681·393	0·0784	10 37 26·2	——	——
Pallas	2·772	1686·538	0·2416	34 34 55·0	——	——
Jupiter ...	5·202	4332·584	0·0481	1 18 51·3	953570222	10·860
Saturn	9·538	10759·219	0·0561	2 29 35·7	284738000	9·987
Uranus ...	19·182	30686·820	0·0466	0 46 21·4	55809812	4·332

(*From Sir John Herschel's Astronomy.*)

TEMPERATURE OF THE GLOBE.

165. Land.—The mean temperatures near the level of the sea vary nearly as the cosines of latitude. Thus, if the equatorial mean temperature = 81°·5 Fahr., the mean temperature for any latitude = 81°·5 cos. lat. This is found to apply very well until we arrive near the polar circle, when several anomalies occur, which seem to indicate at least two centres of maximum cold, one in America, one in Asia.

166. Water.—The oceanic temperature is not subject to the same extremes as that of the land: it does not diminish so fast toward the poles, and consequently permits the existence of marine animals in latitudes which are fatal to nearly all terrestrial beings.

Fresh water is heaviest at about 38°·75 Fahr., growing lighter both by heating and cooling; and consequently, in latitudes which permit of this degree of cold at the surface, during the winter, there will then be a falling of cold water, and a rising of warm water, so as to counteract materially the rigour of the season. In latitudes where it is only in summer that the surface water can be heated to 38°·75, the warmed water will then sink from the surface, which at other times may freeze, and experience extreme cold, while the bottom is warm.

This does not apply to the ocean; for it is found that salt water goes on increasing in density as it cools, even to some degrees below freezing. The variations of the temperature of the sea, in relation to depth from the surface, are not yet sufficiently known. It appears, however, that the reduction of temperature in the deep parts of the tropical seas is very considerable.

In lat. 3° 26′ S.	surface... 73°	1000 fath..	42°	Wauchope.
20 30 N.	83	1000	45·5	Sabine.
9 21 N.	83	250	77	Kotzebue.
0 0	83	300	55	

Mean reduction of temperature in tropical latitudes, 1° F. in 25 fathoms.

In lat. 36° 9′ N.	surface...71°·9	100 fath..	52°·8	Kotzebue.
30 39 S.	67	300	44	
44 17 S.	54·9	196	38·8	

Mean reduction of temperature in lat. 37° 2′......1° in 28 fathoms.

In lat. 79° 4′ N.	surface...29°	13 fath...	31°	Scoresby.
		37	33·8	
		57	34·5	
		100	36·0	
		400	36	
		730	37	
76° 16′ N.	28·8	50	31·8	Ditto.
		123	33·8	
		233	33·3	
78° 2′	32	761	38	
60° 44′		100	30	Ross.
		200	29	
		400	28	
		600	25	
67°		4400 par. feet	2°·6 R.	Irving.
78°		660 ditto	0 ·4	

167. Atmosphere.—The decrease of temperature, as we ascend from the level of the sea, is sub-

ject to so many causes of fluctuation and local diversity, that it has been found very difficult to come to any general conclusion. In equatorial regions, according to Humboldt, there is a diminution of temperature = 1° Reaum. for 121 toises of ascent: at St. Bernard, 1° R. for 123½ toises = 1° Fahr. for 352 feet English. At Ventoux, near Avignon, 1° R. corresponds to 80 toises in summer, and to 100 in winter: on the Righi, 1° R. for 97 toises. In the North of England, Mr. Nixon's experience on mountains of 1000 to 2000 and 3000 feet, gives 1° F. in 230 feet. Dr. Dalton allows 1° F. to 100 yards elevation. Generally it is found that the temperatures diminish more rapidly from the lowest stations.

The above statements apply to the air *near the ground*, where it is influenced by the heating surface of the earth. We do not know what is the law of diminution of the heat in the air directly upwards from the ground. The observations for this purpose by Gay-Lussac and Biot, and Lord Minto, should be followed up.

168. Springs.—The unfailing springs which gush out from fissures of rocks, bring with them the temperature of their shallow subterranean channels; and this temperature is generally found to be constant, and in cold regions a little higher than the mean temperature of the air. This was first noticed by Dalton, and has since been made the subject of extended inquiry by Prof. Küpffer, from whose researches it appears, that the difference of shallow subterranean mean temperature from that of the air above the surface of the ground, follows a certain law, depending on the latitude and on local

influences. Near the equator, the ground, at 25 metres depth, appears to have a temperature 2° R. *below* the mean temperature of the air; whilst in Lapland it is 2° *above* it. This appears to be a strong corroborative argument for the internal temperature of the earth depending on a cause distinct from solar influence.—(Forbes, in Report to the British Association, 1832.)

169. SUBTERRANEAN HEAT.—The fluctuations of superficial temperature diminish as we descend into the earth, so that at last we arrive at a point where, through the whole year, there is no change, and consequently below which the variation of solar influence is insensible. This depth is called the *invariable plane*. From the observations in the caves at Paris, it is inferred to be nearly 30 metres, or 100 feet from the surface. Below this plane, any differences in the temperature of the earth must be ascribed to internal terrestrial peculiarities. It is found that below the invariable plane the temperature of any point is wholly uninfluenced by seasons, and is constant; that the temperature augments regularly in proportion to the depth, at a rate, upon the average, of 1° F. for 15 English yards. It is clear, therefore, that there is a proper source of heat within the earth.

The warm and hot springs which issue from great depths, yield another and very satisfactory proof of the existence of great heat within the earth. Some of these are closely connected with existing volcanos, others with lines of convulsion, which open a communication to the deep parts of the earth. It is clearly to this communication that the heat is owing, and not to any local chemical actions along the channels; for the chemical composition of the waters is by no means uniform, and, perhaps generally, hot waters are as pure as others. In some places hot and cold springs rise within a few feet of each other.

Temp. of the Great Geyser	209°	Sir G. Mackenzie.
La Trinchera, 3 leagues from Valencia	194·5	Humboldt.
Carlsbad	165	Ure's Chemical Dictionary.
Aix-la-Chapelle	143	
Bath	116	
Buxton	82	
Hotwells	74	
Matlock	68	

THERMOMETRICAL SCALES.

170. The freezing-point of water is marked 32° on Fahrenheit's thermometer; but on Reaumur's, and Celsius's or the centigrade, it is marked 0°. The boiling-point of pure water (when the barometer is at 30·0) is marked 212° on Fahrenheit's, 80° on Reaumur's, 100° on the centigrade. Hence the relative *values* of the thermometrical unit or degree are, on Fahrenheit, 1°; on the centigrade, 1°·8; on Reaumur's 2°·25. Hence the following rules:

1. To reduce to Fahrenheit the observations on the other scales,
   Multiply the number on Reaumur's by $2\frac{1}{4}$, and add 32°.
   Multiply the number on the centigrade by 1·8, and add 32°.

2. To reduce to the centigrade scale observations on the others,
   Multiply the number on Reaumur's by $1\frac{1}{4}$.
   Diminish the number on Fahrenheit by 32°;
   And multiply the remainder by 0·555 +,
   Or divide it by .... 1·8.

It is much to be recommended that English philosophers should adopt the centigrade scale.

Value of English Measures in French Metres.	*Value of French Measures in English Inches.*
English INCH ....0·0254	French Millimètre...0·03937
Foot ....0·3048	Centimètre...0·39371
Yard ....0·9144	Decimètre ...3·93708
Fathom ......1·8287	MÈTRE.....39·37079

THE BAROMETER.

171. A little experience in moderately elevated regions of stratified rocks will convince the geologist who values the connexion of the physical sciences, or desires to give the utmost accuracy to his results, that it is wrong to neglect the use of the portable barometer. The objections usually urged against the Englefield barometer are of little importance, if the construction of the instrument has been properly attended to. Heights of ground, thicknesses of rocks, otherwise often unascertainable, extent of dislocation, and many other useful data may be thus quickly obtained, *at the time when they are most wanted*, by the geologist. No apparatus is needed for the support of the instrument; and, provided the observer be steady of hand and sure of eye, his observations can hardly fail to be correct. The observations are, 1. The height of the barometer, in inches, tenths, hundredths, and thousandths, at each station; 2. The degree of the thermometer *attached* to the instrument at each station; 3. The degree of this or another thermometer *detached* from the instrument, and exposed to the air in the shade, at each station.

172. To calculate with tolerable accuracy the difference of level corresponding to any two sets of ob-

servations, the following easy and brief processes will be sufficient, without special tables or logarithms, for altitudes under 4000 feet, and in the latitudes of Great Britain. The geologist is recommended to copy them into his *field note-book.*

1. Having written down the observations as they were made, take the mean and difference of the barometer, the difference of the attached therm., and the sum of the detached thermometer.

2. Correct the barom. difference for relative capacity of tube and cistern. This correction is always additive, and its value is marked on the barometer.

Mr. Nixon has explained a method of construction which removes the necessity of this correction in his portable barometers.

3. Correct for difference of att. therm., by multiplying that difference by $\frac{1}{10000}$th of the mean barometric pressure. The product must be subtracted from the barometric difference (2.) when the upper station is colder; added to it when warmer.

4. Correct for the temperature of the air above 0° Fahr. by the following process: Consider the sum of the det. therm. as thousandths; add to it the integer 1·000; multiply together this sum, the corrected barometric difference (3.), and the constant number, 24900; divide the product by the mean barometric pressure (1.). The quotient is the height in English feet, nearly.

Example of the whole process:

	Bar. Press.		Att. Ther.		Det. Ther.
(1.) Lower station, Bar. Press.	30·040	Att. Ther.	72·5	Det. Ther.	72·0
Upper station	26·575		63·5		62·6
Mean............	28·307	Diff.....	9	Sum...	134·6
Difference.....	3·465				

(2.) In this instrument the capacity is allowed for by the construction.

(3.) 9 × ·00283 = ·0254 and 3·4650 − ·0254 = 3·4396.

(4.) Sum of Det. Therm. + 1·000=1·1346 $\frac{1·1346 \times 3·4396 \times 24900}{28·307} = 3433·7$ feet. In lat. 54°, the height by Oltmann's tables in De la Beche's Manual, is 3432·3 ; height by Nixon's Tables (Phil. Mag.), 3435·9.

The fluctuations of the barometer are not necessarily productive of error in the use of the instrument. It is not requisite to have more than one barometer, provided the observer returns again, in the course of the day, to the point which he has chosen for his reference station, or verifies his results by including amongst his measures some point whose height, compared to that reference station, is known, or in any other way can know the hourly rate of the rising or falling of the barometer.

For Example, Sept. 22, 1832:

	Bar.	Time.	Att. & Det. Therm.	Correction for Temp.	Corrected Pressures.
Inn at Hawes.........	29·878	9h. 40m.	60°	·000	29·878
Gale.....................	29·800	11 0	58	+ ·006	29·806
Summit of a hill.....	28·735	12 0	55	+ ·015	28·750
Inn at Hawes.........	29·850	2 0	64°	− ·012	29·838

Hence it is seen, that in 4h. 20m. the barometer fell ·040; and by applying a correction, in this proportion, to all the observations,

$$\text{we have}\left\{\begin{array}{l} 29{\cdot}878 + {\cdot}000 = 29{\cdot}878 \\ 29{\cdot}806 + {\cdot}012 = 29{\cdot}818 \\ 28{\cdot}750 + {\cdot}022 = 28{\cdot}772 \\ 29{\cdot}838 + {\cdot}040 = 29{\cdot}878 \end{array}\right\}\text{true relative pressures.}$$

CLINOMETER.

MAGNETIC INSTRUMENTS.

173. In ascertaining generally the direction and angle of the dip, and direction of the horizontal line or strike of the stratified rocks, nothing is more convenient than the pocket clinometer, fitted with a compass-needle, as usually sold in London. Mr. Pratt has lately (Philosophical Magazine) proposed an improvement in it. A very ingenious instrument applicable to geological surveys, as well as ordinary clinometrical uses, is manufactured by Mr. Dunn of Edinburgh. For accurate determination of the strike of beds, direction of joints, and bearings of objects, (which the geologist will often need,) a good compass-box is very desirable. This instrument may often be found to give curious results among certain

primary rocks, along dykes of basalt, &c. The variation of the needle (now about 24° to N.W. in England) being marked on the circle, the geologist may record his observations in true bearings.

Unprovided with a clinometer, a jointed rule will suffice to those acquainted with trigonometry; and a faithful drawing will often be as good as any measure. When it happens (as in a cliff) that there are two or more lines of section exposed, neither of which passes along the line of dip, or line of strike, the amount of dip, and direction of dip and strike, can be calculated trigonometrically from the observed dips and directions of the rocks exposed in the sections. (See a Paper on this subject in the Transactions of the Royal Society of Edinburgh, by M. Necker.)

NOTICES OF MAPS AND BOOKS.

174. Mr. Smith's Map of the Strata of England and Wales, and Mr. Greenough's Geological Map of England and Wales, may be consulted as general guides: both require much correction. Mr. Smith's Geological County Maps are of great value as a basis of accurate topographical geology. Reduced copies of Mr. Greenough's and Mr. Smith's large Maps, may be had for the convenience of travelling. Boué's is the only published Map of Scotland: MacCulloch's labours in that country will soon be made useful to the public, through the liberality of the Highland Society. Mr. Weaver's Charts of parts of Ireland may be consulted in the Geological Transactions. It is hoped that Mr. Griffith will soon publish a general map of the country which he

has so well explored. I have been for some time occupied in the attempt to construct a convenient geological map of the British Islands. As representing the geology of a large part of Europe, Von Buch's Map, published by Schropp and Co., of Berlin, may be consulted with advantage. Considerable progress is made towards the publication of a valuable map of France. The geology of America will also be soon rendered more familiar to us by the production of detached maps of counties and interesting districts.

175. The Transactions of the Geological Society of London contain a fund of original and valuable communications, relating chiefly to the geology of the British Isles, or to the labours of British geologists in Europe, India, and America; excellent plates accompany most of the papers. The Transactions of the Geological Societies of Dublin, Cornwall, and France; those of the Wernerian Natural History Society, of the Natural History Society of Newcastle, the Sociétés d'Histoire Naturelle of Geneva, Bonn, and Strasburgh, and of some scientific bodies in America, are also of great importance. The Outlines of the Geology of England and Wales by the Rev. W. D. Conybeare and the late W. Phillips, the Geology of Scotland by Dr. Boué, the volumes of Jameson and MacCulloch on the Western Islands, are general works of standard reputation. Mr. Griffith's Reports contain abundance of information on the geology of Ireland.

Among the works on Organic Remains most useful to an English reader, we may notice the valuable Mineral Conchology of Great Britain by Sowerby, Parkinson's Organic Remains, and Woodward's Convenient Synopsis. The history of fossil plants has been for some time successfully prosecuted by Count G. Sternberg, M. Adolphe Brongniart, and Dr. Lindley and Mr. Hutton. The admirable delineations in the Petrefactenkunde of Goldfuss deserve all praise. Miller's work on the Crinoidea still retains its value. M. Agassiz's Researches on Fossil Fishes form a new æra in this department of Palæontology. To the student of the higher vertebrata, Cuvier's Ossemens Fossiles is an invaluable instructor, and Meyer's Palæologica a faithful guide.

AUTHORS QUOTED.

176. The following List contains the names of the Authors who have been quoted as specially illustrative of the history of particular formations or regions, with the titles of their works: some other authors and works of reputation are also noticed; but many of great merit (especially foreign) are unavoidably omitted. The mere list of eminent authors and titles of their works would fill a volume.

AGASSIZ. Histoire des Poissons Fossiles, 4to & fol., pl.
AIKIN. Trap in Birchhill Colliery, near Walsall.
ALBERTI. On the Formations of Würtemberg.
ARAGO. Elevation of Scandinavia, in the Annuaire; Temp. of Artesian Wells, in Jameson's Journ.
ARTIS. Antediluvian Phytology, 4to, pl.
BABBAGE. Displacements of the Temple of Serapis, in Geol. Proceedings.
BAKEWELL. Introd. to Geol., 8vo.

BASTEROT. Bassin Tert. du S. O. de la France, in Mém. de la Soc. d'Hist. Nat. de Paris.

BEAUMONT. Sur les Revolutions du Globe, in Ann. des Sci. Nat., Mém. Geol. de la France, &c.

BENETT, MISS. Catalogue of Wiltshire Fossils, 4to, pl. (Printed for private distribution.)

BERTRAND GESLIN. On the Val d'Arno, in Ann. des Sci. Nat.

BEUDANT. Geology of Hungary, 4to, pl.

BIGSBY. On the Geology of North America, in Geol. Trans.

BOASE. On Primary Rocks; on the Geology of Cornwall, 8vo.

BOBLAYE. Sur la Form. Jurass., &c., in Ann. des Sci. Nat., 1829.

BOUÉ. Géologie de l'Ecosse, 8vo, pl. Many Memoirs on Foreign Geology, in Ann. des Sci. Nat., Journ. de Geol., Edin. Phil. Journal, Geol. Proceedings, &c.

BRANDER. Fossilia Hantoniensia, 4to, pl.

BROCCHI. Conchyliologia Subapennina, 4to, pl.

BRONGNIART, ADOLPHE. Histoire des Végétaux Fossiles, 4to, pl.

BRONGNIART, ALEX. Géologie des Environs de Paris, 4to, pl.; Tableau des Terrains, 8vo.

BRONGNIART et DESMAREST. Sur les Crustaces Fossiles, 4to.

BRONN. Gæa Heidelbergensis, 8vo; Lethæa Geologica.

BUCKLAND. Reliquiæ Diluvianæ, 4to, pl.; On Coprolites, On the Highclere Elevation, and many Memoirs in the Geol. Trans. and Phil. Mag.

BUCKLAND and CONYBEARE. On the Somersetshire

Coal-field, On the North-east of Ireland, in the Geological Transactions.

BUDDLE. On the Newcastle Coal Series, in Trans. of Nat. Hist. Soc. of Newcastle.

CARNE. On the Veins of Cornwall, in Trans. of Royal Geol. Soc. of Cornwall.

CHARBAUT. On the Env. of Lons le Saulnier, in Ann. des Mines.

CLIFT. On the Irawadi Fossils, in Geol. Trans.

CONRAD. On American Geology, in Journal of Academy of Sciences.

CONYBEARE, W. D. Report on Geology to Brit. Assoc.; On the Valley of the Thames, &c., in Geol. Trans., Phil. Mag., &c.

CONYBEARE and DE LA BECHE. On Saurian Animals, in Geol. Trans.

CONYBEARE and W. PHILLIPS. Geology of England and Wales, vol. i.

CORDIER. Essays relating to Igneous Rocks, Interior Heat of the Globe, &c., in Mém. de l'Acad. des Sciences and Ann. du Museum.

CROISET et JOBERT. Ossemens Foss. du Puy de Dôme.

CUVIER. Recherches sur les Ossemens Fossiles, 4to, pl.

DAUBENY. On Volcanos, 8vo, pl.; On Sicily, in Jameson's Journal; Article GEOLOGY in Encycl. Metrop.

DAUBUISSON. Traité de Géognosie, 8vo.

DE BEAUMONT. Rapport de la Société Géolog. de la France.

DE CAUMONT. Géologie du Calvados, 4to, pl.

DECHEN (VON). The German Edition of De la Beche's Manual, 8vo.

DEFRANCE. Tableau des Corps Organises, 8vo; Géologie du Nord de la France, 8vo.
D'HALLOY. Various Memoirs.
DE LA BECHE. Manual of Geology, 8vo; Researches in Theoretical Geology, 12mo; Translations of Memoirs from the Ann. des Mines, &c., 8vo; Memoirs in Geol. Trans., Phil. Mag., &c.
DE LUC, J. A. Sur les Blocs eparses, &c., in Trans. Soc. d'Hist. Nat. de Génève, 4to.
DESHAYES. Coquilles Caracétristiques des Terrains, 8vo; Coquilles Fossiles du Terrain Tertiaire de Paris, 4to, pl.
DESNOYERS. Sur un Ensemble de Depôts, &c., in Ann. des Sci. Nat. 1829.
DUFRENOY. Mémoires sur la Géologie des diverses Parties de la France, in Ann. des Mines, Ann. des Sci. Nat., Bull. de la Soc. Géol., &c.
ELLIS. Sandwich Islands, 8vo.
FAREY. Report on Derbyshire, 8vo, pl.
FEATHERSTONHAUGH. Series of American Rocks, in Geol. Proceedings.
FITTON. Notes on the History of English Geology, 8vo; On the Green-sand, On the Stonesfield Strata, and other Memoirs, in the Geol. Trans., Phil. Mag., &c.
FLEMING. British Animals, 8vo.
FORBES. Phys. Changes in the Bay of Naples, in Edinb. Phil. Journal.
FORCHHAMMER. Kreide-formation Dännemarks, in Leon. Zeitschrift.
FORSTER. Description of a Whindyke, and of South Wales Coal-field, in Newcastle Trans.

Forster, W. Section of Strata from Newcastle to Carlisle, 8vo.

Franklin. Geology of India, in Geol. Proceedings.

Freiesleben. Geogn. Arbeiten.

Goldfuss. Petrefactenkunden, folio.

Greenough. Elements of Geology, 8vo.

Griffith. Reports on the Coal Tracts of Ireland, 8vo.

Harcourt, W. V. On the Ossiferous Deposit of Bielbecks, in Phil. Mag.

Hart. On Cervus Megaceros, 8vo.

Hausmann. Researches in Spain, Sicily, and North-west of Germany.

Hawkins. On Saurian Remains, 4to, pl.

Hennah. On Plymouth Limestone, in Geol. Proceedings.

Henslow. Geology of Anglesea, in Camb. Trans.

Henwood. On the Mineral Veins and Geology of Cornwall, in Phil. Mag. Many of his observations are yet unpublished.

Herschel. On certain Revolutions affecting Geology, in Geol. Proceedings.

Hibbert. Volcanos of the Rhine, 8vo, pl.; on the Burdiehouse Limestone, 4to, pl.

Hoffmann. On North-western Germany.

Holland. On the Salt of Cheshire, in Geol. Trans.

Horner. On the Malvern Hills, in Geol. Trans.

Humboldt. Gisement des Roches, 8vo; Essays on Climate, &c., in Brewster's and other Journals; Fragmens Asiatiques, Relation Historique.

Hutton. On the Rotheliegende; On the Great Whin Sill, &c., in Newcastle Trans.

Jäger. Über die Fossilen Reptilien, &c. 4to.

JAMESON. Mineralogy of the Scottish Isles, 8vo; Mineralogy of Dumfriesshire, &c. 8vo; Translations of Cuvier's Discours Prél.; Memoirs in Wernerian Transactions.

KÖNIG. Icones Fossiles Sectiles, fol. pl.

LEA. Contributions to American Geology.

LEONHARD. Taschenbuch, 8vo.

LIEBNITZ. Protogæa, 4to.

LINDLEY and HUTTON. Fossil Flora of Great Britain, 8vo.

LLWYDD. Lithophyl. Brit. Ichnog., 8vo, pl.

LONSDALE. On the Oolitic Formation of Bath; Survey of the Oolites in Gloucestershire, in Geol. Trans. and Proc.

LYELL. Principles of Geology, 8vo; On Marl of Forfarshire, and other Memoirs, in Geol. Trans., &c.; On the Elevation of Scandinavia, &c.

MACCULLOCH. Western Isles, 4to; On Rocks, 8vo; On Quartz Rock, and other Memoirs, in Geol. Trans.

MACKENZIE. On Iceland, 4to.

MANTELL. Geology of the Southdowns, 4to, pl.; ...of Tilgate Forest, 4to, pl.; ... of the South-east of England, 8vo, pl.

MARTIN. Geology of Western Sussex, 4to.

MARTIN, W. Petrificata Derbiensia, 4to.

MEYER. Palæologica, 8vo.

MILLER. On Crinoidea, 4to; On Belemnites, in Geol. Trans.

MILNE. Essay on the Geology of Berwickshire, in Brit. Association Report for 1834.

MITCHELL. On Caves in Australia, in Geol. Proc.

MORTON. Synopsis of Cretaceous Fossils of America.

MUNSTER, COUNT G. On Clymenia and Goniatites, in Ann. des Sci. Nat. 1834.

MURCHISON. On the Brora Deposits; On the Secondary Rocks of Scotland; On the Gosau Deposits; On the North-west of Sussex, and parts of Surrey and Hants, all in Geol. Trans.; On the Transition Rocks, and many other Memoirs, in Geol. Proc., Phil. Mag., &c.

NECKER. On Somma, and on the Valorsine, in Mém. de Génève; On Veins, &c., in Geol. Proc.

NILSSON. Petrificata Suecana, 4to.

NÖGGERATH. On Westphalia, 8vo.

OEYNHAUSEN. On Silesia.

OTLEY. Guide to the English Lakes, 8vo, map.

PARKINSON. Organic Remains, 4to, pl.

PENTLAND. Fossil Quadrupeds from North-east of Bengal, and Quadrupedal Fossils of Italy, in Geol. Trans. and Proc.

PHILLIPS, PROF. Illustrations of the Geology of Yorkshire, 4to, pl.; On the Slate Rocks of Craven, in Geol. Trans.; Yorkshire Coalfield, and other Memoirs in Phil. Mag.; Art. GEOLOGY in Encycl. Metrop.

PHILLIPS, W., with CONYBEARE. Geology of England and Wales, 8vo.

PLAYFAIR. Illustrations of the Huttonian Theory.

PUSCH. Geology of Poland, &c., in Journal de Géologie.

RISSO. Hist. Nat. de l'Europe Méridionale.

ROGERS. Report on Geology of America to Brit. Assoc.

SAUSSURE. Voyages dans les Alpes, 8vo.
SCHLOTTHEIM. Petrefactenkunde, 8vo, pl. 4to; Flora zur Vorwelt, 4to.
SCROPE. On Volcanos; Memoirs in Geol. Proc.
SEDGWICK. On the Carboniferous Limestone Series, in Geol. Trans.; On Magnesian Limestone, in Geol. Trans.; On the Slate System of Wales, &c., and other Memoirs, in Geol. Proc.; On Basalt of Teesdale, in Camb. Trans.; several Memoirs in Phil. Mag., &c.
SEDGWICK and MURCHISON. Memoirs on the Geology of Scotland; on the Deposits of Gosau; the Geology of the Danube, Alps, &c., in Geol. Trans.
SERRES. Geognosie des Terrains Tertiaires, 8vo.
SILVERTOP. Geology of Spain, in Geol. Proc.
SMITH. Strata identified by Organic Remains, 4to, pl.; Stratigraphical System of Organic Fossils, 4to; Memoir to Geol. Map; Maps, Sections, &c.
SOWERBY. Mineral Conchology of Great Britain, 8vo, plates.
STEINHAUER. On certain Coal Plants, in American Trans.
STERNBERG. Flora der Vorwelt, fol., pl.
STRANGWAYS. Geology of Russia, in Geol. Trans.
STUDER. Sur la Molasse.
TAYLOR, J. Report on Mineral Veins, in Brit. Ass. Rep.; Records of Mining; and other Memoirs.
TAYLOR, R. On the Crag, in Geol. Trans.
THIRRIA. In Mémoires de la Soc. d'Histoire Nat. de Strasburg.
THOMAS. Mining Survey of part of Cornwall.

Townsend. Character of Moses, &c., 4to.
Traill. Geology of Orkney, in Rep. of Brit. Assoc.
Trevelyan. On a Dyke, in Geol. Proc.
Villefosse. La Richesse Minérale, fol., pl.
Voltz. On Belemnites, 4to, pl.; Sur les Environs de Vic, &c., in Ann. des Mines.
Von Buch. Travels in Norway; On Volcanos, &c.; On Ammonites; On Dolomite, in Ann. des Sci. Nat., &c.
Walcot. Petrifactions of the Vicinity of Bath, 8vo.
Warburton. On Bagshot Sand, in Geol. Trans.
Weaver. Geology of Ireland, in Geol. Trans. and Proc.; On Rotheliegende, &c., in Phil. Mag.
Webster. On the Strata of Hastings; On the Basins of London and Paris, in Geol. Trans.; Essays in Englefield's Isle of Wight, &c.
Werner. On Veins (translated by Dr. Anderson).
Whitehurst. Theory of the Earth, 4to, pl.
Williams. The Mineral Kingdom, 8vo.
Winch. Geology of Northumberland, in Geol. Trans.; other Memoirs in Phil. Mag., &c.
Witham. On Fossil Vegetables, 4to.
Wood. Geology of Northumberland, in Newc. Trans.
Woodward, J. Natural History of Fossils, 8vo.
Woodward, S. Synoptic Table of British Organic Remains, 8vo; Geology of Norfolk, 8vo, pl.
Yates. On Deposits in Lakes, &c., in Edinb. Phil. Journ.
Young and Bird. Geological Survey of the Yorkshire Coast, 4to.

EXPECTED NEW WORKS ON ENGLISH GEOLOGY.

Buckland. Bridgewater Treatise on Geology.

Conybeare and Sedgwick. Geology of England and Wales, Part II.

Fitton. On Green-sand, in Geol. Trans.

Murchison. On the Transition Rocks of the Welsh Border.

Phillips. Geology of Yorkshire, Part II.

REFERENCE TO THE PLATES.

Fig. 1. Shows the real proportions of the height of ground above the sea level from Bridlington to Whitehaven: a line drawn sloping from west to east marks the depth to which the composition of the earth is *known* in that country.

2. This section shows the distinction, as to arrangement, between the superficial deposits and the interior strata. A dislocation, or fault, affects the latter.

3. Here the stratified rocks (*b.*) are contrasted with the unstratified rocks (*a*).

4. An outline Geological Map of England, to show the relative extent of certain systems of strata.

5. From the axis of crystalline rocks (*a.*) the strata decline on both sides; those which rise highest on the mountains sink lowest under the plains.

6. Near the axis of uncrystalline rocks (*a.*) the stratified rocks are thrown into great and sometimes inexplicable confusion of dip, broken by faults, and bent in violent curves. (Alps.)

7. After the occurrence of the convulsions which displaced the formation (*c.*), marine strata (*d.*) were deposited level on the edges and slopes of the previously disturbed rocks.

8. Shows the course of the Shap-Fell granite boulders across three vales and three abrupt ridges of hills, a distance of 110 miles.

9. Aspect of a volcanic cone, and section of its concentric layers of scoriæ, &c.

10. Effect of local depression (*d.*) and of local elevation (*e.*)

PLATE III. (FRONTISPIECE.)

This geological view of the Isle of Wight, comprising a plan and elevation of the surface, the natural section of the South Cliffs, and an ideal section through the middle of it, is designed as an instructive example of the relations between the superficial and the interior or subterranean arrangement of stratified rocks. Minute topographical accuracy was not essential for this object, yet the leading physical features of this remarkable island are not ill represented by the lines which portray its geological structure. While the northern half of the island, consisting of tertiary formations, partly marine, partly lacustrine, extends into a low triangular space, the southern portion, formed of secondary strata, swells into boldly undulated ridges, which are abruptly truncated by the sea.

From the pinnacles of chalk in the west, called "The Needles", to "Culver Cliff" in the east, is the line of a remarkable dislocation, which has thrown the lower tertiary beds and the chalk from a horizontal into a vertical position. In the drawing the island is supposed to be cut through by a broad channel passing nearly north and south, and exposing on one of its sides a complete section of all the strata, in their real order and arrangement. It is there seen that both to the north and the south of the line of vertical strata the rocks recover their nearly horizontal position; further, we remark the Wealden formation rising into the imaginary cliff in the form of an arch, which agrees with the appearance of that formation both in Brixton Bay to the west, and Sandown Bay to the east, in a kind of "saddle", parallel to the line of vertical strata before mentioned.

Drawings of this nature are peculiarly useful, and there are few interesting geological tracts to which they are inapplicable: in many instances, especially in mining and coal districts, it will be proper to construct them upon the principles of isometrical perspective, as proposed by Professor Farish, and developed with much ingenuity and practical skill in Mr. Sopwith's recent Treatise.

The letters h, l, g, &c., mark the strata.

h. Hastings Sands, or Wealden formation.

l. Lower Greensand, nearly horizontal in the southern cliffs, rising thence towards the north, and passing inland, over the Hastings Sands, and returning to the cliffs near Culver and the Needles, with a steep dip northward.

g. Gault, ranging parallel to and above the Lower Greensand.

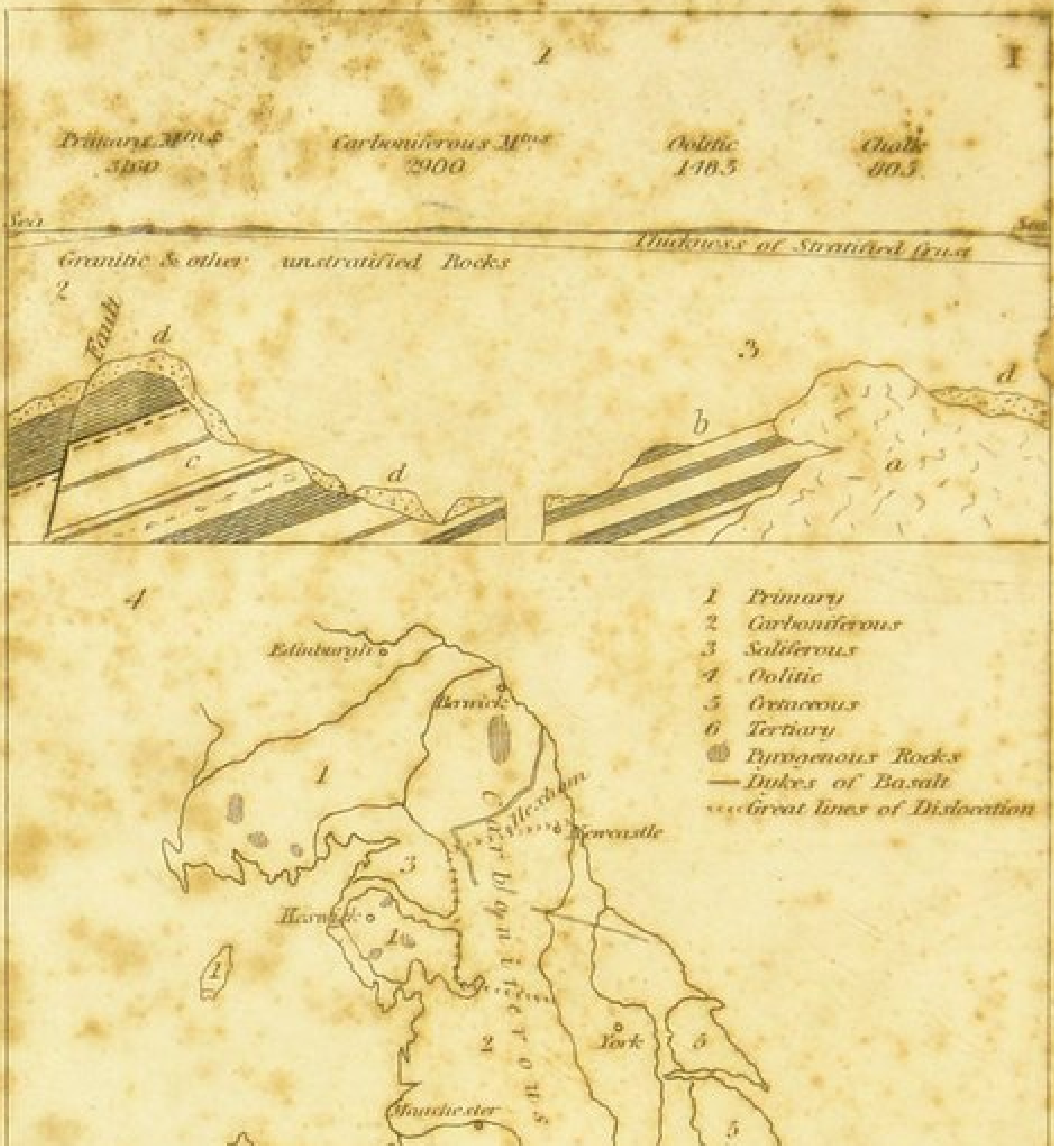
u. Upper Greensand, forming the highest points ofsome of the southern cliffs; then ranging inland, and returning to the cliffs, and dipping north under the chalk of the Needles and Culver.

c. CHALK, in ramified and detached high masses or downs on the surface, dipping very steeply to the north at Culver, and acquiring at the Needles almost a vertical position. The flints which lie in the upper part of the chalk near the line of dislocation are in a singular condition, penetrated by secret fissures, so as to fall to fragments on being removed from the rock.

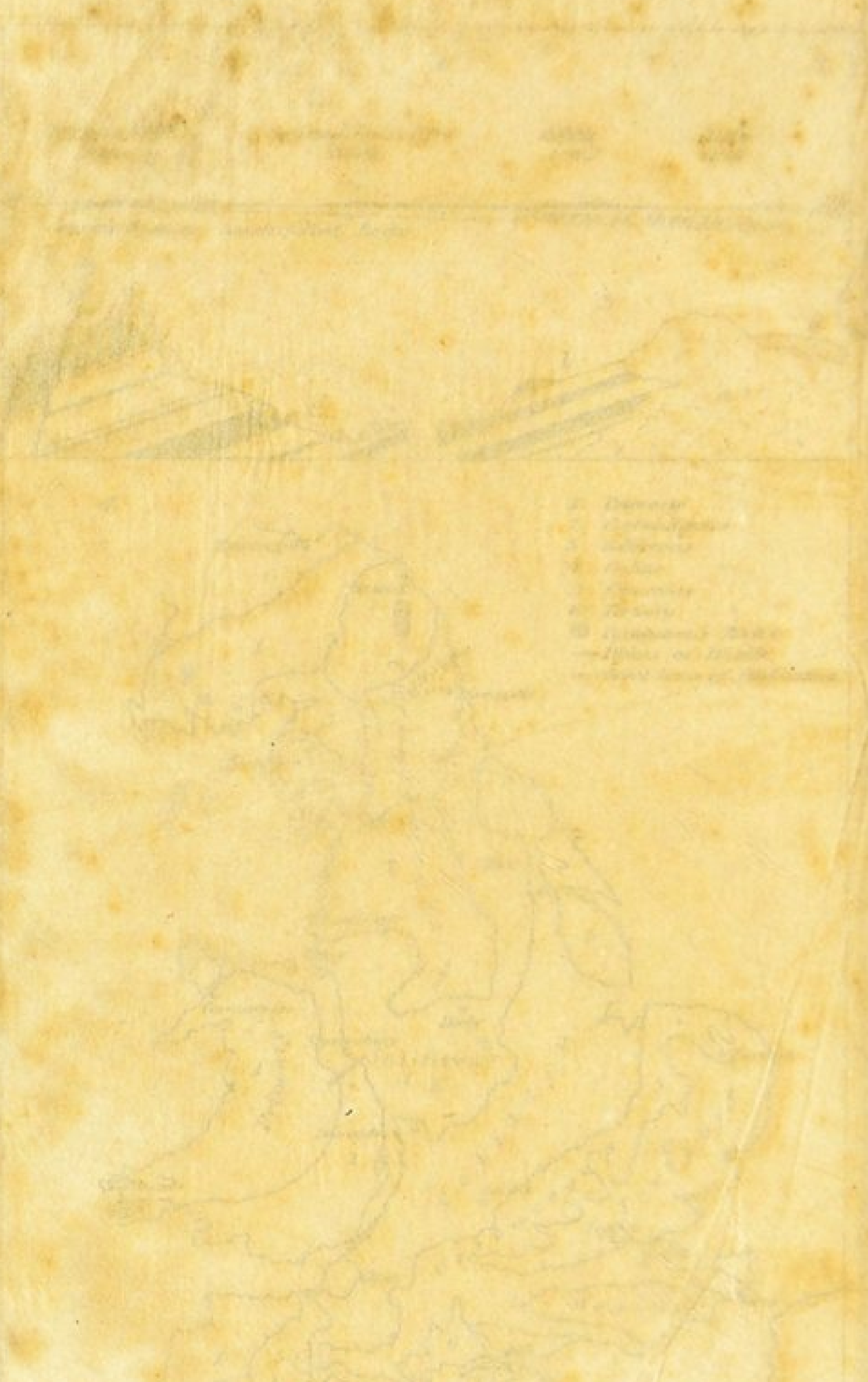
t. THE TERTIARY STRATA. Of these the London clay, and a great variety of coloured sands, with mottled clays, beds of lignite, and layers of pebbles, are placed directly vertical at Alum Bay, north of the Needles, while the upper beds of the sandy series turn under the horizontal freshwater marls and limestones of Headen Hill, which is a little further north.

THE END.

Printed by Richard Taylor, Red Lion Court, Fleet Street.



J. Phillips, delint. J. W. Lowry, sculp.



J. Phillips, delin.

J.W. Lowry, sculp.